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RADIO BUILDER'S HANDBOOK

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HOW RADIO HAS EARNED ITS PLACE IN THE SUN

When Guglielmo Marconi finally succeeded in 1895 in transmitting a "wireless" message over a distance of a mile and a half, he set in motion a chain of development that has revolutionized the art of communication. Marconi did not "invent" radio nor was he alone in the early work in this new art. Yet from that small beginning, radio has steadily advanced to the point where today it provides communication facilities across continents and oceans, furnishes entertainment and instruction to millions of people, saves lives at sea and on land, aids police authorities in enforcing the law, transmits news dispatches to the daily press, guides airplanes along the skyways, and in a hundred other ways serves mankind and aids the progress of civilization.

We shall not attempt here to trace the history of the development of radio. There are dozens of good books and articles on the subject. A half hour spent in reading even an encyclopedia article on the subject will tell you more than we can say in our limited space. Suffice it to say, however, that the history of radio in the past forty years has been a history of perseverance against obstacles, of unstinted toil by thousands of plodding workers in the vanguard of science. It is a heroic story—one well worth studying.

Today radio has definitely earned its place in the sun. It has made the world smaller. It has linked far-flung countries. It has brought to all of us—in the comfort of our homes—the leaders of the world in politics, science, drama, music, literature, art, and every other field of endeavor. It has made London and Paris and Rome and Buenos Aires and Sydney, Australia, as close to us as the switch on our short-wave set. Radio has proved itself as the greatest force in the twentieth century for bringing knowledge, pleasure, and joy to all of mankind.

The average radio listener—if he stops to think about it at all—regards radio as a deep and dark mystery. He is content merely to twirl a dial (or, now, to push a button) and to sit back quietly and be entertained. If something goes wrong in what he calls the "works" he is positively baffled and has to go out and call in an expert.

But radio need not be a deep and dark mystery. To thousands of government licensed Amateurs and to multitudes of experimenters and radio builders, radio is a fascinating hobby that gives endless hours of real thrills, a vast store of useful knowledge, and the deep satisfaction of knowing that the radio equipment one has built by himself will really work.

To you, therefore, who are interested in the science of radio—in learning how to build practical radio circuits, in understanding some of the fundamentals of radio—this book is addressed. We have not attempted to make this an exhaustive, complicated treatise. We think that you will get more real help by covering thoroughly only those basic details and practical applications that will be of real use to you. Our aim, in short, has been to give you a good working knowledge of radio building and experimentation, and to set you on the right path toward more advanced work.

If you turn back right now to glance through the latter pages of this book, you will probably feel bewildered at what seem to be complicated diagrams and tables. You may even say to yourself, "Well, this looks much harder than I expected. Maybe I've tried to tackle too much." But if you will patiently work your way through these earlier pages, if you will master each section thoroughly before you go on to the next, you will be fully prepared for the more advanced material by the time you get to it.

THE EXPERIMENTER-BUILDER AND WHAT HE DOES

No matter how far radio progresses, there will always be a place for the experimenter-builder. He is the fellow who tries out new circuit designs and new gadgets. Sometimes he stumbles across a new idea that is of distinct value to radio manufacturers. Sometimes, he plans a career for himself as a future radio engineer or a radio servicing expert. Sometimes, he decides to go into radio more thoroughly, becomes an Amateur, and goes on the air with his own transmitter.

But generally, the experimenter-builder is a radio "fan." He is in radio because he likes it—because he likes to build his own sets, experiment with circuit layouts, and try to improve the results he gets. True, he could buy a ready-built set and let his pleasure come only in listening to what's on the air. But the real "fan"—the true "Radio Bug"—is the fellow who gets as much pleasure out of building his set as he does later on in operating it.

It is safe to say that there are hundreds of thousands of these experimenter-builders in the United States. Perhaps you know several fellows yourself who have set up a little radio workshop somewhere in a basement, a garage, or a bedroom. Perhaps it is because of your acquaintance with one of these fellows that you yourself have become interested in radio. Whatever your reason for taking up radio and whatever the facilities you have available for work, you will get as much out of your hobby as you put into it. If, some day, you can turn your hobby into your profession, all the better. But even if your interest in radio remains a hobby, you will get from it the advantages of acquiring some mechanical skill, using tools properly, joining a wide fellowship of friendly men and boys, developing your ingenuity, and doing real, constructive work.

Radio need not be an expensive hobby. The tools required for the beginner are few and inexpensive. And parts used in building any one circuit can often be used again in many other circuits.

GETTING A START IN RADIO BUILDING

There are really two chief ways of learning any new handicraft or skill. One way is to begin by reading all of the theoretical discussions, plodding on through page after page of material that becomes very involved and seems almost useless, and finally after many weeks of study, arriving at a point where some of this great mass of information can be put to practical use. For the expert radio engineer, perhaps, this method is satisfactory.

But for the average radio newcomer, there is a far better way of beginning. Do you remember how you learned to play baseball, or to drive a car, or to do any one of a hundred different things that require a development of skill? Not all the explanations in the world seemed of much use until you had actually tried out these methods yourself. Not until you had the actual conditions of playing baseball or driving a car before you, did you begin to see how different the job really was from what it had sounded like.

Now, in the same way you can learn radio by doing simple but effective practical work, by putting the knowledge you gain to actual use, and by working up gradually to more advanced material. We believe that for radio newcomers this method is by far the best.

By building a simple radio set from a circuit diagram, you will become familiar with basic radio parts and their functions, with set layout and construction, with the meaning of the various radio symbols, and with some of the fundamental notions behind radio design. You will get that feeling of real achievement when you find that the first simple set you have built will actually work. And, finally, you will bring an intelligent understanding to your work when you approach the more difficult phases of radio.

Accordingly, in our discussion, we shall keep uppermost in our minds the needs of the radio newcomer whose first goal is to build a radio set that will work. We shall discuss the tools and materials you will need. We shall find out the most efficient way of putting a radio set together. And we shall nevertheless introduce whatever theoretical knowledge you need as you need it—and when you are ready for it.

WHAT KIND OF SET SHALL I BUILD FIRST?

To answer this question you will have to consider for a moment just what type of radio reception you are most interested in at present. If you want a set that will tune only regular Broadcast stations, you will need a kit of parts that includes a coil kit which covers the Broadcast band. Or, if you want a set for Short Wave work, you need a kit that includes Short Wave coils.

The Broadcast set will tune the stations you ordinarily get on your regular home radio. That is, you can tune in your local stations that broadcast the chain programs, police calls (if there is a police transmitter in your area), and powerful distant stations which also transmit on the Broadcast band. The Broadcast set is so called because it tunes only the Broadcast band which extends from 550 to 1500 kilocycles (or 545 to 175 meters). This section of the radio spectrum is set aside by the U. S. government for regular commercial radio broadcasting.

Kilocycles	Meters	
550 - -	- - 545	BROADCAST BAND— (Local stations and chain programs.)
1500 - -	- - 175	
		SHORT WAVE BAND No. 1— (Police, amateurs, airplanes, foreign stations.)
5650 - -	- - 52	
		SHORT WAVE BAND No. 2— (Foreign stations, ships-at-sea, amateurs, commercial phone.)
56000 - -	- - 5	

THE RADIO SPECTRUM

The table above covers only the major portion of the radio spectrum on which transmitting is done. Above 545 meters, there are a few weather report and time signal stations and some foreign long-wave stations. Below 5 meters, only experimental and Amateur high-frequency work is on the air, and special high-frequency receivers are required to tune in these signals.

The tuning range of Short Wave sets varies according to the range of the coils used. Usually, this range is from about 16 to about 217 meters, and is covered by four separate plug-in coils. In this range you can tune in Amateur stations in the United States and other countries, Short Wave police calls, ships-at-sea, airplane calls, commercial radiophone transmission, and foreign Short Wave stations which transmit from Canada, Mexico, South America, Europe, Asia, Africa, and Australia. If your set is sensitive enough, and if such conditions as atmosphere, time-of-day, etc., are favorable, you can tune in stations in foreign countries many thousands of miles away from your home.

Whether you decide to build a Short Wave set or a Broadcast set first depends on which type of reception is of most interest to you. Since, however, the chief difference in these two types of sets is in the coils used, you can change the coils at any time and thus adapt your set for the other reception range.

Another point for the beginner to consider is the type of power supply to be used. Now, since everyone living in a large city, or even in many rural areas, has some type of electric current available, the first thought would probably be to build a set to operate right from the 110 volt house current. Keep this in mind, however: for a beginner, the easiest type of set to wire is a battery-operated receiver. In the second place, by building a battery-operated set, you will avoid all possibility of harm to radio parts or to yourself. (You ought to know a good deal about electric current and radio circuits before you begin to work with A.C. sets.)

With all these considerations in mind, we have included on pages 20-23 of this book, diagrams, parts lists, and construction articles on the Knight Two-Tube DX'ER and "Ocean Hopper." These are both battery-operated receivers which use plug-in coils covering either Broadcast or Short Wave bands. From every standpoint of assembly and operation, either of these sets is ideal for the beginner to start with.

The Knight Two-Tubers must be used with headphones because they do not develop sufficient output to operate a loudspeaker. However, at any later time you can add a 3 watt amplifier and power supply (pages 24-25), thus enabling you to use a loudspeaker. In other words, you begin with a two-tube set, but you can eventually turn this into an efficient five-tube loudspeaker set for A.C. operation.

Perhaps a word should be said here about crystal sets. Since receivers of this type are so simple to construct, beginners sometimes wonder why it would not be better to begin their radio-building work with sets of this kind. There are two chief reasons why we do not advise you to start with crystal sets. First, because of the nature of the crystal set circuit, it is impossible to get any selectivity from such a set. Thus, if you live in a locality where there are several radio stations within a fifty mile radius, you would probably find it difficult to tune out interfering stations so that you could get only the station you wanted. On the other hand, if you are more than fifty miles away from a broadcasting station, you would probably not be able to tune any stations at all. In the second place, the construction of a crystal set offers little or no value in an understanding of advanced radio work. Because crystal sets do not utilize external electrical current (see page 5), you could build a dozen of these sets without ever adding to your knowledge of radio theory and practice.

However, in building a set which operates from electric current (whether from batteries or a power line), you acquire certain knowledge and techniques which are not only immediately useful, but which also give you a sound foundation for your future work. For these reasons, a crystal set circuit has not been included in this book.

The chief characteristics to be looked for in any radio set are: *selectivity* (ability to separate stations); *sensitivity* (ability to pick up weak signals); *stability* (ability to offer good performance day after day); and *fidelity* (ability to reproduce exactly what is put on the air from the transmitter).

The most selective type of circuit is the *Superheterodyne.* Such a circuit, roughly speaking, converts the wave lengths of incoming signals, making it possible to obtain greater amplification. This circuit is employed in most commercially built sets. Its only limitation is that it tunes so sharply that it does not permit "high fidelity" reception.

The *Tuned Radio Frequency* (T. R. F.) circuit is one in which R. F. amplifier circuits are tuned to the desired frequency by varying inductance or capacity. This circuit offers good fidelity, but is less selective than the Superhet.

The *Regenerative* circuit is the third chief type. In such a circuit, in effect, sensitivity is increased by superimposing the amplified variations of the plate circuit on the input circuit. For the purposes of the beginner, the Regenerative circuit is probably the best because it is easiest to wire, most inexpensive insofar as parts are required, and both selective and sensitive enough for ordinary purposes. That is why we recommend the Knight Two-Tube DX'ER as the first set for you to build.

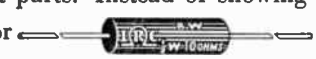
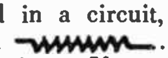
HOW TO READ SCHEMATIC DIAGRAMS

Now, if you have already turned ahead to look at the diagrams in the latter portion of this book, you will have seen that they consist of numerous symbols, lines, circles, and arrows, with occasional labels in words or letters. Let us see why radio circuits must be represented in terms of such symbols.

In the first place, you will agree that some sort of diagram or blueprint is necessary as a basis for construction work. The function of such a diagram is, of course, the same as that of any blueprint used in constructing a desk, a table, a ship model, or a house. You want to know just how every part fits together. You want to have an accurate guide to follow as you work. You want to know exactly what is coming next and where it goes. You want to be sure that when you have completed your job, the finished receiver will be exactly what you set out to build. Hence, a diagram is needed.

It is perfectly possible to use a picture drawing (sometimes called a *pictorial diagram*) as a guide from which to build up a set. But since pictorial diagrams require a great deal of effort and the skill of an artist to make, they are very seldom used. Instead, most magazine construction articles, most radio handbooks, and even beginners' manuals employ what are known as *schematic diagrams.*

A schematic diagram is simply a plan or drawing of a radio set in which the various parts and connections are indicated by standard radio symbols.

The symbols used in schematic diagrams are explained in the chart (Fig. 1) on the next page. These symbols are merely a kind of shorthand in which we use a standard symbol to represent radio circuit component parts. Instead of showing a picture of a fixed resistor  every time this part is used in a circuit, we employ the corresponding symbol . This symbol always means a fixed resistor. If you will turn back to one of the diagrams at the back of this book, you will easily be able to pick out the portions of the circuit in which a fixed resistor is used. (Let's not worry just now about what

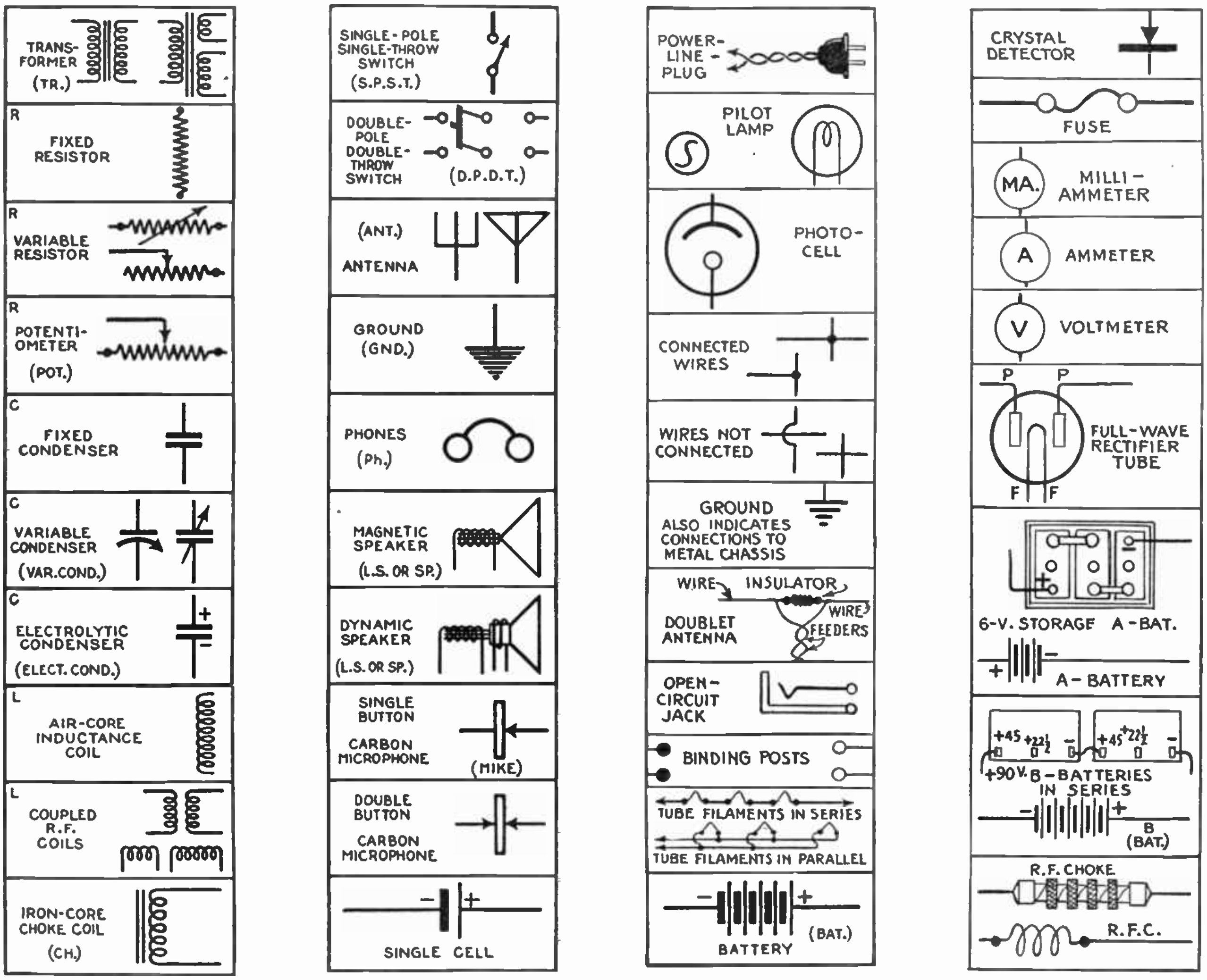


Figure 1. Schematic symbols used in circuit diagrams.
(Furnished through the courtesy of *Popular Mechanics Magazine.*)

such a resistor is or what it is used for. That will be explained later on.)

Again, instead of drawing a picture for a condenser, we use the symbol ; or, for a variable condenser ; and so on. Examine the chart of symbols and explanations that is shown above. Once you understand the meanings of the symbols, radio circuit diagrams will no longer seem mysterious to you. Spend some time studying these symbols and what they stand for. You might also refer to your Allied catalog to see what the actual items look like as they are sold commercially. Finally, study several schematic diagrams and identify every one of the parts.

Since you will frequently find it necessary to use symbols in drawing circuits by yourself (in making copies of diagrams published in periodicals available to you only in libraries, or in writing letters to radio firms or radio magazines), it is also advisable for you to obtain practice in drawing these symbols as well as in recognizing them. This, of course, is a rather simple procedure since it requires only the ability to copy symbols as shown above. It is suggested that you first learn how to draw the individual symbols—memorizing them as you draw them. After a time, you would find it beneficial to copy an entire diagram so that you can gain proficiency in arranging the elements in a diagram. And, finally, after sufficient practice, you ought to be able to draw simple diagrams from memory.

It is essential to learn to read schematic radio diagrams in order to be able to make progress in the field of radio. With a little patience and some practice, you will soon be able to recognize all the symbols without difficulty. Once you have completely mastered the meanings of these symbols, you can consider yourself as having graduated from the primary grade.

SOME THEORETICAL BACKGROUND

At this point we shall take time to discuss, briefly, some of the theoretical considerations which underlie the whole science of radio. We shall not go into too great detail, but we shall describe radio theory to the extent necessary for your purposes as a radio-builder. You could skip over to page 8, go on with the instructions for putting a set together, and get the set to operate without having read the material on these three pages, but you would never really know just why you had to do certain things in constructing your set—you would really be working in the dark.

To begin with, radio and electricity are both branches of the science of *Physics*, which the dictionary defines as:

> The science that treats of the phenomena associated with matter in general, especially its relations to energy, and of the laws governing these phenomena, excluding the special laws and phenomena peculiar to living matter (biology) or to special kinds of matter (chemistry). Physics is generally held to treat of (1) the constitution and properties of matter, (2) mechanics, (3) acoustics, (4) heat, (5) optics, and (6) electricity and magnetism.

The force of electricity plays a leading role in making possible the whole range of radio transmission and reception. In the first place, your home radio depends on the electrical power line or on batteries (which are reservoirs of electrical power) for operating current. This electrical power may be changed in form and increased or decreased in voltage (electrical pressure) before it is made to serve the circuit. In the second place, besides this external electrical energy, the incoming electro-magnetic waves striking the antenna of your radio set up minute but definite electrical currents in the input circuit of the radio receiver.

Electricity itself is a mysterious agent made to serve our needs in many ways. While we are able to control and use this energy quite safely, we really do not know exactly what it is. Over a period of years, however, scientists have been able to devise a useful theory which fits all the facts and is now quite generally accepted.

THE ELECTRON THEORY

Briefly, this theory might be summarized somewhat as follows: All matter in the world is made up of ninety-two fundamental materials known as *elements*. These include such familiar elements as oxygen, hydrogen, carbon, gold, etc., and some rare substances known as radium, tungsten, yttrium, helium, etc. A combination of these elements yields other substances; for example, hydrogen and oxygen, combined in proper proportions, result in water. The elements themselves are composed of a number of *atoms*. No one has ever seen an atom, since even the most powerful microscopes cannot magnify an atom sufficiently to make it visible.

If an atom could be isolated, however, we should find, according to modern theory, that it is made up of a central body of positively charged electricity consisting of a number of *protons*, surrounding which are bodies of negatively charged electricity called *electrons*. The opposing electrical forces in the proton and electron serve to keep the atom united. Electrons and protons are the same in all atoms. The difference between atoms lies in the number of electrons and protons and in the method of their combination.

Each electron, of course, is very small, and millions upon millions are required to form the current used to heat the filament of a single radio tube.

Electrons exist everywhere in nature and free electrons tend to be present in equal numbers in all places.

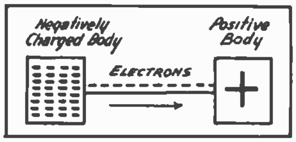


Figure 2. Diagram shows flow of electrons.

If a body has more electrons than surrounding bodies, it is negatively charged. But if a body lacks sufficient electrons to be neutral, it will be positively charged. Now, if a positively charged body is brought into contact with a negative body, there will be a flow of electrons from the negative to the positive (see Fig. 2) until both bodies will become neutral (that is, both will have an equal number of electrons). In short, electrons, being negative in potential, are always attracted to a positively charged body.

The charged bodies need not be brought into direct contact for the electrons to flow—a wire which acts as a conductor may be used instead. Practically all metals are good conductors of electricity. Silver is the best, but since it is too expensive for ordinary use, the next best conductor, copper, is widely used.

RESISTANCE

Any conductor, however, has a certain amount of opposing force to the passage of electrons. This opposition is known as *resistance*. Silver or copper wire has very little resistance (which is why copper is so extensively used for carrying electric current). Iron wire, on the other hand, has quite a bit of resistance, and may become hot when many electrons are retarded in their passage. Heavy, thick wire—which permits the easy passage of millions of electrons—has less resistance than fine, thin wire of the same material—which slows up the electron flow. (See Fig. 3.)

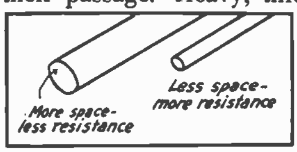


Figure 3. Relation of wire-size to resistance.

Some substances other than metals have extremely high resistance; they permit very few electrons to pass. Some of these substances are rubber, bakelite, glass, and porcelain. Because of their high resistance they are used as *insulators*.

The unit of measurement for resistance is the *ohm*.* Assume that we have a battery of one volt connected to

*Named for Georg Simon Ohm (1789-1854), a pioneer German physicist. Ohm's interest in the phenomena of the relation of resistance to current intensity and electromotive force led to his formulation of the Law named for him and published in 1827.

a wire of one ohm resistance. Then an electrical current of one *ampere** will flow. You can see, now, that the voltage, the current, and the resistance of any circuit are interconnected. In Direct Current circuits, this relationship is expressed mathematically according to Ohm's Law: $V = I \times R$. In this formula, each symbol stands for one factor: V for voltage, I for current, in amperes, and R for resistance, in ohms.

THE BATTERY

In the early days of radio, batteries were used as the source of power. Even today in communities not yet reached by the power line, battery-operated radio receivers of the modern type afford facilities for quality reception.

Batteries are simple chemical machines producing electrical current from a chemical reaction. A battery consists of a number of cells, each cell producing a quantity of electricity. The ordinary flashlight cell, for example, produces 1½ volts. In such a battery the zinc can is used as the negative terminal, and the carbon rod in the center of the cell is used as the positive terminal. Inside the cell are a number of chemicals; a chemical reaction takes place each time current is drawn from the battery. The larger "B" batteries are simply composed of a number of these smaller cells connected together.

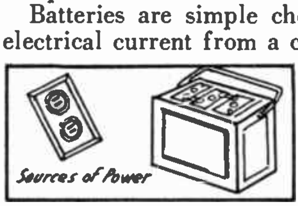


Figure 4. Electric power is obtained from battery or light outlet.

There are two chief types of batteries. One which produces electrical current of itself until it is discharged and must then be discarded uses *primary* cells. The storage battery used in automobiles and for radio service operates on a different principle, and is known as the *secondary* cell type. Such a storage battery acts as a reservoir of electrical energy. First, the electricity must literally be "poured" in—that is, the battery must be charged. After the battery has been charged, electricity may be drawn out until the battery becomes discharged, at which time it must be charged again, and so on.

MAGNETISM

Another force closely related to many radio and electrical components is *magnetism*. Transformers, phonograph pickups, loudspeakers, relays, and other radio parts, operate on the principle of magnetism. Since magnetism is similar to electricity, we cannot really see it or feel it, but its effect can be detected and accurately measured with simple instruments.

As you already know, a magnet will attract objects made of iron or steel. This is accounted for by the fact that any magnet has two poles of opposite polarity (that is, of opposite force). When two separate magnets are brought together, the like poles will repel each other, while the unlike poles will have a strong attraction for each other. This is the same as the action of electrons and protons. Since the entire earth may be considered as a giant magnet, a compass using a small magnet on a pivot will tend to point to the North and South Poles.

One of the laws of magnetism we might mention is that *the force of attraction and repulsion between two magnets is inversely proportional to the square of the distance.* North and South magnet poles will attract each other four times as much at a distance of one inch, as at a distance of two inches. When a magnet is dipped into iron filings, most of the filings stick to the poles, indicating that the force of attraction is greatest at the poles (Fig. 5).

Magnetism may also be produced by the flow of electrical current through a conductor. Every wire which carries electric current has an associated magnetic field proportional to the current strength and the placement of the wire. By winding a number of turns of wire in the form of a coil, a much stronger magnetic field can be produced, since the field of each individual turn will add up. And, since the magnetic field of force of each turn is added to that of the next turn, the greater the number of turns of wire, the stronger the magnetic field.

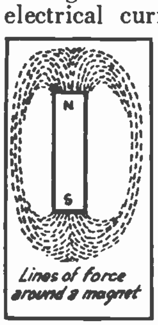


Figure 5.

The total magnetic *flux* (lines of force) depends on the number of turns and the strength of the current. If the current is strong, relatively few turns of thick wire will be required. On the other hand, if the current is weak, a great many turns of thin wire will be needed.

A stronger electromagnet can be made if a bar of iron is placed in the center of a coil, since the lines of force produced will be concentrated and stronger magnetic action will result. In any electromagnet, of course, the magnetism will be lost immediately when the current is shut off, whereas in natural magnets the magnetism is more or less permanent.

INDUCTANCE AND REACTANCE

The property of a coil to set up a magnetic field when current is flowing through it is called *inductance*. Such a coil tends to oppose any changes in current intensity. Therefore, an inductive circuit makes the current lag behind the voltage if changes in the supply voltage are taking place. A time must pass before the current changes in accordance with the changes of the voltage.

The opposing force of an inductance, known as *reactance*, is directly proportional to the inductance of the coil. The inductance is measured in units called *henries*, while the reactance is measured in *ohms*. (In radio work, the *henry** is rather too large, and so the *millihenry*—one thousandth of a henry—and the *microhenry*—one millionth of a henry—are commonly used terms.) The same inductance will have a greater

*Named for Andre Marie Ampere (1775-1836), distinguished French scientist. Ampere's work in the field of electrodynamics helped to lay the foundation for Edison's work in electricity.

*Named after Joseph Henry (1797-1878), one of America's pioneers in the science of Physics. Henry was especially interested in electromagnetism, but also made important contributions in other fields.

reactance at a higher frequency. This is why an R.F. choke will have a "choking" effect on high radio frequencies, but will permit low frequencies and D.C. (direct current) to pass unobstructed.

So far, in talking of electric current, we have assumed that it is a steady flow of electrons in one direction. However, unlike Direct Current, which is such a more or less steady flow in one direction, *Alternating Current* (A.C.) is constantly varying in intensity and in direction. First it rises from zero to a maximum in one direction; then it returns to zero and rises to maximum in the opposite direction, and again returns to zero. This completes the *cycle* (Fig. 6). The same variations go on so long as current is flowing. In 60 cycle current, which is now largely standard for power circuits in the United States, these complete cycles take place sixty times each second. In radio circuits the changes (frequency) may take place many thousands or even millions of times per second.

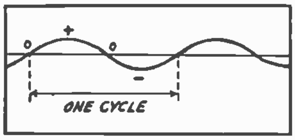


Figure 6. The alternating current cycle.

CAPACITANCE

Two similar metal plates facing each other, but separated by air or by a thin piece of insulation, form what is known as a *condenser.* If such a condenser is connected to a battery, the electrons will accumulate on the plate connected to the negative terminal—the condenser will be charged. By disconnecting the battery and shorting the condenser, the electrons will leak off the plate and the condenser will be discharged (Fig. 7).

The charge is stored in condensers, not in the metal plates themselves, but in the insulating material between the plates known as the *dielectric.* The actual *capacitance* (storage ability) of a condenser depends on three factors: (1) size of plates, (2) spacing of plates, and (3) the dielectric used. The larger the plate area, of course, the greater the capacity. The unit of measurement of capacitance is the *farad.** (In radio work, the farad, like the henry, is too large a unit of measurement, and so the microfarad—millionth of a farad—or the micromicrofarad—millionth of a microfarad—is used; these are abbreviated as *mfd.* and *mmfd.*)

The term *capacity* is now quite generally used as meaning exactly the same thing as *capacitance.* Strictly speaking, *capacitance,* according to some experts, should be used only to refer to the electrostatic capacity of a body, and *capacity* should be used to refer only to current carrying ability. However, in general usage, these terms have been confused and are now taken by many to be synonymous. Accordingly, we have used the term *capacitance* above rather loosely. You need not worry about this matter, however, since only the expert radio engineer or theoretician will be very critical of your usage of these terms.

*From the name of Michael Faraday (1791-1867), an English scientist who made many notable contributions in chemistry and in physics. Also a pioneer in electricity.

Different dielectrics give different total capacities, even though the plates and spacing are not altered in any way. If a condenser has a given capacity with air as the dielectric, it will have seven times the capacity with mica substituted as the dielectric. The *dielectric constant* of air is taken as 1, of mica as 7; other substances have their corresponding dielectric constants.

Condensers not only store up energy, but are also important in radio work for another reason. If a condenser is connected in a circuit with direct current being supplied, the condenser permits the current to flow only for a very short time while it is being charged. If alternating current (see above) is supplied, the condenser will permit the current to flow through the circuit. Thus a condenser which permits A.C. to flow, but does not allow D.C. to pass through, is called a *blocking condenser;* one which permits A.C. to pass through a shorter path than D.C. would follow is called a *by-pass* condenser.

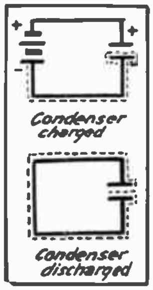


Figure 7.

In many radio condensers waxed paper or mica is used as the dielectric. Those circuits in which D.C. or pulsating D.C. is present may use *electrolytic condensers,* in which an extremely thin film forms on one of the plates and serves as the dielectric. Since this film is so thin, it permits high capacity condensers to be constructed very compactly.

THE PARTS OF A RADIO SET AND THEIR FUNCTIONS

In the simplest language, *a radio receiver is nothing more than a device to capture radio signals which travel through space and to reproduce them as audible sound.*

These radio signals, of course, are emitted by the transmitter where the process is just the reverse of that in a radio receiver. In other words, a transmitter "converts" audible sound into radio signals and radiates these signals through space.

Now, how are these signals which we cannot see or hear or feel captured by the radio set and transformed from mere electrical impulses into the voice of Bing Crosby or Rudy Vallee or the music of the Philadelphia Symphony Orchestra?

This is a good place in which to explain the functions of the various radio parts so that when you come to a later section in which we tell you how to construct a set, you will understand why a great variety of parts is needed and what these parts do.

Broadly speaking, any radio receiving set has five chief sections—all concerned with turning those invisible, intangible radio signals into sound that you can hear. These sections are:

1—The antenna
2—The Radio Frequency amplifier (if used)
3—The converter (or detector)
4—The Audio Frequency amplifier (if used)
5—The Loudspeaker or Headphones.

And what, you will ask, are all these for?

Well, in the first place, the antenna—which is a piece of wire, either long or short, and either indoors or outdoors—pulls in the radio signals which are dashing through space at the approximate speed of 186,000 miles per second. (That great speed explains why radio signals can be sent around the world and heard almost simultaneously whether you are in Singapore, or Copenhagen, or New York City, or San Francisco, or Sydney, Australia.) As a matter of fact, if you were to dangle a piece of wire out your window you would have the rudiment of a radio set because you would receive signals—although there would be no apparent result because you would lack the necessary conversion device.

Now, the Radio Frequency amplifier (practically always a tube in conjunction with a number of tuned circuits) amplifies the very weak signals which have been received so that they are strong enough to be passed on through the rest of the circuit. Incidentally, the term *Radio Frequency* is used to indicate the frequencies above 40,000 cycles per second which are not audible to the human ear.

From the Radio Frequency amplifier (commonly abbreviated as R.F. amplifier), the radio signals go through the converter or detector stage which, very roughly speaking, serves to break up the incoming signal so that only the Audio Frequency component is left, and the carrier wave which has been bringing the signal along is disposed of. This function is also performed by a tube.

Next is the Audio Frequency amplifier (or A.F. amplifier) which increases the strength of the A.F. signal.

And the final stage is that in which this strengthened A.F. signal is converted by a loudspeaker or headphones into audible sound.

Actually, this whole process we have described takes place in a period of time so short that it can scarcely be measured. Practically speaking, the sound of the program you hear leaves the loudspeaker at almost the same instant it has entered the antenna as radio signals.

In order to operate the tubes used in a radio set, it is necessary to employ some sort of electrical current, whether it be from batteries or from a regular electric outlet in the wall. If you live in a city, you probably have 110 volts 60 cycles Alternating Current. Since the tubes used in a radio set require direct-current power to make them operate, it is necessary to break down and convert the incoming current to the proper type and voltage needed for the tubes. This is the function of the *transformer*, the *rectifier* and of the *resistor network* in the set.

The *condenser and coils* comprise what we call the *tuned circuit* or circuits. When adjusted by the tuning knob controlling the condenser to the frequency or wave length of the station wanted, the tuned circuit passes signals from that desired station on to the tubes, from which point the process goes on as we have already described it above.

As for the remaining parts in a set, we may say that a *volume control* is simply a type of variable resistor which, by increasing or decreasing the amount of power passed through, increases or decreases the volume; a *choke* is a kind of fixed inductance (see page 6); a *rheostat* or *potentiometer* is also a kind of variable resistor. *Sockets* are necessary to hold tubes or coils in place and to permit correct wiring connections to be made to the various parts of the tubes or coils. A *chassis base* is needed to provide a foundation for the parts in the set. The *dial* is required so that we can revolve the tuning condenser and locate stations at a definite point on the dial scale. Wire and hardware, including screws, cords, clips, plugs, etc., are needed to make the connections between the various parts of the circuit and to hold all parts rigidly in place.

By now we have said practically everything that the beginner needs to know about the various radio parts. Something more must be told about tubes—their various types and their functions—but we shall reserve that for a later section.

THE TOOLS NEEDED FOR RADIO CONSTRUCTION

In order to assemble the various parts of a radio set, you will require a number of simple, inexpensive tools. No doubt you already have some of these tools somewhere about your home.

Practically all the radio work encountered by a beginner can be taken care of with these tools:

1 soldering iron (electric, if possible, of 60 or 100 watt size)
1 pair of side-cutting pliers (large)
1 pair of side-cutting pliers (small)
1 screwdriver (5" or 6" size)
1 screwdriver (2" or 3" size)
1 drill kit, consisting of hand drill and assorted drills such as Nos. 11, 18 and 28
1 file (medium coarseness)
1 hammer
1 steel rule (12" size)

Optional Tools

1 vise (4" size)
1 hacksaw
1 square
1 center punch

With a little practice you can soon acquire a certain dexterity in using your tools so that your work will always be neat and shipshape. There is no special knowledge required for using most of the tools mentioned above. The soldering iron, however, calls for a little extra skill and so we have devoted a separate place (page 9) to a discussion of this tool.

As a matter of fact, you can assemble many radio sets (for example, the Knight kits shown in the section beginning on page 20) with exactly three tools: screwdriver, soldering iron, and pliers. This is because special care has been taken to supply such kits in a form which will require the minimum of work and ingenuity on the part of the radio builder.

However, this will not always be the case, as, for example, when you want to build up a circuit for which a specially prepared kit is not available, although all of the parts needed will be supplied. In such cases, which you will find more frequently in your later work, you will need to make use of most or all of the tools listed above.

It is also advisable to get in the habit of keeping your worktable as efficiently organized as possible. Many radio builders, it is true, manage to get all of their set-building done in a more or less haphazard fashion, using thhe kitchen table as a workbench. The ideal set-up, however, is to have a place of your own—small as it may be—in which to handle your radio work. A table in your bedroom, a bench out in the garage or in your basement, are examples of what we mean. Try to get into the habit of keeping tools and parts stored in definite places. A small cabinet with a number of drawers is an excellent place to keep small parts such as hardware, extra condensers, tubes, and so on. Tools may be kept in a drawer of your workbench (if the bench is so equipped) or any other place where you will find them at hand when you need them.

One final point on this subject: make sure that you have all the parts or tools you need when you begin to work. If you purchase a complete kit of parts for any set, this will almost always take care of itself. However, if you are building up a special circuit, you will find it most annoying to have to stop in the middle of your work because a couple of screws or some hook-up wire, or a resistor or two are not available when you need them. Also: never throw anything away. So many times an odd piece of equipment for which you have no use will come in handy at some later time.

SOLDERING

In the construction of any radio set, wire connections to sockets, coils, or to other wires are made by means of soldering. The purpose of soldering is to provide connections which are firm and secure both mechanically and electrically.

You must not depend on soldering alone, however, to provide the correct connections. It is always necessary to wrap the wire around the terminals *first* and then to apply the solder to seal the connections.

Successful soldering depends on your following a few simple but important instructions. Always hold the heated iron to the joint (point of connection) until it becomes hot enough so that the solder, when applied, will melt when it comes in contact with the joint. When the solder on the joint is melting, the iron must be removed at once. Your connection will then be secure and foolproof.

A soldering iron is easy to care for, and, when properly used, will last for a long time. Always keep the tip of the iron clean and well tinned. This tip is made of copper and, when in good condition, will either be clean and shiny or covered with solder. If, however, the tip gets black and rusty, the copper is being oxidized, and cleaning is necessary. To clean the iron, secure what is called a "tinning block," which consists of a solid block of material soap-like in appearance. Heat the iron and then rub it across the surface of the block several times, until the tip is perfectly clean.

Several types of solder are commercially available. In general, the radio builder should use solder which has a core of flux (a kind of paste) so that soldered connections will be made permanent. *Acid core* solder should be used for all sheet metal work. *Rosin core* solder is best for radio connections, such as are made in wiring a circuit. *Aluminum core* solder must be used when aluminum is to be soldered.

Caution: In using solder, take care to use only as much as is necessary to cover the joint. If too much solder is used, and if it spreads over nearby insulation, the result will be either breakdown of the insulation or excessive electrical leakage between adjacent terminals.

GETTING THE RIGHT CHASSIS BASE

If you will look into the cabinet of your home radio set you will notice that all of the tubes and other parts are mounted on a metal base, usually about two or three inches in height. This is known as the *chassis base*, because the assembled radio set, exclusive of the cabinet, is called a *chassis*, and this metal piece provides a foundation or base for the chassis.

For simplicity and ease in circuit wiring and in making changes, many experimenters prefer to use a wood base. A base board of proper size and with smooth finish is supplied as a part of several of the kits included in the latter portion of this book. Of course, you can prepare your own base, if you wish. A piece of wood about a half inch thick, sandpapered to a smooth finish and stained to a dark shade, is all that is needed. In the so-called "breadboard" style of layout—as used, for example, in the Knight Two Tube DX'ER—all parts are mounted on the surface of the board with wood screws and no drilling or punching of the base is necessary.

To improve the operation of the set and to give it a professional appearance, a metal chassis base is used (Fig. 8). All commercially built radio sets use a base of this type. Several different metals are available. The most popular is *electralloy*, a soft, easily worked material that can be soldered with ordinary flux. *Ternplate* is a steel alloy material lower in price than electralloy, but considerably more difficult to handle.

Both the chassis bases and the matching front panels are usually furnished with a polished natural finish. However, crackle-finished metal is also available.

HOW TO PUNCH AND DRILL CHASSIS BASES

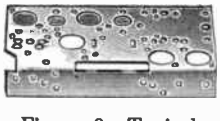


Figure 8. Typical punched and drilled chassis base.

If you want to avoid the time and work involved in preparing your own chassis base, you will want to take advantage of ALLIED'S special chassis service, fully described in the ALLIED Catalog.

However, should you prefer to

make your own chassis base, you will find these suggestions valuable:

The first step is to determine what size chassis base will be needed. If the construction article or parts list from which you are working does not tell you this, it is advisable to lay out the parts to be used in the set on a table and experiment with placing until you have a compact and neat arrangement. You can then estimate what size the surface of the base must be. It is necessary to remember, also, that the chassis base is not merely a flat piece of metal when finished, but has a height at the sides of from two to three inches. Accordingly, in figuring your dimensions, allow for these sides.

Assume, for example, that you will require a chassis base measuring about 7"x10"x2". You must then obtain a piece of metal that is at least 11½"x14½". Then follow this procedure:

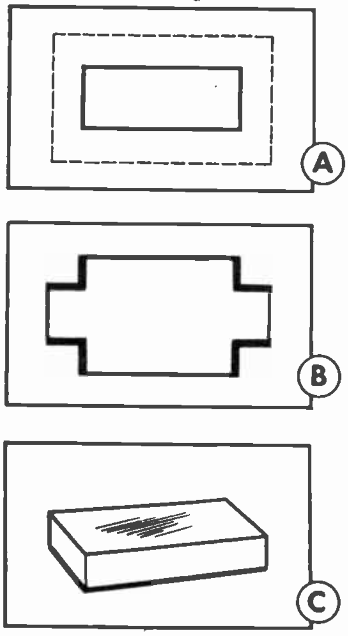


Figure 9.

Measure out guide lines about 2¼" along three sides of the metal. From these guide lines, plot out the lines for the surface, which will be 7"x10". Be sure to allow about ¼" where the sides will be, so that in folding the sides you will secure a neat, squared-up finish. Trim off any excess metal on the fourth side. (Fig. A.)

Cut out a square notch about 2¼" at each of the four corners, so that the side pieces can then be folded under. (Fig. B.)

Fold these sides and your finished base will appear much like that shown in Figure C.

To cut sheet metal to proper size, scratch guide lines for cutting with a nail or a sharp-pointed tool. Then, using a hacksaw, cut off the metal along the guide lines. Use a file to remove rough edges. And, finally, to finish the edges smoothly, use a piece of sandpaper or emery cloth attached to a flat surface and rub the edges down until they are perfectly smooth and straight.

To cut aluminum or alloy, the best method is this: Make deep scratches along the line of the cut on both surfaces of the metal. Place the metal in a vise, bend it back and forth, and it will soon break at the line. In the event that the metal to be cut is much wider than the vise, insert a pair of iron bars, one placed on each side of the metal, tighten the vise, and then proceed as above to break the metal.

Whenever holes are to be drilled in metal, always use a center punch first to locate the exact center of the hole. A valuable guide in this job is a heavy sheet of paper on which an outline of the exact placing of the components has been plainly traced. This sketch may easily be fastened to the metal chassis by using gummed paper or adhesive tape. The holes may then be punched through the paper and you will thus avoid marring or scratching the metal surface.

Some care should be taken to get the measurements of the holes as accurate as possible. If the holes are too large, the parts will not fit properly; if the holes are too small, you will need to spend some time in filing them down before they are the proper size.

To cut out the holes you can use either a drill or a hole-punch. Holes smaller than $\frac{3}{16}$ of an inch can easily be made with a drill. Larger holes should first be made with a small drill, after which larger drills are used to enlarge the hole until the proper size is reached. A circle-cutter or a radio chassis punch is also useful for this work. These tools are not expensive and, if you do a great deal of work of this type, will easily be worth their cost.

When all holes have been drilled, the chassis base should be cleaned and polished. Aluminum or alloy parts can be given a smooth, clean finish by placing them in a solution of lye (about 3 tablespoonfuls to a gallon of water) and allowing them to rest for about a half-hour. Do not put more than one piece of metal into the solution at a time, since a stain will result if pieces overlap.

MOUNTING THE PARTS

One aspect of radio building which sometimes puzzles beginners unduly is that of actually mounting the parts on the chassis base. To clear up any vagueness you may have on this subject, we shall talk about this problem now.

In the first place, the chief idea to keep in mind when mounting parts on a chassis is this: Always arrange the layout so that all leads will be as short and direct as possible. *Above all, the grid and plate leads must be very short.* The reason for this is to assure best operating results, because long leads will result in excessive coupling and stray pickup, which may prevent the set from performing as it should.

Another point to remember is this: When placing parts tentatively for mounting, see that all controls are at the front panel. For example, the tuning condenser and its associated dial should be mounted so that stations can be tuned from the front panel. In the same way the volume control, tone control (if any) and other controls such as a rheostat or potentiometer should always be placed so that the control shaft will protrude from the front panel. You can easily see why this is necessary—otherwise, you would have a good deal of inconvenience in operating the receiver.

If the set you are building is described in a magazine construction article, you will usually find an illustration showing how the parts are laid out. It is best to follow such a layout because the author of the article has undoubtedly spent some time in experimentation to assure best results. If you are working from a diagram of the pictorial type, you will also be given definite clues as to how parts should be laid out. But remember—*always try for the shortest possible leads.*

In your first tentative layout of parts, you may find that better wiring facilities can be obtained by changing the position of two or three parts. Accordingly, juggle the parts around until you are sure you have the best possible plan. Then, but not before, go ahead with the final drilling and punching.

Another hint to keep in mind is this: always wire the filament and power supply portion of the set first. When this unit has been wired according to the circuit diagram, test it by plugging in the line cord (if it is an A.C. or A.C.-D.C. receiver) or by attaching batteries (in the case of a battery set). If the tubes light, you will know that the wiring is correct up to this point at least, and you can go ahead with your work. If the circuit uses metal tubes, you cannot tell whether or not they are working except by touching the tubes to determine whether they are heating up. In a few moments after the power supply is connected, the metal tubes will begin to feel warm to the touch.

Now, if by any chance the tubes do not light up, you will know definitely that you have not followed your diagram exactly. Disconnect the power supply. Go back and check over the wiring very carefully, noticing at every point whether you have done exactly as the diagram indicates. In this way you can soon discover whether you have made an error and you can quickly correct it.

After the filament and power supply has been correctly mounted and tested, disconnect the power supply (pull out the line cord or disconnect batteries) and go ahead with the remainder of the circuit. Place all mounted parts such as tubes, upright condensers, transformers, etc., on the chassis in accordance with the holes you have previously drilled. Set in any screws or terminals which hold these parts in place. After all these parts are mounted, you can proceed with wiring.

If your set is being constructed on the "breadboard" layout plan, all of the wiring will be on the top surface of the chassis base. However, if you are using a metal chassis base, the wiring will be done on the under surface of the chassis. In this latter type of job, you must turn the chassis upside down, so you can get at the terminals from the under side. When such a set is completely wired, you will find that the upper surface will be very shipshape—the only apparent parts will be such upright units as tuning condenser, tubes, transformer, controls, etc. All wiring—in most cases—will be underneath the chassis.

Another point to remember in order to make the construction work a little easier is this: As you proceed with the layout of parts and the wiring, use a colored pencil to check off on the diagram each step that you have finished. Unless you do this, you may find that you have omitted some essential bit of wiring and your set will not work. *Every part and wire indicated on a circuit diagram is essential* if the set is to operate correctly. Make it a habit to check your work as you go along. This will save time in the long run and will assure you of best performance from your radio set.

When you have at last finished mounting all parts, connected all leads, and checked your work, you are ready for the final test. Plug in to the electrical outlet (or connect the batteries if a battery set), turn on the switch, allow the tubes a few moments to heat up, and then operate the tuning control until you hear a station. If your work has been satisfactory, you will experience quite a thrill in listening to your first program coming in on a set you have built yourself.

THE ANTENNA AND THE GROUND

To obtain the best results from any radio set—whether a 1-tube radio with earphones or an eight-tube superhet with loudspeaker—you must have a satisfactory antenna and ground connection.

It is impossible to state categorically just what type of antenna is best. To determine which is best for any specific installation, you must consider such variable factors as the sensitivity, selectivity, and power of the radio receiver itself; the distance from the nearest broadcasting stations; the number of stations within the local area; the kinds and intensity of interfering devices such as electric flashing signs, trolley-cars, high power lines; the physical conditions which limit space for antenna installation, and so on. We can say, however, that in general, for the smaller home-built sets in which good broadcast band reception is the goal, a suitable antenna is a single wire about 50 feet long, installed as high off the ground as possible. That figure—50 feet—should not be taken too literally. We suggest it only because it is about the correct length for a good many installations. If it is found that too many stations interfere and prevent good reception when a 50-foot antenna is used, it is advisable to shorten the antenna. On the other hand, after some experimentation, it may be found that a longer antenna offers better reception. So we say, the length of the antenna required for best reception can be determined only by "trial-and-error" methods.

The ordinary antenna for the beginners' sets may be a length of No. 14 or No. 12 (B. and S. gauge) enameled copper wire. The *lead-in* (the wire connecting the antenna to the radio receiver) could be of the same material as the antenna, but it is better to use a shielded (rubber-covered) wire to prevent loss of signal strength. All contacts should be solid and secure. Loose contacts at lead-in or joint may cause intermittent reception because of signal leakage. Solder the lead-in securely to one end of the antenna, and drop it down directly to the receiver where connection is to be made.

There are a number of points concerning which some specific cautions may be advisable:

1—Since the antenna is exposed to the elements, your installation should be strong and secure so that the first high wind which comes along does not blow the wires down. Poles affixed to buildings should be carefully set up and securely nailed or bolted.

2—Not too much sway of antenna and lead-in wires should be permitted. If the antenna is installed during warm weather, however, allow enough slack so that cold weather will not contract the wires so much that they will snap.

3—Try to prevent aerial or lead-in from rubbing against a tree or a building. Such contacts cause signal leakage which will result in reduced volume.

4—If there is a high-power line or similar source of interference near your house, point the antenna *toward* the source of interference, to minimize undesirable effects. Never install an antenna parallel to a high-power line if you want good reception from your radio.

For advanced circuits of the superhet type—especially for all-wave receivers—a doublet type antenna should be used. Since a good deal of theoretical knowledge is required for construction of an efficient antenna of this type, and since excellent doublet antennas are commercially available at very reasonable prices, you will probably find it better policy to purchase a factory-assembled doublet antenna, rather than to attempt to construct your own.

Something, too, should be said about *insulators* which are needed for a good antenna installation. Ordinary insulators prevent dissipation of signal strength, although insulators of the lightning arrester type are supposed to prevent lightning bolts which may strike the antenna from entering the radio set itself. There are several types of insulators, the best of which are of glass or glazed porcelain. One insulator should be used at each end of the antenna, and another (of the porcelain nail-knob type) should be used at the window where lead-in enters your house.

We have said that the antenna should be installed as high off the ground as possible; a minimum of twenty or thirty feet is usually satisfactory. In the city this is easily done by installing the aerial on the roof of your building. In rural areas, one end may be strung from the roof of your house, and the other from a barn or outlying structure, or a pole.

Indoor aerials, in general, should not be used unless physical conditions are such that the alternatives are either an indoor aerial or else none at all. Indoor aerials can never be as efficient as outdoor aerials and at their best are only a compromise. "Aerial eliminators" are not particularly useful if long-distance reception is one of your aims, although they are frequently suitable for local-area reception.

A good *ground connection* is almost as important as the antenna for good DX reception. Its purpose is to permit a completion of the circuit involved in the transmission of radio signals and to pass off any extraneous signals or power into the ground. The ground wire makes the connection between the "Ground" post of your set and a metal pipe or rod, which is driven into or connected with the earth. Use a ground clamp which will assure a good, solid connection. Suitable grounds are: a radiator pipe, a water pipe, or a rod of iron driven into the earth. The ground clamp should touch bare metal; paint or gilt should be scraped off of the pipe used for ground at the point where the contact with the clamp is made.

To conclude, we might mention the fact that people may tell you of the "marvelous" reception they got without using an aerial at all. That may be—but for *consistently* good reception, you cannot dispense with an aerial.

NOTE: Receivers of the A.C.-D.C. type—that is, sets which are designed to operate from either Alternating or Direct Current rated at 110 or 220 volts—do not have a power transformer in the circuit. Voltages from the power line are obtained directly. Accordingly, no ground connection should be used with an A.C.-D.C. receiver.

RADIO TUBES: SOME BASIC INFORMATION

Vacuum tubes are actually the heart of modern radio sets. While reception is possible without the use of tubes (for example, in a crystal set), such reception is indeed limited both in selectivity, sensitivity, and power. Accordingly, all sets designed or built today use a number of vacuum tubes. The number of tubes employed may vary from one tube—in a simple beginner's set—to 20 or 30 tubes—in custom built sets for special purposes.

Ordinarily, a radio receiving tube consists simply of two or more electrodes within an evacuated glass or metal shell (Fig. 10). This glass or metal envelope is needed to maintain the vacuum inside the tube. The vacuum itself is necessary so that the electrical reaction in the tube can be regulated according to certain specified requirements and so that filaments will not burn out. Only in a vacuum can the flow of *electrons* to one or more of the electrodes be regulated.

As we have already explained (page 5), electrons, essentially, are tiny invisible charges of negative electricity which are capable of traveling at a speed of thousands of miles per second. These electrons make modern tubes possible. Without the constant, regulated flow of these tiny bits of electricity, a tube could not be operated.

Tubes contain several components. The *cathode* is the element in the tube which supplies the electrons. A *directly heated cathode* consists of nickel alloy wire coated with a special substance which gives off electrons when heated. The necessary heat is furnished by passing an electric current through the filament wire. (This is one reason for the fact that some kind of electric current—whether from batteries or from an electric outlet—is required to operate any radio set which employs radio tubes.) Examples of directly heated cathode tubes are these types: 30, 31, 32, 33, and 34—all for operation from batteries; and these types: 2A3 and 45—for A.C. operation.

An *indirect or "heater" cathode* tube has a heater or filament inside a metal sleeve. This sleeve is coated with a special substance which emits the electrons. Most present-day A.C. operated tubes have heater cathodes.

A *diode* is a two-element tube with a cathode to supply the electrons and a *plate* to attract and receive the flow of electrons. This plate has a positive voltage applied to it. (Remember that, as we said above, electrons are negative charges; you can see, then, why the plate which is charged positively will attract these electrons.) Types 80, 5Z3, and 5Z4 are examples of

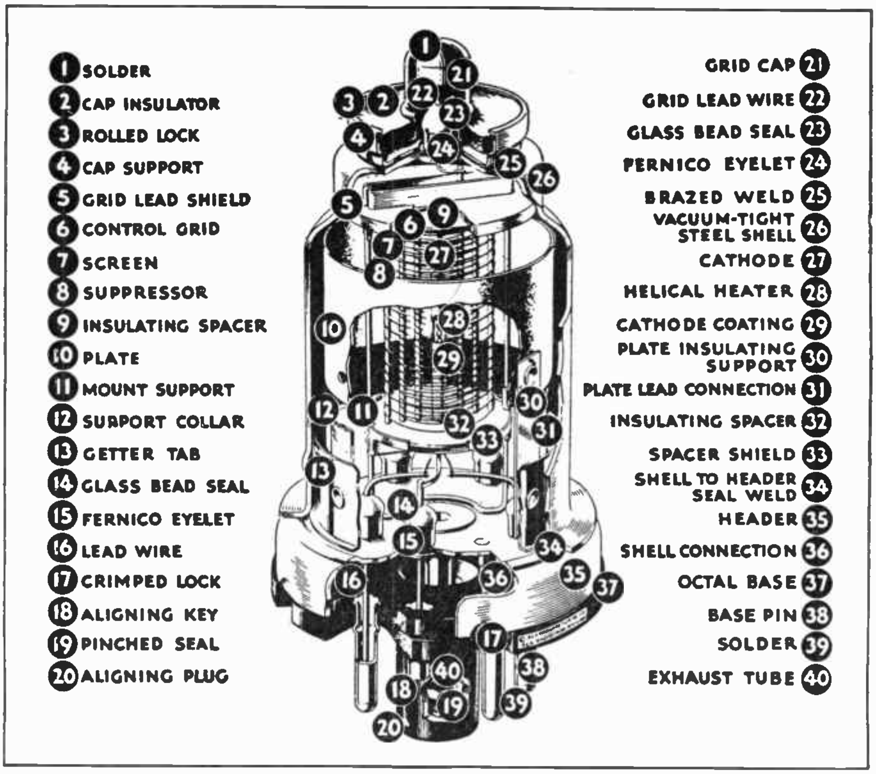


Figure 10. Cross-section of a typical RCA Metal Tube.
This diagram illustrates in detail the construction of a modern radio tube. All elements are clearly indicated. The complexity of the modern tube is here readily apparent. A good basic understanding of tube design and function is essential to good radio building.

rectifier diode tubes. Diodes are used most frequently as rectifiers in power supplies or as special detectors.

In order to control the flow of electrons most efficiently, Dr. DeForest (the inventor of the triode vacuum tube) introduced a control element called the *grid*. This was the beginning of the triode radio tube which has permitted highly efficient methods of transmission, detection, and amplification of radio signals. The grid is a winding of wire extending the length of the cathode and placed close to the cathode in order to affect the flow of electrons. Commonly used triodes are such types as 56, 45, and 30.

A small changing voltage on the grid varies the plate current by a larger amount and thereby permits amplification. Thus radio signals which are weak in intensity can be amplified and reproduced almost as powerfully as signals which are originally strong.

The three elements in the triode: grid, plate, and cathode, have existing capacities among themselves which are detrimental to perfect operation. The capacity between grid and plate in a triode limits the possible gain (or increase in amplification).

Accordingly, while a triode represents an advance over the diode tube, a still greater advance was made possible with the invention of the *tetrode*. (The names given to these tubes can easily be explained when you remember that *diode* means two elements; *triode* means three elements; *tetrode* means four elements; and *pentode* means five elements.)

A *tetrode* is similar to a triode but has an additional screen grid to eliminate the undesirable inter-electrode capacity which is found in triode tubes. This screen is mounted between the grid and the plate, connected to a positive potential, and by-passed to ground. Representative types of tetrodes are the 32 and 35.

A phenomenon known as secondary emission—the only limitation of the tetrode tube—is eliminated by the suppressor placed between the plate and screen grid in the more recent *pentode* types. Ordinarily, this suppressor is connected to the center tap of the filament or cathode (as in types 47 and 6F6) or is brought out externally in types 57, 6K7, and 78.

Until about 1935 radio tubes were manufactured with glass shells. This was due partly because of the fact that the manufacturers of early tubes drew on the experience of the makers of electric lighting bulbs, and partly because it was felt that glass was the most efficient substance for this purpose. In the year mentioned, however, after several years of preliminary research, the so-called metal tubes were first introduced on a large scale. These tubes employ a special steel shell which tends, in general, to reduce the hazard of breakage, and to provide somewhat better operation because of the elimination of stray noise interference. Metal tubes which have octal (8-prong) bases are interchangeable with glass tubes of the same type.

For the purposes of the beginner this information on tubes is sufficient. However, as you advance in your radio work, you will want to know more about tube theory and function; you can acquire this advanced knowledge from any one of a dozen tube manuals or radio theory books (see page 19).

If you will turn to the back of this book, you will find included a radio tube characteristic data chart compiled by the Raytheon Corporation. While the characteristics listed are based on Raytheon engineering specifications, the data is, in general, applicable to tubes of any brand. This chart includes a listing of practically all tubes now made and gives such data as description of tube, dimensions, electrical characteristics, and operating conditions and characteristics. Also included are pin data, showing the required connections to the elements in the tube.

This tube chart deserves a good deal of study. It will tell you practically anything you may want to know about the performance of any specific tube type. While some of the information contained in the chart may seem of limited use to you just now, eventually, you will find it to be one of the most important pieces of literature in your radio library.

COILS AND COIL WINDING

We have previously mentioned the fact that *coils* are used in the tuned circuit or circuits of a radio receiver, but we have said nothing about these coils. Essentially, they are used to permit reception of radio signals on specific frequencies as desired. For example, a set of Short-Wave coils is required to cover Short-Wave frequencies, and Broadcast coils are needed to cover the Broadcast band.

As we have already stated (page 6), the wire used in winding the coils has magnetic properties when an electric current is passing through. When a certain gauge of wire is wound over a coil form in a certain number of turns, the coil is sensitive to a definite sector of the radio spectrum.

Coils are wound with magnet wire on forms usually made of bakelite or similar composition material. For convenience in changing bands, some coil forms have prongs at the base such as radio tubes have. Thus, to change bands, you remove one coil from its socket and replace it with another coil that covers the required band.

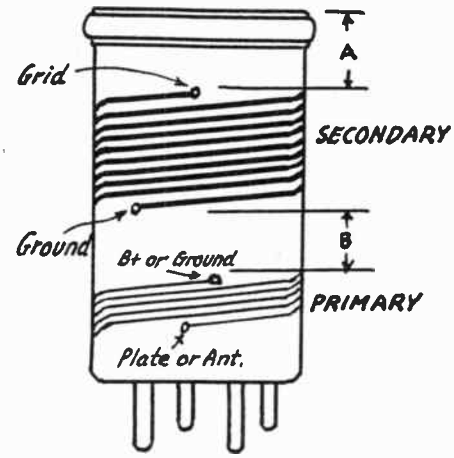


Figure 11. Method of winding a coil.

The chart below contains complete coil data for winding four- and six-prong plug-in coils to cover all Short-Wave and Broadcast bands. P. E. means plain enameled wire; D. S. C. means double silk covered wire. Any round or ribbed coil forms may be used; dimensions should be 1⅜" diameter by 2¼" height.

In winding coils care should be taken to do all winding in the same direction—that is, either clockwise or counter-clockwise. In beginning, drill a tiny hole in the coil form about ⅜" below and parallel to the top edge (Fig. 11). Pass one end of the wire through this hole, down through the coil form, and through one of the prongs at the base. (Your circuit diagram or coil instructions will tell you which prong is to be used in

COIL-WINDING DATA CHART

Wavelength covered with .00014 mfd. condenser	A	SECONDARY		B	TICKLER OR PRIMARY		In 6 prong coils, use this winding as the tickler, and the tickler as primary†	
		Turns	Wire		Turns	Wire	Turns	Wire
10-20	1"	3½	16 P. E.*	¼"	3	30 D. S. C.	2	30 D. S. C.
17-41	1"	8½	"	¼"	3	"	6	"
33-75	½"	17½	20 P. E.§	¼"	5½	"	11½	"
66-150	½"	38½	"	¼"	10½	"	24	"
135-270	½"	78	28 P. E.	⅛"	16½	"	45	"
250-560	½"	160	"	⅛"	32	"	82	"

† Wind tickler over or between secondary turns.
* Space between turns ⅛ inch.
§ Space between turns 1/16 inch.

any specific case.) When the bare wire protrudes through the hole in the bottom of the prong, solder the wire to the prong very neatly.

Now, proceed to wind the other end of the wire around the coil form for the number of turns specified for any particular coil. When the correct number of turns is made, cut off the wire—allowing about three or four extra inches, pass the end of the wire through another hole drilled at the end of the winding, put the wire through the coil form, and proceed to pass it through another prong and solder it as described above.

You have now finished the secondary winding (when using four-prong coils, the primary winding is connected to two prongs, and the secondary winding to the other two prongs). You can proceed now with the primary winding, in the same general way as described above, except that the first hole in the form will be drilled about midway down the coil form at the point where the primary winding is to begin.

When the proper number of turns and windings have been completed, it is advisable to apply a coat of "coil dope"—a special kind of lacquer. This serves two purposes: it holds the windings firmly in place; and it prevents absorption of moisture which might disturb the distributed capacity of the coil and thus affect the tuning range the coil is to cover.

In general, a good deal of time can be saved by purchasing ready-wound coils or a complete coil kit usually offered with construction kits. However, it is suggested that the beginner take the time to wind the coils for the first set he builds so that he will understand exactly how the coils are made.

RADIO OPERATING HINTS

Tuning a Short-Wave set or an All-Wave set that covers the Short-Wave bands requires a procedure different from that of simply twirling the dial for Broadcast reception. In the first place, it is necessary to keep in mind such factors as time difference between your own region and foreign countries, atmospheric conditions, and time of transmission schedules. It is advisable to consult a Short-Wave Time Table—included in most good radio magazines or in Short-Wave Logbooks—to determine just what stations are on the air in any particular band at the time you are operating your receiver.

Foreign Short-Wave stations frequently have available a number of different frequencies for transmission—and they shift from one frequency to another at different times of the day or in different seasons of the year. Some foreign stations transmit simultaneously on several frequencies; for example, the British Broadcasting Corporation transmits the identical program over stations GSB, GSC, GSD, and so on—each station being on a different frequency. Thus, if at any particular time conditions are such that you cannot pick up GSB, you may find that your set will bring in GSC because conditions are favorable for reception on its particular frequency. British stations—or other foreign stations transmitting in English—are easiest for the new DX'er to identify. But you will soon learn to recognize foreign language stations, too. "Ici Paris Mondial," you will learn, means "This is Paris." And other stations, too, have easily recognizable catch-phrases. In addition, in many instances, the foreign announcer makes his announcement in English and French, as well as in his native language.

Since stations are crowded closely together on the Short-Wave portions of the dial, you must learn to tune very slowly and patiently in order to "pull in" the signals you want. This is a point which cannot be too strongly emphasized. Unless your Short-Wave set has provision for *bandspread* (an arrangement making it possible to spread out stations over a larger dial scale area), you must not expect to tune in foreign stations as you would local stations. Tune up and back very slowly within the precise area on the dial covering the frequency of the station you want. Often, if your dial needle is even the merest trifle away from the exact spot, you do not get the station you want; but a scarcely perceptible adjustment of the tuning knob will bring the station in "on the nose."

If, after careful tuning, it appears to be impossible to tune in a specific station at one time, try again on another occasion—because when atmospheric conditions change, the station may "come in like a local." Remember that even the big commercial radio networks—with all of their costly and elaborate equipment (much of which is specially built and runs up into enormous sums of money)—sometimes cannot pick up programs from abroad scheduled for rebroadcast simply because atmospheric conditions are unfavorable.

Static—which means simply disturbance caused by atmospheric electricity—is a matter over which we have no control. This, of course, applies only to "true" static. ("Man-made" static—disturbances caused by electric motors such as those used in electric shavers, vacuum cleaners, toasters, mixers, etc.,—can be entirely eliminated by efficient filter devices attached to the source of the interference, although these filters are also sometimes useful when used between the electric outlet and the radio set. Battery-operated sets are not usually affected by "man-made" static caused by the devices mentioned since such sets do not get their power from the electric line.) A good deal of scientific research has been done to show that static is somehow connected with sun-spots—that at periods when sun-spots are most violent, static is worst. While this idea is now generally accepted, we have no way of eliminating the effects of sun-spots.

During the winter months static is seldom as severe and as detrimental to good radio reception as it is during the summer. Accordingly, long-distance radio reception is almost always better during winter than during summer.

In spite of difficulties which are beyond our control, long-distance reception on the Short-Wave bands is constantly being improved as new circuits and new ideas are developed. And as the art of radio progresses, the Short-Wave bands will grow to be even more important than they already are today.

NOTE: In operating a regenerative receiver (a set of the type of the Knight DX'ER), a special tuning procedure is required. After the set has been turned on, turn the rheostat about half-way up and rotate the regeneration control knob until *oscillation* results. This is a phenomenon you can recognize by a single click followed by a hissing sound after you have passed a certain point in turning the knob. When oscillation begins, you have reached the sensitive point of the set for C.W. (code) reception. Then, turning the dial slowly, always readjusting the regeneration control to keep the set at the point of regeneration, you will find that your station comes right in.

To tune 'phone stations, you must keep the set *just below* the point of oscillation. This can be done by trying first for oscillation, then turning back until oscillation is gone, then working up again until you know that you are at the point just below oscillation. Then proceed to turn the tuning knob until you can hear the 'phone station very plainly.

A little practice with this procedure will soon make you an efficient short wave operator.

AMATEUR RADIO

We come now to a subject which could be treated adequately only in far more space than we have available. This is the subject of Amateur Radio. Since this book has been planned especially for the beginning radio builder and experimenter, and since there are already dozens of manuals for the Amateur, we shall confine ourselves to material of a rather general nature.

The Amateur (or "Ham," as he also calls himself) is the aristocrat of non-professional radio circles. Strictly speaking, an Amateur is a person who holds a Federal license to operate a transmitter on the radio bands restricted to non-commercial use. In order to obtain this license (issued by authority of the Federal Communications Commission) the prospective Amateur must meet a number of requirements which have been set up by the government to assure that all Amateur stations are competently operated.

The Amateur license is issued in three classifications. *Class A* licenses are issued to persons who have held an Amateur license for at least a year and who have appeared in person at the regional F. C. C. office for examination. A code speed in sending and receiving of at least 13 words per minute; a technical knowledge of Amateur equipment; and a knowledge of the F. C. C. regulations relative to Amateur stations are the three chief requirements. *Class B* licenses are issued to those who have never held an operator's license. The examination is similar to that for Class A licenses, but less knowledge of 'phone equipment is required. *Class C* licenses are issued on the same basis as Class B, but the examination is given by mail to persons living more than 125 air-miles from the nearest F. C. C. office.

In all cases, the Amateur operator must be a citizen of the United States and the Amateur station must be operated on premises not owned or controlled by an alien. There is no age limitation—and so Amateurs range in age from young boys of 14 or 15 to men and women over 60.

Full details of the license requirements and the addresses of your nearest F. C. C. office can be obtained from the Federal Communications Commission, Washington, D. C. (In Canada, details of requirements may be obtained from the Canadian Radio Commission, Ottawa, Ontario.)

For purposes of radio administration, the continental United States is separated into nine districts. Amateur station call letters are based on this separation. In the first place the prefix W was assigned to the United States by international radio convention. To this prefix is added the number corresponding to the district number. W9, for example, is the prefix for the district comprising the Midwest region. Added to this prefix are two or three letters, identifying the individual station.

The U. S. districts are:

- W1—New England states, including Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, upper New York State.
- W2—North Central Atlantic States, including New Jersey, New York.
- W3—Middle Atlantic States, including Delaware, Maryland, North Carolina, Virginia, District of Columbia, Northwestern Pennsylvania, Eastern West Virginia.
- W4—Southern Atlantic States, including Tennessee, Alabama, Georgia, Florida, South Carolina.
- W5—South Central States, including Mississippi, Louisiana, Arkansas, Oklahoma, Texas, New Mexico.
- W6—Pacific States, including California, Nevada, Utah, Arizona.
- W7—Northwest States, including Montana, Wyoming, Idaho, Oregon, Washington.
- W8—Great Lakes States, including Pennsylvania, New York, West Virginia, Ohio, Michigan.
- W9—Middle West States, including Nebraska, Kansas, Iowa, Missouri, Colorado, Illinois, Indiana, Kentucky, North Dakota, South Dakota, Minnesota, Wisconsin.

The K prefix is used for U. S. territories, including Alaska, Hawaii, Philippine Islands. The VE prefix is used in Canada.

To secure the address of the radio inspector in your district, see any copy of the *Radio Amateur Callbook*, write to ALLIED, or get in touch with the F. C. C. as recommended above.

CODE

We have already mentioned the fact that a knowledge of radio code is required of all Amateurs. Learning this code and acquiring proficiency in transmitting and receiving in code should therefore be an early step in the procedure of every one who intends to become an Amateur. The Continental Morse Telegraph Code used in radio consists of short signals (called *dots*) and long signals (called *dashes*) which are about three times as long in duration as the short signals.

The following table shows the code for letters of the alphabet, for numbers, and for common punctuation marks:

LETTERS

• —	A	— •	N
— • • •	B	— — —	O
— • — •	C	• — — •	P
— • •	D	— — • —	Q
•	E	• — •	R
• • — •	F	• • •	S
— — •	G	—	T
• • • •	H	• • —	U
• •	I	• • • —	V
• — — —	J	• — —	W
— • —	K	— • • —	X
• — • •	L	— • — —	Y
— —	M	— — • •	Z

NUMBERS

• — — — —	1	— • • • •	6
• • — — —	2	— — • • •	7
• • • — —	3	— — — • •	8
• • • • —	4	— — — — •	9
• • • • •	5	— — — — —	0

PUNCTUATION

• • • • • •	Period
• — • — • —	Comma
• • — — • •	Question Mark

While the long and short signals are called dashes and dots, when heard over the air they sound like "dit" for the dots and "dah" for the dashes. The letter *P*, for example, sounds like "dit-dah-dah-dit." In learning the code, therefore, the letters should be memorized with the "dit-dah" sounds, not as "dot-dash."

We lack the space to say very much about the process involved in learning the code. Furthermore, it is adequately covered in several books for the Amateur. However, we can suggest that a "code-learning" device or "code practice set" of some kind should be used. A typical set consists of a telegraph-type "key," buzzer, and battery. Pressing the key produces a high-pitched note exactly like the sound of code as it is transmitted. The code-learner can thus associate the "dit-dah" combination of sounds with each letter and fix the sound-combination firmly in mind. If two persons work the set together, they can learn to send and to receive code in a short period of time and then to increase their efficiency by regular practice.

Another possibility for the code learner is to use an "audio oscillator" or a "code-reader" device; the latter is a motor driven device which records code signals on paper tape. The unit is connected to the voice coil of any radio set loudspeaker and the sounds are then reproduced so that the code-learner can get practice in decoding the signals.

As we have said, however, the best procedure is to learn the code cooperatively with another person. Each individual can take turns in sending and in copying (receiving) so that the whole process is made a unified experience.

Many Amateurs operate radiophone transmitters, in which transmission is by voice rather than by code. However, before the Ham can operate a 'phone transmitter, he must have previously demonstrated his ability to use code. You can listen to Amateur 'phone con-

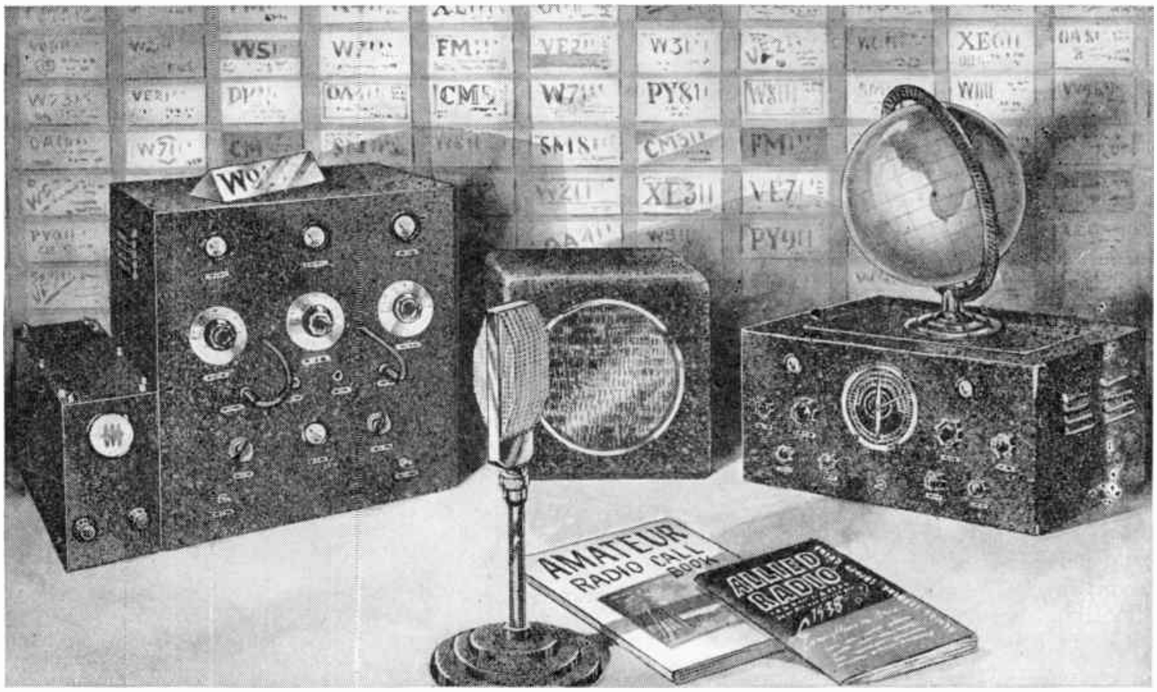


Figure 12. A typical, well-arranged amateur station

versations on the short-wave bands in the following ranges:

1800-2000	K.C. (166-150 meters)
3900-4000	K.C. (76.9-75 meters)
14150-14250	K.C. (21.2-21.05 meters)
28000-28500	K.C. (10.7-10.5 meters)
56000-60000	K.C. (5.36-5 meters)
400000-401000	K.C. (.7496-.7477 meters)

The complete range at present reserved for Amateur station operation is as follows:

1715-2000	K.C. (175-150 meters)
3500-4000	K.C. (85.7-75 meters)
7000-7300	K.C. (42.9-41.1 meters)
14000-14400	K.C. (21.4-20.8 meters)
28000-30000	K.C. (10.7-10 meters)
56000-60000	K.C. (5.36-5 meters)
400000-401000	K.C. (.7496-.7477 meters)

The Amateurs of the world maintain several organizations, the most noted of which is the American Radio Relay League (A. R. R. L.). A full description of this group, its aims, and its operation is included in the A.R.R.L. *Handbook* (see List of Books, Page 19). Amateurs have on several occasions rendered immeasurable service to our government and to our people. In times of disaster especially, as in the devastating floods of 1936, the Amateur station operators maintained the only contacts with the rest of the nation when almost all other communication facilities had failed. The newspapers frequently tell of how lives of persons in isolated localities are saved by Amateur radio communication.

But even aside from times of disaster and heroism, Amateurs are constantly active to improve the art of radio and to further fellowship and good will. The radio-builder and experimenter who passes beyond the beginning stages can well set as his goal the operation of his own Amateur station.

Here, again, expense is not as high as one might imagine. The transmitter described on pages 26-27 can be built at remarkably small cost and will put you on the air with a power of ten watts. True, this transmitter is far from elaborate, yet it has been designed for maximum serviceability for the newcomer Amateur, and over a period of time you can gradually expand your facilities until you have a first-class rig, such as that shown in Figure 12.

A LIST OF COMMON ABBREVIATIONS

As you read circuit diagrams or radio magazines and books, you will frequently run across a good many abbreviations or symbols for radio terms. While the radio Amateur has a whole scheme of abbreviations all his own, we believe that even the radio beginner ought to know the meanings of some of the more common abbreviations in general use. It is advisable that you become familiar with these terms in order to facilitate your understanding of radio "lingo."

A. C. —Alternating current
A. F. —Audio frequency
A. F. C. —Automatic frequency control
amp. —Ampere
ant. —Antenna
A. V. C. —Automatic volume control
A. V. E. —Automatic volume expansion
BC —Broadcast
B. F. O. —Beat frequency oscillator
cap. —Capacity
CW —Continuous wave (used to refer to *code* transmission)
DB. —decibel (unit of measurement for sound)
D. C. —Direct current
DX —Long distance
EMF —Electromotive force (voltage)
gnd. —Ground
Ham —Licensed Amateur
HF —High frequency
Hy. —Henry (unit of measurement for inductance)
I —Symbol for current in amperes
I. F. —Intermediate frequency
KC —Kilocycle (1000 cycles)
KW —Kilowatt (1000 watts)
Meg. —Megohm (1,000,000 ohms)
ma. —Milliampere (1/1000 amperes)
MC —Megacycle
mfd. —Microfarad
mh. —Microhenry
mike —Microphone
mil. —One-thousandth
mmfd. —Micro-microfarad
Ω —Ohm
P. A. —Public Address
'phone —Radiophone (voice transmission)
QRM —Noise interference
QST —General call to all Amateurs
R —Resistance
RF —Radio frequency
SG —Screen grid
SOS —Distress signal at sea
Superhet —Superheterodyne (a type of radio circuit)
SW —Short wave
SWL —Short wave listener (a radio fan who is not an Amateur station operator)
TRF —Tuned radio frequency (a type of radio circuit)
UHF —Ultra high frequency
V —Volt
W —Watt
X'mitter —Transmitter
X'tal —Crystal
Z —Symbol for impedance

CONVERSION TABLE

MULTIPLY	BY	TO GET
Amperes	× 1,000,000	microamperes
Amperes	× 1,000	milliamperes
Cycles	× .000001	megacycles
Cycles	× .001	kilocycles
Farads	× 1,000,000,000,000	micromicrofarads
Farads	× 1,000,000	microfarads
Henrys	× 1,000,000	microhenrys
Henrys	× 1,000	millihenrys
Kilocycles	× 1,000	cycles
Megacycles	× 1,000,000	cycles
Microamperes	× .000,001	amperes
Microfarads	× .000,001	farads
Microhenrys	× .000,001	henrys
Micro-ohms	× .000,001	ohms
Microvolts	× .000,001	volts
Micromicrofarads	× .000,000,000,001	farads
Milliamperes	× .001	amperes
Millihenrys	× .001	henrys
Milliohms	× .001	ohms
Millivolts	× .001	volts
Ohms	× 1,000,000,000	micro-ohms
Volts	× 1,000,000	microvolts
Volts	× 1,000	millivolts

A LIST OF USEFUL BOOKS

The following books are suggested as reference works for the student of radio, and as sources of further information for the advanced radio builder. As you progress in your radio work, you will want to add some or all of these books to your library.

Amateur Radio Relay League: *The Radio Amateur's Handbook.* The official handbook of the A. R. R. L., covering every aspect of Amateur radio from the beginning stages to advanced station operation. Valuable for all radio builders. *The Radio Amateur's License Manual.* Complete information on how to apply for an Amateur license, how to pass examinations; also contains government regulations covering Amateur station operation.

Ghirardi, A. A.: *Radio Physics Course.* A textbook offering a complete course in the theory of radio and television. Essential for the student who wants a sound background in radio theory.

Henney, Keith: *Principles of Radio.* A popular textbook in radio theory and practice.

Radio Amateur Call Book, Inc.: *Radio Amateur Call Book Magazine.* Lists over 70,000 U. S. and foreign Amateurs; includes Short Wave schedules of time, weather, and press reports. Published quarterly.

Manly, H. P.: *Radio and Electronic Dictionary.* A useful reference book defining some 3,000 radio terms in clear, understandable language.

Radio, Ltd.: *The "Radio" Handbook.* Covers all aspects of radio building and operating, including Amateur radio. Diagrams and instructions for building everything from a 1-tube receiver to a 1 K.W. transmitter.

Radio Corporation of America: *R. C. A. Tube Manual.* Complete technical specifications on all R. C. A. receiving type tubes. *R. C. A. Transmitting Tube Manual.* For the Amateur station operator.

Raytheon Production Corporation: *Raytheon Tube Databook.* Complete data on all Raytheon tubes, including practical applications.

(For prices of above, for more complete descriptions, and for lists of other useful books, consult your current ALLIED catalog.)

RESISTOR COLOR-CODE GUIDE

The Radio Manufacturers' Association (R. M. A.) has adopted a standard system for coding resistors with colors to indicate the resistance value. Since resistors are used in all radio circuits, and since the values are indicated on the resistors by coloring, the radio beginner must learn how to read this color-code.

Three color indications are used. "Body" color is the color of the body of the resistor itself. "End" color is the color at the end of the resistor. "Dot" color is the color of a dot on the resistor body. These stand for the resistance in this way: Body color represents the first figure of the resistance value; end color represents the second figure; and dot color represents the *number of zeros* following the first two figures.

For example, to indicate a resistance of 25,000 ohms, under the R. M. A. color-code system, a resistor would have a red body, a green end, and an orange dot. (Red stands for 2, green for 5, and orange for 3 zeros.)

The following table shows the values represented by the various colors:

BODY COLOR (*1st Figure*)	END COLOR (*2nd Figure*)	DOT COLOR (*No. of Zeros*)
0—black	0—black	none—black
1—brown	1—brown	0—brown
2—red	2—red	00—red
3—orange	3—orange	000—orange
4—yellow	4—yellow	0000—yellow
5—green	5—green	00000—green
6—blue	6—blue	000000—blue
7—violet	7—violet	
8—gray	8—gray	
9—white	9—white	

A handy pocket-size celluloid guide with rotary discs showing body, end, and dot colors of resistors according to R. M. A. standard color-code can be purchased from ALLIED. This pocket guide shows the figure for each color on each scale so that resistance values can be obtained instantly.

Many manufacturers also mark small mica condensers with three colored dots following the same code employed for resistors. For condensers, all readings are in micromicrofarads (mmfd.). A 250 mmfd. condenser (.00025 mfd.) would be coded as follows: red dot (2), green dot (5), brown dot (1 zero).

SOME INTERESTING CIRCUITS

On the pages that follow we have included diagrams and construction notes on a number of circuits of especial interest to radio newcomers. As we have previously mentioned, the Knight 2-tube DX'er or the Knight "Ocean Hopper" are ideal as the beginner's first set. The Knight 3-watt amplifier and power supply is intended to be used with either of the above sets and makes it possible to adapt them for loudspeaker use.

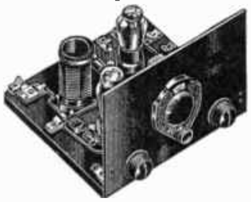
A diagram and notes on a 10-watt transmitter have been included especially for those who plan eventually to go into the field of Amateur radio. Of particular interest to the experimenter are the circuits for an Electric Fence Control and the Photo-Electric Cell.

In addition to these circuits, the beginner will find all types of sets described in construction articles in the current radio magazines and in other handbooks. Also, every ALLIED catalog devotes a number of pages to listings of construction kits, blueprints, and diagrams for hundreds of other sets. In every instance, a parts list showing a complete kit of matched parts for building any circuit is available from ALLIED on specific request.

The construction notes on the following circuits are based on actual laboratory construction of these sets. In each case, the beginner should follow the instructions faithfully. Failure to do so may result in poor operation—or total lack of operation—of the circuits described. In most cases, both pictorial and schematic diagrams have been included to clarify as much as possible the exact procedure to be followed in wiring the circuit. Parts list include ALLIED'S low net price quotations for each part and for complete kits.

KNIGHT 2 TUBE "DX-ER"

The 2-Tube "DX-er" is a dependable battery operated short-wave receiver which can be built quickly and easily. The tuning range is 15 to 500 meters when used with proper coils, covering the important foreign and domestic 'phone and code Amateur bands, as well as regular standard broadcast programs.



Assembled "DX-er"

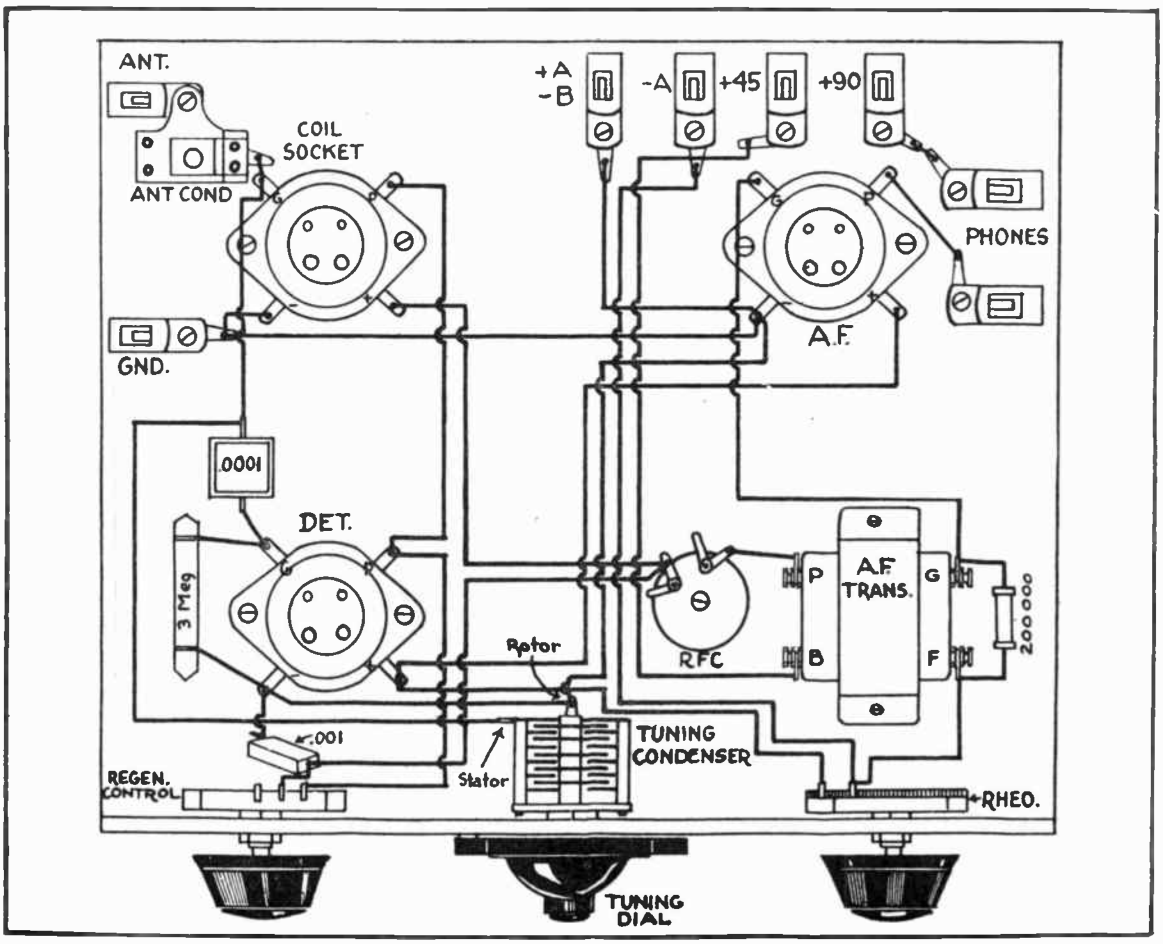
Before you begin to wire, you should mount all the parts as indicated on the pictorial diagram. This is extremely important for effective results. You can then start the wiring, following the schematic diagram and checking your work from time to time with the pictorial diagram. As you proceed, trace the completed connections with a colored pencil. This will help you to remember exactly which connections have already been made.

After the set has been wired and one of the coils and the two type 30 tubes are in place, connect the "A" battery and advance the rheostat until a filament glow is noticeable in the tubes. This is a safety step to check if the filaments are wired correctly. No glow indicates that an error has been made in the filament circuit of the tubes. When the filament glows, connect the "B" battery and insert the headphones into the proper Fahenstock clips.

Now test the set to see if it will regenerate. Advance the regeneration control to the right, and a whistle will be heard. If you do not hear this whistle, check the coil socket and the "B" batteries to see that they are wired correctly.

Next, connect the antenna and ground. With these in place and the regeneration control just below oscillation (whistling point), turn the tuning control and you will receive several stations. You will find that adjusting the antenna trimmer will help a great deal. The antenna condenser should be adjusted so that the detector tube will oscillate at all points on the tuning dial. The point of adjustment depends entirely upon the degree of absorption of the antenna circuit from the tuning circuit. Once the trimmer is adjusted for any one of the coils, no other changes need be made until

PICTORIAL WIRING DIAGRAM



KNIGHT 2 TUBE "DX-ER"

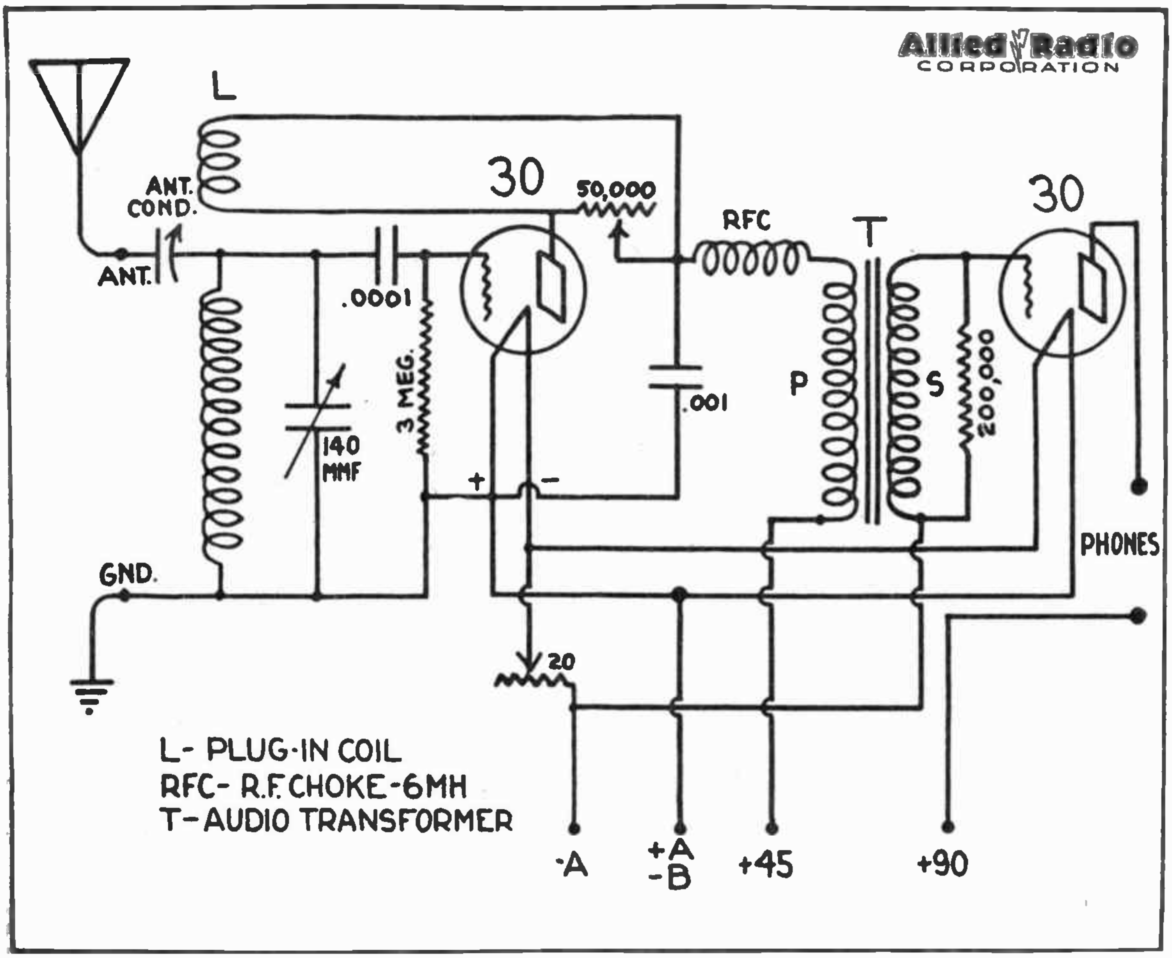
a different coil is used. This adjustment is not critical except when you actually want some real DX. It is worth mentioning here that a good aerial is essential for efficient short wave reception, particularly for a set of the "DX-er" type. Both the aerial and lead-in should be well insulated and kept as far away from walls, roofs, etc., as possible.

You will soon learn in using the "DX-er" that broadcast and amateur 'phone stations come in best when the regeneration control is below the point where oscillation starts. Code signals, however, come in best above this point. In working on the short wave bands, keep the set just oscillating, and tune very slowly. The incoming "dit-dit-dah" will tell you that you have a code station. A whistle, on the other hand, should serve as a warning to reduce the regeneration control setting, and then to listen to a 'phone station at this dial setting.

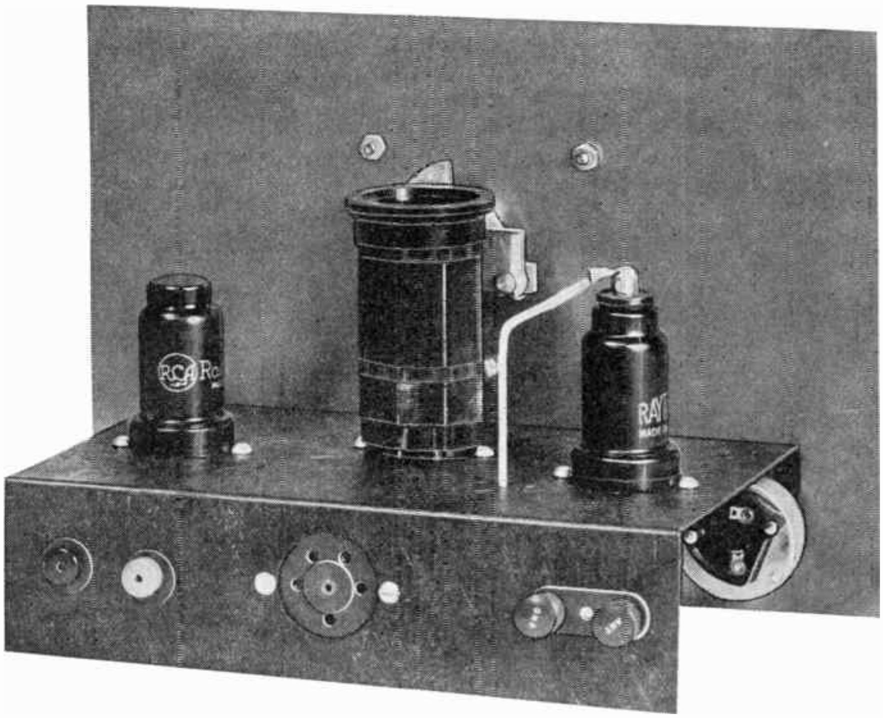
While there is nothing tricky about the operation of the "DX-er," it is well to spend some time in learning how to tune it so that you may derive maximum reception. (See right for complete parts list.)

N2791	1	Knight 7x9 drilled Masonite panel	$ .40
E4000	3	Eby 4-prong sockets @ .18	.54
E4130	1	140 mmf. variable condenser	.57
E9037	1	Carter 30 ohm rheostat	.24
E5966	1	Knight 50,000 ohm regeneration control	.28
E11647	1	3 to 1 audio transformer	.71
E5374	1	Hammarlund antenna condenser	.18
E5605	1	Knight R.F. choke	.18
E7830	1	" .0001 mfd. condenser	.08
E7837	1	" .001 mfd. condenser	.08
E4905	1	I. R. C. 3 megohm resistor	.04
E4993	1	Knight 200,000 ohm resistor	.05
E6320	8	Fahenstock single clips @ .01	.08
N2239	1	Knight baseboard	.15
E6200	1	Kurz Kasch dial	.38
E6208	2	Knight knobs @ .05	.10
N1615	1	" hardware kit of screws, nuts, wire, etc.	.15
E9873		Complete kit of parts as above	$3.98
E5565	1	Coil kit 16 to 217 meters	.85
E415	2	Raytheon 30 tubes @ .46	.92
E8925	2	Knight dry cells @ .21	.42
E8920	2	" "B" batteries @ .94	1.88
E8930	2	" plugs for batteries @ .03½	.07
E9839		Accessory kit as above	$3.15
E2908	1	Brandes 'phones, 2400 ohms	1.59

SCHEMATIC WIRING DIAGRAM



KNIGHT 2 TUBE "OCEAN-HOPPER"



Many stations across the Atlantic can be heard with clarity and volume on this two-tube short-wave receiver. If Rome, Berlin, and London all try to crowd into the same division on the tuning dial, the full band-spread tuning control may be used to spread them apart.

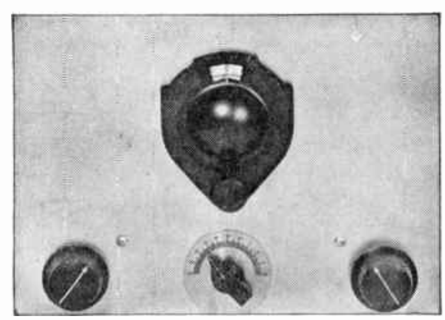
A soldering iron, pliers, and a screwdriver are the only tools needed for building the set. A complete ready-to-wire kit containing all required parts together with a drilled metal chassis panel may be purchased. This powerful little receiver is ideal for the beginner who wants a good set and seeks experience in the wiring of a circuit without the work of punching and drilling holes.

The circuit is of modern design, featuring all-metal tubes, complete shielding, an efficient electron-coupled detector with ultra-smooth regeneration control, and one high-gain audio amplifier stage to give the set plenty of "sock." It will operate either from batteries or from a special AC power supply, the parts for which are also available in a ready-to-wire kit. Power requirements are 6.3 volts AC or DC for filaments and 90 volts DC for plate and grid voltages.

Each of the four coils covers a portion of the range from 16 to 195 meters. Pulling out one coil and plugging in another to change bands requires only a few seconds, and gives a far more efficient band-changing arrangement than an expensive coil-changing switch.

The regeneration control resistor, which also serves as volume control, varies the screen grid voltage for

Views of two-tube "Ocean-Hopper" set showing positions of parts on panel and chassis. Controls, left to right: Regeneration control, tuning control (top center), band-spread control (below), and filament switch.



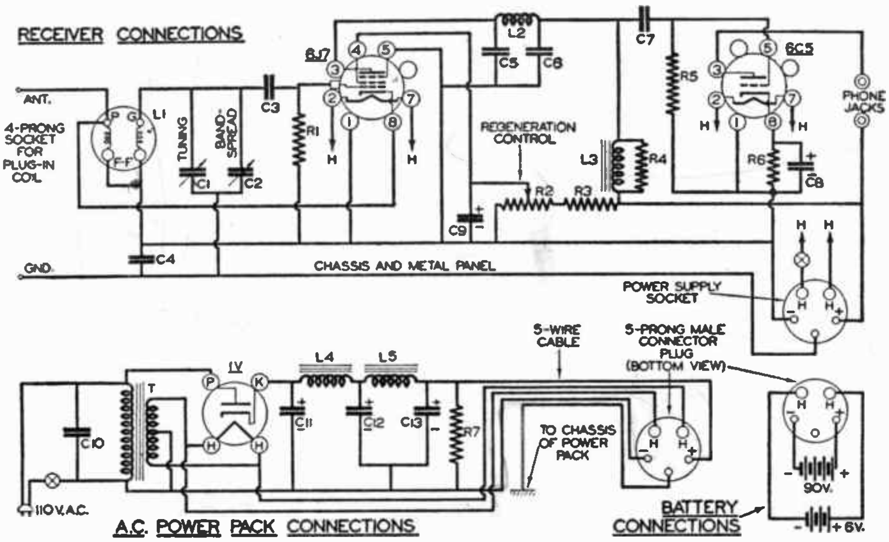
the 6J7 tube, thus controlling the amount of feedback voltage in a smooth, efficient manner.

The connections for all parts are shown on the circuit diagram, and the positions of the parts may be seen in the photographs. The four-prong socket for the plug-in coils and the two variable condensers are centrally mounted. The octal socket for the 6J7 tube, the regeneration control resistor, and the ANT.-GND. binding post strip are at the left on the chassis and panel, while the octal socket for the 6C5 tube, the 5-prong socket for the power supply plug, the headphone jacks, and the rotary single-pole, single-throw switch are at the right.

The GND. post is connected directly to the chassis. The bandspread and tuning condensers are automat-

KNIGHT 2 TUBE "OCEAN-HOPPER"

ically connected to the front panel by the mounting bolts. The chassis of the power supply (if used) connects to the receiver chassis through the power supply socket and plug. Condensers and resistors are supported by their own leads and located so as to keep all connecting wires as short as possible. Filament leads for the two tubes should be twisted together to prevent hum. Instead of making power supply connections directly to terminals on the chassis, a plug-and-socket arrangement is used, with a five-wire cable running to the batteries or power supply unit located as far as five feet away from the receiver.



Circuit diagram for the two-tube receiver, with diagrams for battery and AC power supply units directly below. Bottom views of sockets are shown in all cases.

This makes it possible to place the receiver almost anywhere desired, and to keep the batteries or power supply out of sight, or in a separate cabinet.

Electrolytic by-pass condenser C8 must be connected with the indicated polarity. This means that its black lead (which is negative) goes to the common negative power supply lead.

Octal socket connections are shown as though viewed from the bottoms of the sockets; hence the connections are exactly as seen when working underneath the chassis. The aligning plug for an octal socket is always between terminals 1 and 8; hence any desired terminal may easily be located. Bottom views are also shown of the power supply socket and of the 1V rectifier tube socket.

Reprinted from *Science and Mechanics*—Article prepared by ALLIED RADIO CORPORATION

PARTS LIST FOR TWO-TUBE OCEAN-HOPPER

N2228	1	Knight drilled electralloy panel, 7"x9"	$0.95
N2226	1	" drilled steel chassis, 5"x8"x2"	.60
E11654	1	" 750 henry choke (L3)	.89
E6200	1	Kurz Kasch vernier dial, 3"	.38
E6171	1	Knight bar knob	.04
E5741	1	" dial plate	.28
E6208	2	" arrow knobs @ .05	.10
E4129	1	" 100 mmfd. tuning condenser (C1)	.48
E4126	1	" 30 mmfd. bandspread condenser (C2)	.38
E5605	1	" 2.5 millihenry R. F. choke (L2)	.18
E6950	1	Carter 50,000 ohm variable resistor (R2) regeneration control	.31
E4031	2	Knight octal sockets @ .06	.12
E4026	1	" 4 prong socket	.05
E4027	1	" 5 prong socket	.05
E4905	1	" 3 megohm ¼ watt resistor (R1)	.04
E4994	2	" 250,000 ohm ½ watt resistor (R4 and R5) @ .05	.10
E5091	1	" 100,000 ohm 1 watt resistor (R3)	.06
E5065	1	" 1,500 ohm 1 watt resistor (R6)	.06
E7830	1	" .0001 mfd. mica condenser (C3)	.08
E7833	2	" .00025 mfd. mica condenser (C5 and C6) @ .08	.16
E7838	1	" .0015 mfd. mica condenser (C4)	.12
E7927	1	" .1 mfd. condenser, 400 volt (C7)	.08
E3776	1	" 1 mfd. electrolytic, 200 volt (C9)	.20
E3790	1	" 5 mfd. electrolytic, 35 volt (C8)	.16
E5462	1	" SPST switch	.17
E6364	1	" red tip jack, insulated	.06
E6365	1	" black tip jack, insulated	.06
E6305	1	Knight terminal strip, 2 lugs	.03
E4059	1	Eby twin binding post strip	.14
E6335	1	Knight small grid clip	$0.01
E3560	1	" 25' roll hookup wire	.10
N1644	1	" hardware kit	.10
E9844	1	Complete kit as above	$6.40

ACCESSORIES

E1070	1	Knight 6J7 tube, metal	$0.58
E1066	1	" 6C5 tube, metal	.51
E8925	4	" 1½ volt dry cells @ .21	.84
E8920	2	45 volt "B" batteries @ .94	1.88
E9845	1	Set of 4-4 prong coils, 16 to 195 meters	1.25
E8930	2	Plugs for "B" batteries @ .03½	.07

POWER SUPPLY PARTS LIST

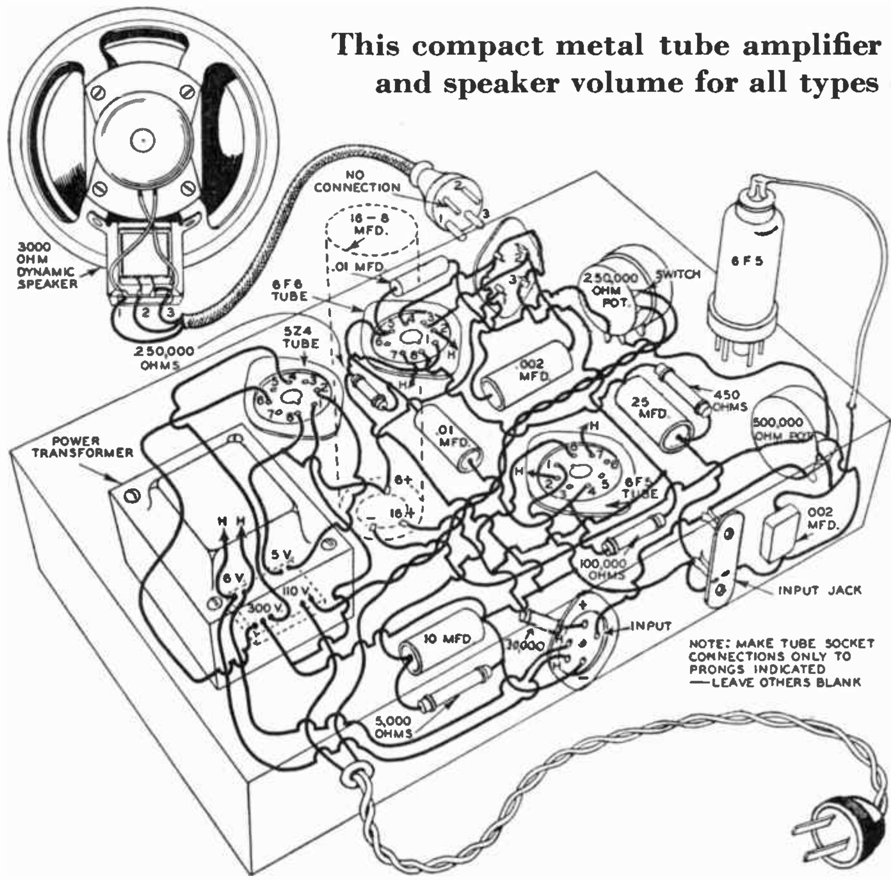
N2227	1	Knight drilled steel chassis, 4½"x6¼"x2"	$0.60
E11843	1	Thordarson 6.3 volt filament transformer (T)	.92
E11650	2	Knight 25 henry filter chokes (L4 & L5) @ .68	1.36
E11710	1	Mallory 12 mfd. 250 volt electrolytic condenser (C11)	.59
E11720	1	" dual 8 mfd. 250 volt electrolytic condenser (C12, C13)	.76
E7910	1	Knight .1 mfd. 200 volt condenser (C10)	.07
E4229	1	7500 ohm 10 watt resistor (R7)	.29
E4026	1	Knight 4 prong wafer socket	.05
E3498	1	" A.C. cord with plug	.14
E5450	1	H&H SPST A.C. switch	.19
N1608	1	Knight hardware kit	.15
E9846	1	Complete kit of parts as above	$4.90

ACCESSORIES

E903	1	Knight 1V rectifier tube	$0.44
E2901	1	4½' 5 wire cable	.24
E1801	1	5 prong male connector plug	.15

3 WATT AMPLIFIER AND POWER SUPPLY

This compact metal tube amplifier provides both "B" power and speaker volume for all types of small radio receivers



Every radio experimenter has occasion at some time to use an amplifier; especially if he owns a small two or three-tube short wave receiver. Until a few years ago any amplifier that had the least bit of output was a bulky affair weighing at least 25 pounds. With the improvements in radio design which have been made during the last few years it is now possible to construct an inexpensive powerful little amplifier in a tiny metal chassis scarcely measuring 7 by 4½ by 2 inches. Small as it may be it is nevertheless capable of delivering nearly 3 watts of good quality power amplification.

Examination of the circuit will reveal the use of three metal type tubes. A type 6F5 tube is used in the input, a type 6F6 pentode in the output, and a type 5Z4 rectifier tube in the power supply circuit. By wiring these tubes according to the numbers appearing on the prongs in both the pictorial and schematic diagrams no difficulties will be encountered.

In order to operate the amplifier at its peak efficiency a novel code tone control is employed. One potentiometer serves as the tone control, while the other is used to regulate volume. The volume control is fitted with an A.C. switch so that this one control turns on the power and regulates the volume of the receiver as well.

A unique feature of this amplifier is the self-contained B and filament power supply for supplying current to a small short wave receiver or other radio device. The two-tube "Ocean Hopper" can be powered with this amplifier.

This simple amplifier has various other practical and useful applications. For instance, it may be used for reproducing phonograph recordings electrically in the following manner. Any record player having a high impedance crystal or magnetic pickup may be connected directly to the input terminals of the amplifier. The output volume level will be controlled in exactly the same manner as mentioned before, while the tone control will permit you to stress the tones needed for most realistic reproduction.

This versatile unit can also be used with extension or additional speakers when hooked up to any large home radio receiver. One of the input terminals should be connected through a .05 mfd., 600-volt condenser to the plate of the detector or first audio tube in the radio set, the other to the chassis. The programs received by the set will also be reproduced in the extension speaker used with the amplifier. This speaker may be placed at some distance away from the set—in another room, on the porch, etc.

Since the pictorial diagrams show the exact locations of all parts and their proper connections, little detail on the wiring is necessary. All resistances are of the carbon pigtail type and are rated at one watt. The fixed condensers are of the tubular type except for the two .002 mfd. units which are small mica condensers. The

3 WATT AMPLIFIER AND POWER SUPPLY

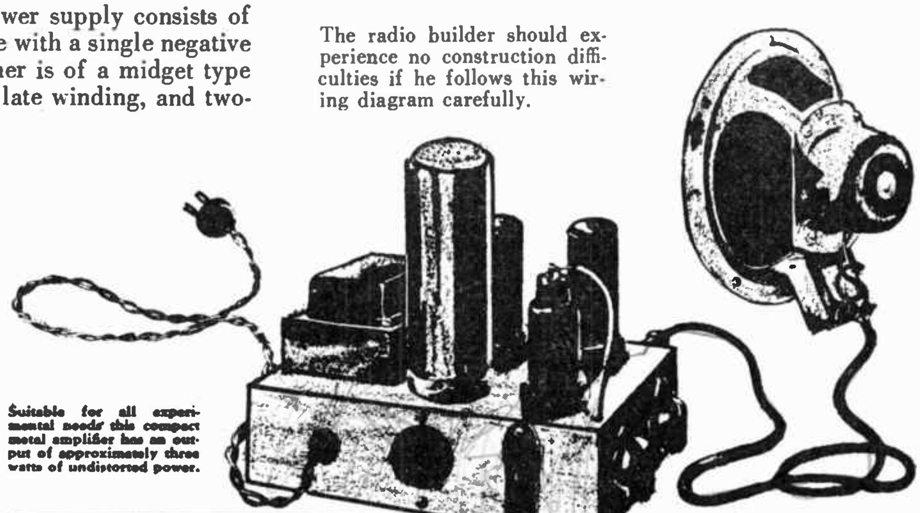
electrolytic condenser in the power supply consists of an 8 and 16 mfd. unit in one case with a single negative lead for both. Power transformer is of a midget type with a 675 volt, center-tapped plate winding, and two-filament winding; one supplying 6.3 volts and the other 5 volts.

The dynamic speaker field winding serves as the filter choke in the power supply. The speaker is a 6-inch dynamic type and attaches to the amplifier through a 4-prong plug. Ordinary tube sockets are used for both the speaker plug connection and the external power supply cable.

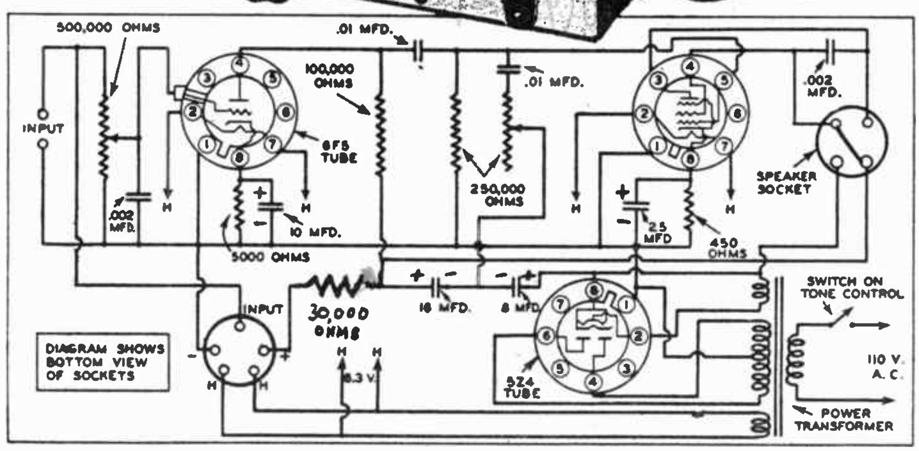
The builder of this compact, versatile amplifier will find a great many uses for it. While it is ideal, as we have mentioned, for use with the Knight Two-Tube "Ocean Hopper" (page 22), it can be used with an extension speaker or with a record player. Since the amplifier has a plug-in cable arrangement, it can be moved around and used for any of the purposes mentioned at almost any time. It should by all means be the next circuit you work with, after you have finished your two-tube set.

Reprinted from
Modern Mechanix Magazine
January, 1937
(Article prepared by ALLIED)

The radio builder should experience no construction difficulties if he follows this wiring diagram carefully.



Suitable for all experimental needs this compact metal amplifier has an output of approximately three watts of undistorted power.



If this schematic wiring diagram is followed along with the pictorial hook-up there is little chance for errors to occur. Note that the tube prongs are not all connected in the circuit since some are blank. Tube sockets, above, show the connections as they appear from the bottom of socket; pictorial diagram shows top view.

COMPLETE PARTS LIST

N2256	1 Special chassis, 7"x4½"x2"	$0.65
E6062	1 Power transformer	1.03
E2738	1 8-16 mfd. 500-volt electrolytic condenser	.88
E3791	1 10 mfd. 35-volt electrolytic condenser	.16
E3792	1 25 mfd. 35-volt electrolytic condenser	.28
E7839	1 .002 mfd. mica condenser	.12
E7937	2 .01 mfd. 600-volt condenser ....@ .08	.16
E5057	1 450 ohm 1 watt carbon resistor	.06
E5074	1 5,000 ohm 1 watt carbon resistor	.06
E5186	1 30,000 ohm 2 watt carbon resistor	.10
E5091	1 100,000 ohm 1 watt carbon resistor	.06
E4894	1 250,000 ohm ¼ watt carbon resistor	.04
E5970	1 500,000 ohm volume control	.28
E5969	1 Tone control	.28
E5972	1 Switch for above control	.12
E4063	1 Double tip jack assembly	.06
E4031	3 Octal sockets ....@ .06	.18
E4026	1 4 prong socket	.05
E4027	1 5 prong socket	.05
E6335	1 Small grid clip for 6F5	.01
E3498	1 A.C. cord with plug	.14
N1644	1 Hardware kit, containing: 12 $\frac{3}{16}$" 6-32 machine screws 14 6-32 Hex. nuts 5 Solder lugs 1 ⅜" rubber grommet	.10
E6171	2 Bar knobs ....@ .04	.08
E3560	1 Hookup wire	.10
E9847	1 Complete kit as above	$4.95

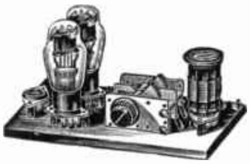
ACCESSORIES

E9259	1 6" dynamic speaker, 2500 ohm field to match single pentode output tube	$1.65
E1800	1 4 prong male speaker plug	.15
E3502	1 5 foot length of 4 wire speaker cable	.16
E267	1 R. C. A. 6F5	.59
E268	1 R. C. A. 6F6	.66
E263	1 R. C. A. 5Z4	1.03

KNIGHT 10 WATT BREADBOARD TRANSMITTER

In its main objective, the radio transmitter is exactly opposite to a receiver; it transmits or sends signals which are picked up by radio receivers. The 10 watt transmitter illustrated will introduce you to transmitting practice. (But remember, you must have a license to operate any transmitter.)

If you will examine the schematic diagram, you will notice that a crystal is placed at the beginning of the circuit, being used to excite the transmitting tubes. This crystal is not the same as that used in a simple crystal receiver, but is made of quartz or Rochelle Salts and has a unique property which permits its use in transmitting circuits. When such a crystal is compressed mechanically, an electrical charge of definite frequency will be developed. Therefore, the crystal is mounted in a special holder and is compressed by means of a spring action. Of course, a correct crystal must be used for the special frequency wanted.



Assembled transmitter.

The use of pentode type 47 tubes eliminates the need for neutralization and simplifies the adjustment after the transmitter is placed into operation.

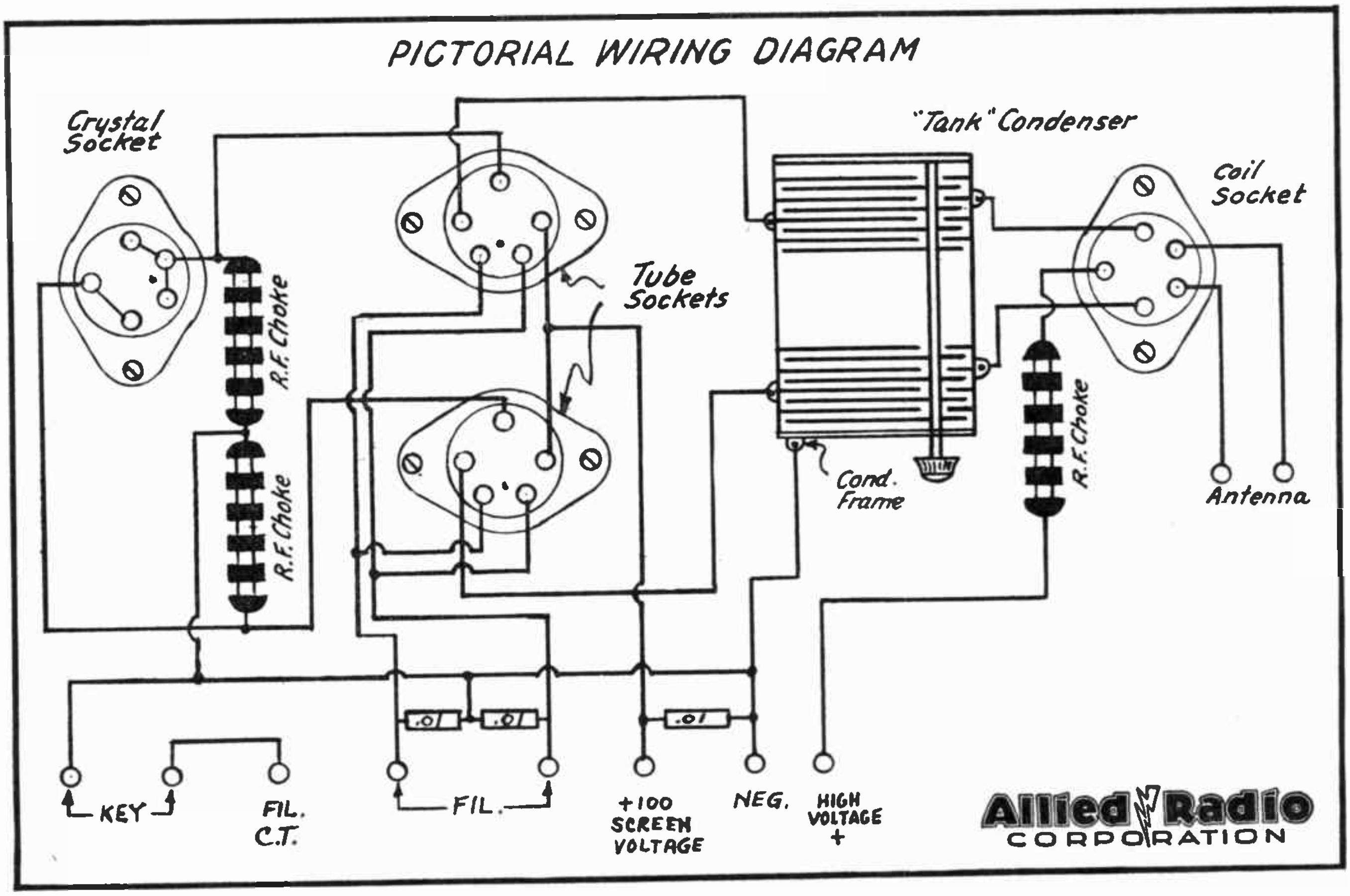
Notice that two tubes are used in a balanced circuit. These tubes operate exactly out of phase—one "pushes" while the other "pulls." That is why this type of circuit is termed "push-pull." It has several advantages over the use of a single larger sized tube.

The coils used are of the plug-in type and the correct one must be employed for the different bands. They should be constructed according to the instructions given in the table above

Band	X-Tal Used	Primary L1 Turns	Secondary L2 Turns
40 Meters	80 Meters	13 Turns Spaced to cover 1¼" coil space	3 Turns Spaced one diameter of the wire
80 Meters	80 or 160 Meters	24 Turns Close-wound	3 Turns Spaced as above
160 Meters	160 Meters	50 Turns Close-wound	5 Turns Spaced as above

Note: Allow ¼" between L1 and L2.
Center-tap the primary coil.

Transmitting antennas, unlike those used for receiving purposes, are more critical as to length, and must be well insulated. The simplest suitable transmitting antenna is a "doublet" type, with the lead-in of low-impedance twisted pair wire attached to the center of the antenna. The overall length of the antenna itself must be equal to one-half the wave-length of the operating frequency of the transmitter as expressed in feet and inches. This antenna length can be calculated easily by using two simple mathematical steps; however, since most transmitting antennas will operate over a wide range of frequencies, it is customary to figure the antenna length for the center of the Amateur band on which it is to be used. These lengths will be as follows: 246 feet long for 160 meters, 132 feet long



KNIGHT 10 WATT BREADBOARD TRANSMITTER

for 80 meters, 66 feet long for 40 meters, 33 feet long for 20 meters.

After cutting the required length of wire for the antenna, divide this wire evenly in the center and insert an insulator about 12 inches long, which will then make an antenna having two sections of exactly one-quarter wave in length. Now split the covering on the twisted pair lead-in for about fourteen inches. Attach the lead-in to the center of the antenna, one lead-in wire soldered on each side of the center insulator, so that the two lead-in wires and the center insulator each form one side of a twelve-inch triangle. The antenna can then be pulled up to its suspended position, and the lower end of the lead-in connected to the antenna binding posts on the transmitter.

For adjustment, obtain a small size pilot bulb, preferably one of the 6.3 volt type. Solder it to a piece of hookup wire about 6 inches long, and shape the wire into a circle. Hold this loop and the bulb connected to it near the coil being used, and turn the condenser until the bulb is brightest. Of course, when this adjustment is carried out the power supply should be connected, the key depressed, in the transmitting position, and the antenna connected.

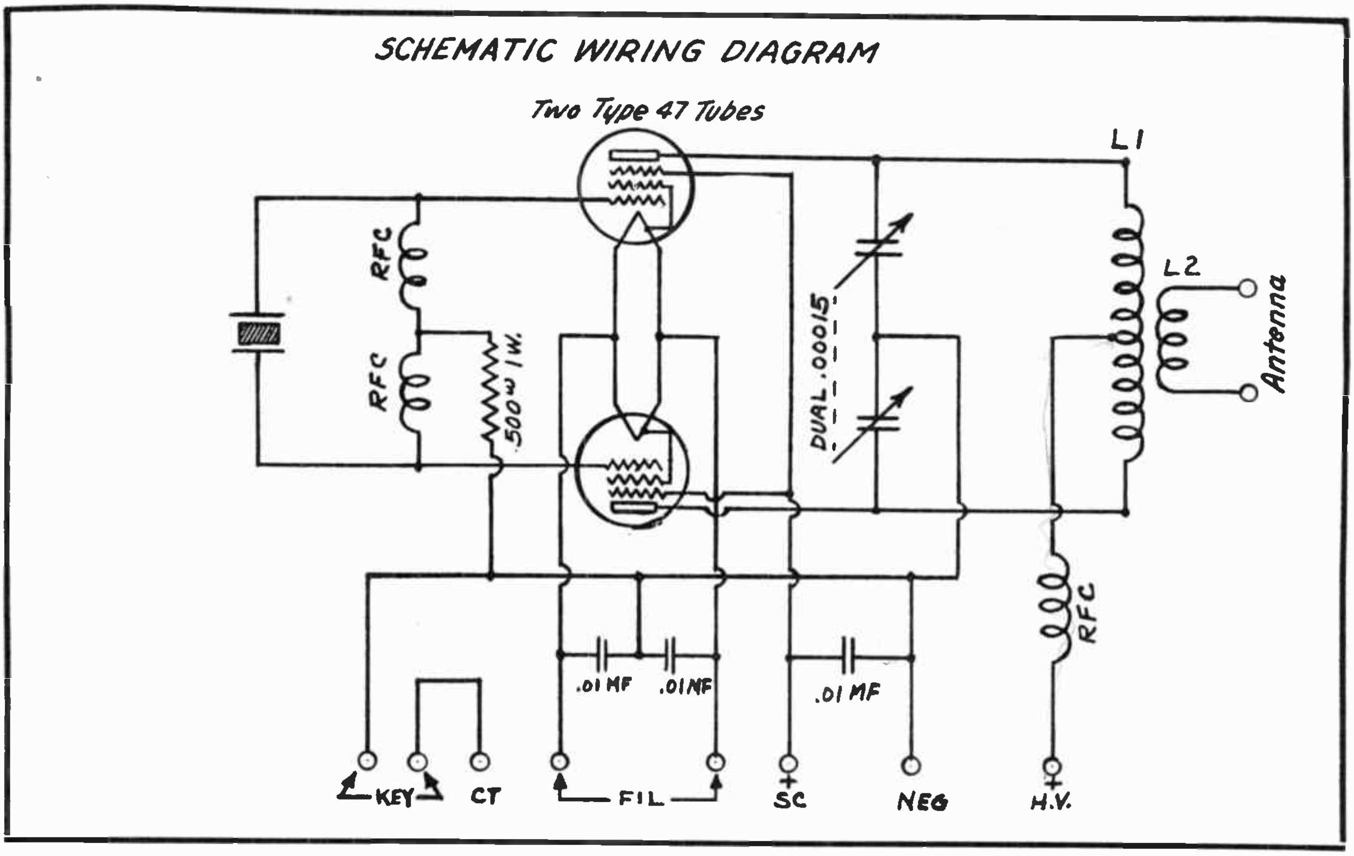
Examine the parts list and notice the accessories which are needed to place the transmitter into operation. The power supply is designed for 110 volt, 60 cycle A.C., but the transmitter may also be operated from batteries. The current drain is quite high, however, and other transmitters are more adaptable for battery use. This is a representative sample of transmitting circuits, and many others are described in the publications mentioned in the List of Useful Books on page 19.

COMPLETE PARTS LIST

E9541	Complete kit, less tubes, crystal and power supply		$2.60
	Consists of:		
E4119	1 2 gang 150 mfd. variable condenser		.95
E7937	3 .01 mfd. 600-volt tubular condenser	@ .08	.24
N1830	3 2.5 mh. R.F. chokes	@ .14	.42
E5058	1 500 ohm 1 watt resistor		.06
E4525	4 5 prong sockets	@ .07	.28
E5578	1 5 prong coil		.12
E6208	1 Knob		.05
N2271	1 7"x13" baseboard		.15
N2272	1 Hardware kit, consisting of:		
	1 Spool No. 22 D. S. C. wire (B2774)		
	16 ½" brass bushings		
	8 6-32 1¼" machine screws (E7015)		
	10 6-32 ¾" machine screws (E7013)		
	2 Spade lug screws (E7007)		
	30 6-32 Hexagon nuts (E7005)		
	10 No. 5 solder lugs (E7049)		
	10 feet of hookup wire (E3560)		.41

ACCESSORIES

E432	2 Raytheon type 47 tubes	@ .66	$1.32
E2533	1 Bliley crystal holder		.95
	1 Knight unmounted crystal (Specify 160 or 80 meters)		1.50
E7960	1 Transmitting key		.88
E9543	1 Power supply for transmitter		5.35
E472	1 Raytheon 5Z3 tube for power supply		.59

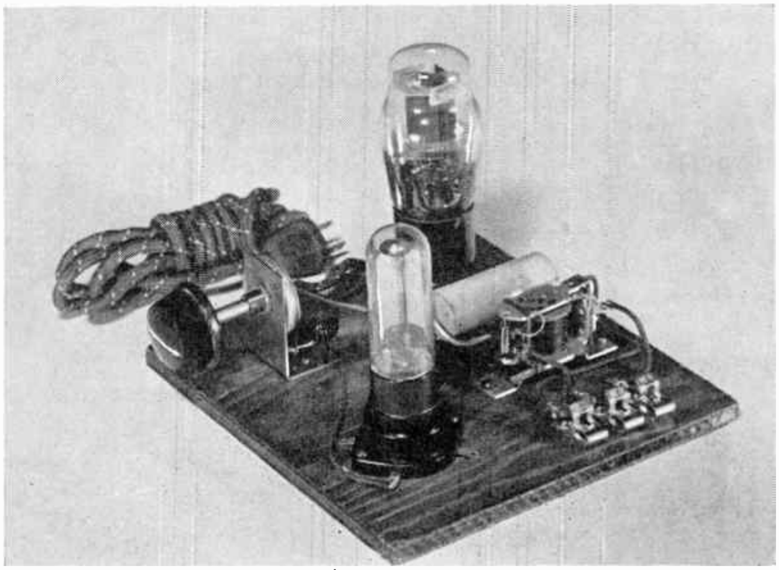


A PHOTO-CELL KIT SET

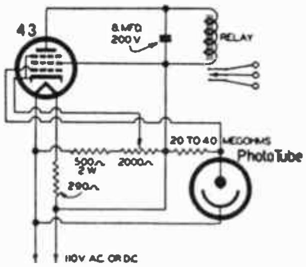
A CIRCUIT THAT PROVIDES MANY POSSIBILITIES

Every day new applications are found for photo-cell equipment. We are well familiar with the mysterious swinging doors, automatic drinking fountains, and animated window displays. In industry, too, photo-cell equipment has found hundreds of uses and is now considered an indispensable tool. For the task of counting, sorting, and checking, no other piece of equipment nor any human being can offer any competition to the efficiency and accuracy of photo-cell methods. The matching of colors has been greatly simplified, and the high-speed counting has been made possible with this "electric eye."

Many new uses of photo-cell equipment are yet to come. Servicemen and experimenters should acquaint themselves with the principles of this art and be ready to service and build this type of apparatus. An excellent way to start is to build a simple single tube photo-cell amplifier.



The Assembled Photo-Cell Unit



The simple photo-cell amplifier circuit.

SENSITIVITY ADJUSTMENT

The unit illustrated at the right above can be built for around $6, including photo-tube, is self-powered, and may be operated from 110 volts A.C. or D.C.; the absolute minimum of inexpensive parts is used; and the breadboard layout simplifies the mounting and wiring.

A type 43 tube serves as the rectifier and amplifier. The constant bias on the control grid will depend on the amount of light and must be adjusted to a sensitive point by means of the 1,500-ohm potentiometer. When connected to a source of A.C. power, the unit operates one-half of the time and the 8 mfd. electrolytic condenser across the relay serves to eliminate chatter.

Consider the circuit at the point where a positive potential exists on the side of the line connected to the relay and screen grid of the type 43 tube. If the control grid of this tube is not biased to a cut-off point, a certain amount of energy will pass through the plate circuit and activate the relay. The actual bias on the grid will depend on the internal resistance of the photo-tube and also on the setting of the potentiometer.

With the photo-cell receiving a definite amount of light, the potentiometer may be adjusted so that the plate current is just below the point where the relay will have sufficient energy to pull down the armature. Now if the source of light is reduced the internal resistance of the photo-tube will rise and cause a higher positive potential to be applied to the grid and counteract the negative potential obtained through the drop in the potentiometer circuit. The net rise of the control grid voltage will cause additional plate current to pass and the armature of the relay to move down to the magnet pole.

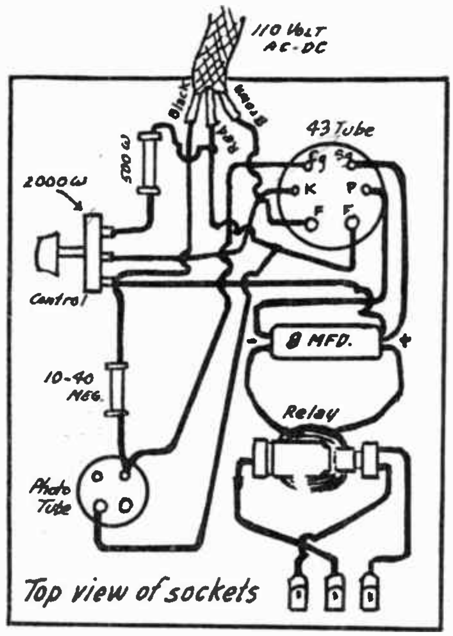
Since the armature has a contact on each side, it will make another circuit and break the previously made circuit. In this manner, associated equipment may be started or stopped with the decrease of light, or with the increase of light.

One specific application of the photo-cell to industry may serve to illustrate just what some of the possibilities are. In the textile industry a common source of difficulty used to occur in checking the colors of materials which had been dyed. In spite of rigid controls, materials which came from different dye vats did not always match exactly in color, and it was a rather laborious process to inspect the color of dyed cloth. In many factories a photo-cell installation now takes care of this job. Light is focused on cloth which passes by on a conveyor belt and is reflected back to the photo-cell. Since variations in color produce variations in intensity of the reflected light, the photo-cell automatically stops the conveyor belt whenever any cloth of the wrong shade passes by.

A PHOTO-CELL KIT SET (Cont'd.)

The parts may be placed on a 7" square plywood base. The layout illustrated should be followed in order to reduce the size of connecting leads. The entire unit may be placed in a closed container with an opening to admit light and thereby increase the sensitivity of the circuit.

This unit may be used for a number of simple photo-cell applications and will be most sensitive where stray light is shielded away and the control light is directed on the photo cell. Generally, photo-cells are more sensitive in localities where comparative darkness exists. In such cases a small amount of additional light is sufficient to operate the unit. On the other hand, in well-lighted places considerable difference in light intensity may be required in order to activate the equipment.



Pictorial wiring diagram

COMPLETE PARTS LIST FOR PHOTO-CELL KIT

N2233	1	Baseboard	$0.15
E5705	1	10 megohm, ½ watt resistor	.10
E4000	1	4 prong socket	.18
E4002	1	6 prong socket	.18
E7205	1	Line cord resistor	.29
E6320	3	Fahenstock clips @ .01	.03
E9028	1	Potentiometer, 1500 ohms	.24
E9719	1	Bracket	.03
N2761	1	Relay	1.75
E1226	1	Photo-cell	1.95
E428	1	Raytheon 43 tube	.66
E3784	1	8 mfd. 200-volt condenser	.27
E5158	1	500 ohm 2 watt resistor	.10
E6208	1	Knob	.05
N2790	1	Hardware kit: 7 ⅜" wood screws, 4 ⅝" wood screws, 10 feet hookup wire	.10
		Complete kit—Special	$5.85

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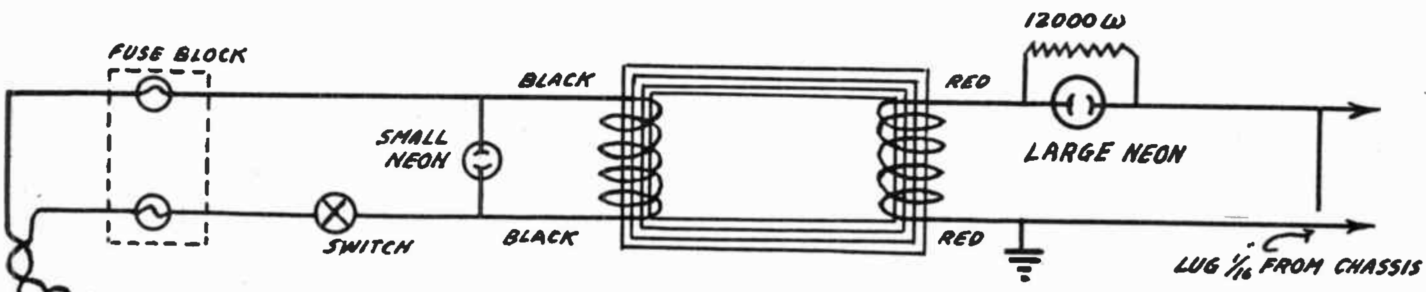
KNIGHT ELECTRIC FENCE CONTROL



FOR 110 VOLTS, 50-60 CYCLES A. C.

Developed only within the last few years, the "Electric Fence" has now become a common device used on the farm, and the State of Wisconsin has even laid down regulations concerning its use. Basically, the Electric Fence Control is a device which puts an electrical charge into a single wire encircling a field and makes it possible to save a great deal on fencing costs.

For fencing-in small livestock such as sheep, goats, hogs, etc., a single wire about 18 inches above ground should be used. For cattle and horses the wire should be placed 36 inches above the ground, or two wires may be used. The posts may be spaced 50 to 60 feet apart, and the wire stretched tight between the posts. Insulators of the nail-knob or screw-eye type should be used to prevent grounding of the fence in wet weather.

The fence is charged with a voltage that is safe and yet effective. No harm can result to man or beast since the transformer automatically limits the current output to less than one-hundredth of an ampere on short circuit. Fuses give added protection. The small bulb indicates when the unit is operating; the large neon bulb glows when a short occurs.

ELECTRIC FENCE PARTS LIST

E5450	1	Toggle "on-off" switch	$0.19
N2683	1	Drilled metal cabinet, 9"x5"x6"	1.50
N1661	1	Double fuse block	.24
E3995	2	10 ampere fuses @ .04	.08
E6454	1	¼ watt neon bulb	.36
E6461	1	Small sub-panel socket for the above bulb	.28
E6451	1	1-watt neon bulb	.36
N1745	1	Sub-panel socket for 1-watt bulb	.10
E5080	1	12,000 ohm, 1-watt resistor	.06
E3498	1	A.C. cord and plug	.14
E6320	1	Fahenstock clip	.01
E6112	1	Feed-thru insulator	.07
N2684	1	Hardware kit for the complete kit	.05
N2682	1	Special current limiting transformer	2.25
N2680		Complete kit of parts	$5.45

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