WIRELESS, THE MODERN MAGIC CARPET

BY

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"MYSTERY OF ELECTRICITY," MYSTERY OF MAGNETISM,"
"MYSTERY OF ETHER," "MATTER AND ENERGY," "ELECTRIFIED MATTER"
"ELECTRONIC CURRENTS," "MAGNETISM AND ELECTRO-MAGNETISM"
"THE MATHEMATICS OF WIRELESS," "BATTERIES AND ACCUMULATORS,"
"SEEING BY WIRELESS," "WIRELESS WAVES,"
"WIRELESS COMMUNICATION AND BROADCASTING," "MODERN VALVES,"
"HOW TO UNDERSTAND WIRELESS DIAGRAMS,"
"SELECTION OF WIRELESS SIGNALS," "TUNING IN AND TUNING OUT."

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Dedicated

TO THE B.B.C.

It is, in my opinion, extremely fortunate that Broadcasting in Great Britain has been entrusted to men and women whose conspicuous practical ability is guided and exalted by splendid idealism. The British Broadcasting Corporation is easily the most efficient organisation of the kind in the world. If this book will help ever so little to enable more people to enjoy and benefit from the transmissions of the B.B.C., I shall consider myself amply rewarded.

RALPH STRANGER.

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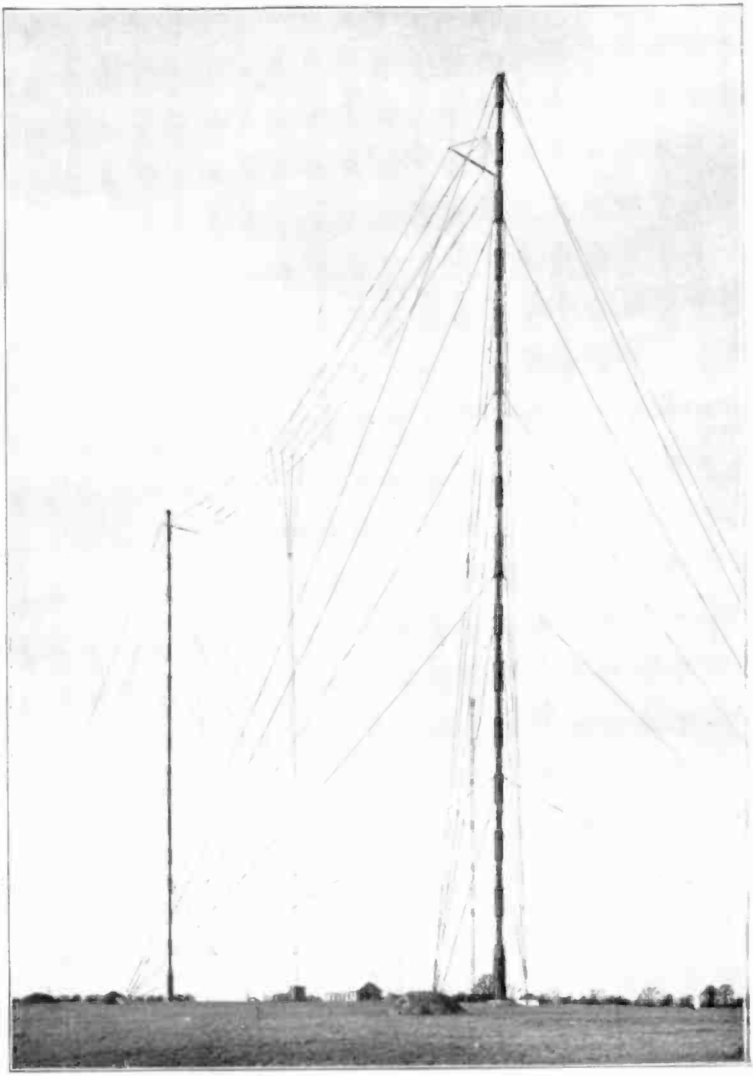
PART I

WHERE DOES THE MAGIC CARPET TAKE US?



[By courtesy of the B B.C

THE MASTS OF DAVENTRY (5GB)

[*By courtesy of the B.B.C.*

MR. NOEL ASHBRIDGE, B.Sc., A.M.I.C.E., THE CHIEF ENGINEER OF THE BRITISH BROADCASTING CORPORATION

CHAPTER I

MAINLY INTRODUCTORY

Everybody has heard in his or her childhood of the Magic Carpet, a carpet that can carry a person from one place to another in an incredibly short space of time. You will say now, being grown up and wise, that it was all an old woman's tale, that such things do not really happen. . . .

If someone should be bold enough to suggest to you that he could transport you to, say, New York, in well under a second, you would no doubt laugh in the man's face and ask him what he had had to drink with his last meal.

And yet . . . It is true! . . . It is possible nowadays to visit America, Australia, India, Japan, Italy, Austria, Germany and France and be back in London again in less than a quarter of an hour!

Not bodily, of course, but nevertheless just as effectively as if you were transported on a magic carpet to the Opera House of Berlin, from there to the Moulin Rouge, in Paris, and back again to Covent Garden. How? . . . By "Wireless" of course!

Yes, by "wireless" that enables you to hear, so "mysteriously," in your own home, something that is going on thousands of miles away.

Do you understand how "wireless" works? Are you in touch with this most important and vital branch of science in our time? Are you listening to daily Broadcasts in this country and abroad?

There is not a single man, not a single woman in this country, in the whole world for that matter, who can afford to neglect and pass by apathetically the rapid development of Broadcasting, with its nightly audience of 20,000,000 people in this country alone.

Nowadays to say: "I am not interested in Broadcasting" is as much as to say: "I am not interested in Newspapers, Books, Politics, Art, Music, Literature, Science and the hundred and one things that go to the making of a cultured person's Universe."

Do you sit in the house night after night and let the world go by? There are millions of vibrations in the ether surrounding you just asking to be picked up. There are Three Hundred Broadcasting Stations throughout the world, sending out, far and wide, the best of entertainment, the best of scientific knowledge, the best of everything for the benefit of humanity at large, for *your* benefit!

You can listen to a fight in America, and know the result within a few seconds of the referee giving his decision.

People throughout this country heard the news that Felstead had won the Derby within one second of the horse romping past the winning post!

During the last deplorable general strike, Broadcasting proved to be the only reliable source of news, since Newspapers ceased to function and wild rumours were spread by irresponsible people.

If it were not for "wireless" most of us would never have the privilege of hearing H.M. the King, H.R.H. the Prince of Wales, the Prime Minister and other prominent public men when they address the whole of the country.

If it were not for "wireless," how many of us would have had the chance of hearing the living voices of such prominent artists as Chaliapin, Dame Melba, Sir Harry Lauder and other brilliant stars of the opera, concert and entertainment world?

If it were not for "wireless," how many of us would have had the opportunity of hearing lectures by Sir Oliver Lodge and other eminent scientists?

Yes, thanks to "wireless," we can do all these things whilst sitting in our most comfortable armchair, and just by pressing a switch and turning a dial we can travel from London to Paris, from Paris to Rome, or wheresoever fancy leads us.

"Wireless" began as a hobby. . . . It is more than a hobby now. . . . It is a national asset . . . It kills melancholy and rests tired nerves. . . . It educates all of us in many subjects of which we know little. . . . It comforts the aged, the sick and the bedridden. . . . To the blind, it is a real Godsend. . . . And to us all it is one of the greatest gifts of science.

is no more obligation to listen than there is to read every line in your morning or evening paper. How on earth can the B.B.C. please 20,000,000 listeners at once? And yet people will not think, they grouse instead, and frighten off those who intend to instal "wireless." There is no reason to grouse. British Broadcasting is the best Service in the world; it is taken as a standard by every foreign country, including America. In addition to its gigantic audience at home British Broadcasting is closely followed and enjoyed not only on the continent of Europe, but also in more distant parts and particularly in our Dominions and Colonies. It is significant that the quality of the programmes is high enough to offset the irritating vagaries of distant reception.

It is impossible to overestimate the value of educational broadcast talks. An educated man is not necessarily one who carries in his brain a vast amount of classical knowledge, but the man who has known how to acquire information on any subject, i.e. *How to teach himself.*

The B.B.C. lecturers are doing this for us, they are teaching us gradually to assimilate information on many subjects. *They are making us an educated people.*

Thus we see that from a purely educational point of view Broadcasting can supply us with the necessary intellectual food and help us to enlarge our mental outlook, increase our capacity for social intercourse and very likely help us not a little in our business.

No man can afford to stop learning. The man who knows "all there is to know" is hopeless—he will never progress.

In order to test the statement that "wireless" Broadcasting can enlarge our mental equipment and teach us a good deal, let us examine the past "talking" activities of the B.B.C.

In 1927 the adult education section of the B.B.C. broadcast talks on the following subjects: Anthropology, Architecture, Astronomy, Botany, Economics and Social History, Foreign affairs, Languages (French, Spanish—and of late German), Literature, Music, Natural History, Psychology and Physiology. In addition to the above there was broadcast a wealth of health lectures, talks to housewives, etc.

Apart from the talks to adults, there are numerous Broadcasts to schools, designed to help teachers to illustrate their lessons and to give the school children a few sweets in addition to the meat of the school syllabus.

One of such series of school lectures is: "Boys and Girls of the Middle Ages"; this is to provide an additional interest in history lessons. Another one is: "Stories in Poetry." There are also others: "London's Great Buildings," "Out of Doors," "Empire History and Geography," "Elementary Music."

Although these lectures are designed for children, adults listen to them with great pleasure.

Thanks to "wireless," nobody nowadays need complain that his or her education has been neglected. All of us can improve our general knowledge, if we will only take the trouble to listen.

Incidentally, "wireless" is now playing a very important rôle in several branches of specialised study. One of them is the study of Foreign Languages. We all know that the best way to study any language is to go to the country of its origin and study it on the spot. Unfortunately not many of us can afford such a procedure. Still, this handicap is now entirely removed. Any person studying a foreign language can hear the living speech in which he is interested, night after night on the "wireless," be it German, French, Spanish, Italian, Swedish, Norwegian, Danish or Dutch.

In addition to this the B.B.C. stations transmit from time to time elementary lessons and dictations (the latter are published in *World Radio*, the foreign programmes paper of the B.B.C., and thus one's writing can be corrected) in French, Spanish, Italian and German.

Is not Radio-land the true abode of the tree of knowledge?

it the work of a long forgotten and recently resurrected composer, or of an ultra-modern revolutionary of music from the continent, you may be sure of one thing—it is good and worth hearing.

Judging from the past activities of the B.B.C., Parnassus has been working at high pressure. In the past the following popular operas were broadcast: *The Marriage of Figaro, The Barber of Seville, Tales of Hoffman, Carmen, Rigoletto, La Traviata, Faust, Romeo and Juliet, Il Pagliacci, Cavalleria Rusticana* and *Tannhäuser* to name only a few.

On the concert side, National Concerts were given and broadcast from the Albert Hall, Promenade concerts from Queen's Hall, and a thousand and one concerts were transmitted from various concert halls throughout the country.

Military band music has also formed an important feature of the programmes, while enormous choirs came in front of the microphone at frequent intervals.

Amongst the prominent artists, the following figured in the programmes:

Feodor Chaliapin, the famous Russian bass, Dame Nellie Melba, Jan Kiepura, Galli-Curci, and a number of others.

The following well-known conductors and composers took part in the concerts:

Sir Henry Wood, Sir Hamilton Harty, Albert Coates, Richard Strauss, Sir Edward Elgar, Sir Landon Ronald, Bernardino Mollinari, Arthur Honneger, Gustav Holst, Ernest Ansermet, Siegfried Wagner, and many others.

The muses of the Drama and Poetry have also been fairly busy at Savoy Hill. Such plays as:

The White Chateau, Trelawney of the Wells, The Yellow Jacket, Paddy the Next Best Thing, Trilby, The Importance of Being Earnest, Mary Stuart, etc., were broadcast. The modern poets were represented by the Sitwells, Edith, Sacheverell and Osbert, as well as by a number of others.

Theatres were not neglected, and the following West-end productions were broadcast:

Act II, *Yvonne* from Daly's Theatre, *Tip Toes* from the Winter Garden Theatre, *The Blue Mazurka* from Daly's, *Der Rosen Cavalier* from Covent Garden, *Carmen* from Covent Garden, *The Lido Lady* from the Gaiety, *Lady Luck* from the Carlton Theatre, etc.

If you have not listened, you see what you have missed? You could have enjoyed first class music, the best of operas, heard bits and pieces from various musical comedies and plays from the best London theatres. Your theatre-going would not have been a gamble, as you would only have gone to plays which you knew were good.

Bring Parnassus to your own drawing-room, if you have not yet done so, and let the muses live with you as the fairies live with your children. Their gifts to us can chase away monotony, and bring the joy of life which is ours to claim.

CHAPTER IV

ALL ROUND THE COUNTRY

No doubt your visits, occasional or frequent, to the cinematograph have familiarised you with the Pathé Gazette . . . a sort of serial film which shows you the most important events that happen in various parts of the country. Thus, sitting in the cinema seat, you travel all over England, Scotland and Ireland and see what happened there a week or so ago.

"Wireless" will enable you to do the same thing, in a different way, and much quicker. Sporting news such as boxing results, cricket, football and tennis scores, you hear immediately the score is made.

Then there are running commentaries broadcast on sporting events.

An expert watches on your behalf the progress of the game, and reports to you the movements of every player who happens at the moment to be taking an important part in the match. Before play begins he will tell you the weather conditions on the spot, the appearance of the field, the names of prominent spectators, and describe what the players are wearing. He may even confide to you what the referee looks like. If the announcer knows his job, and he usually does, his descriptions are so vivid that you can imagine the whole atmosphere of the playing field, and follow the progress of the event as if you were present.

Thus, during 1926 and 1927, "wireless" listeners were mentally present at the following events: They were with H.R.H. the Prince of Wales—who by the way is the best Broadcaster we have—at the annual meeting of the British Association at Oxford.

On the 12th of August, 1926, they took part in the Military Tattoo at Belfast.

[By courtesy of the B.B.C.

THE VILLAGE WIRELESS EXPERT

SPREADING THE NEWS

[By courtesy of the B.B.C.

On the 4th of September, 1926, they listened to the speeches at the meeting of the League of Nations at Geneva (Switzerland).

On the 1st of October, 1926, they met Sir Alan Cobham on the Terrace of the House of Commons, on his return from Australia.

On the 2nd of November, they listened to Sir Austen Chamberlain's rectorial address at Glasgow University.

On the 11th of November, they were present at the Armistice Day Service at Canterbury Cathedral.

On the 9th of December, they assisted at the "Ceremony of the Keys" at the Tower of London.

On the 5th of February, 1927, they watched the International Rugby match, Wales *v.* Scotland, at Cardiff.

On the 2nd of April, 1927, and again in 1928, they watched the Boat Race.

On the 21st of the same month they attended the opening of the National Museum of Wales at Cardiff by H.M. The King and H.M. The Queen.

On the 16th of May, they met the French President Doumergue at Victoria Station.

On the 27th of June, 1927, the "wireless" listeners met T.R.H. the Duke and Duchess of York aboard H.M.S. *Renown* at Portsmouth.

On the 4th of August, they heard H.R.H. Princess Mary presenting the colours to the Royal Scots.

As you can see for yourself, there is not an important event in which listeners do not take part.

The "wireless" set takes you all over the country, and introduces you to people whom you would not have met and heard otherwise.

To hear a prominent person's voice and to link it to the portraits which we see practically daily in the newspapers and journals, helps one to form a much more vivid impression of the individual.

Then there is the thrill of hearing broad Scotch or the Welsh accent, or the Irish brogue during a ceremony when a local worthy starts to reply to a formal speech!

The additional interest that Broadcasting lends to one's morning paper, when, in reading a speech, one can recollect every sound of it, and remember the inflection of the speaker's voice at each sentence!

CHAPTER V

ALL ROUND THE WORLD *

LET us open the foreign programme paper *World Radio*, published by the B.B.C., and see what's doing around the stations abroad.

Let us choose a Sunday, so that we can lock ourselves in and allow no one to disturb us. Like transatlantic fliers we will provide ourselves with chicken sandwiches, oranges and some liquid refreshment.

Now ready? . . . Off we go! . . .

At 10.15 a.m. we are in Cracow (Poland) listening to a church service.

At 11 a.m. off we go to Hamburg, in Germany, to hear all about the Hamburg museums.

11.15 a.m. finds us at Koenigsberg, still in Germany, listening to a concert.

By noon we are back in Poland, Warsaw this time, enjoying the sound of a fanfare from the church of Notre Dame of Cracow.

1 p.m. finds us at Berne, in Switzerland, where we hear the time signal and a weather report.

At 1.30 p.m. Barcelona, in Spain, claims our attention with a trio concert.

From Barcelona we proceed to Madrid for an orchestral selection at 2 p.m.

To Germany again, this time Cologne, to hear all about "wireless" literature.

At 3 p.m. we are at Langenberg (still Germany) listening to a talk on chess.

3.15 p.m. finds us at Munich where a zither recital is in full swing.

* My log is pure imagination, so, please, don't write asking for the circuit—I am still listening on a crystal set, although I use a "super-het now and again.

At 4 p.m. off to Vienna, in Austria, to listen to a concert.

From Vienna, to Riga, in Latvia, to hear a relay of a choral festival.

Let us hurry now, by 5 p.m. we must reach Rome to hear a studio programme.

At 5.40 p.m. we are at Hilversum, in Holland, listening to a concert.

6.15 p.m.—Leipzig in Germany, to hear the latest report of the Olympic games at Amsterdam.

Berlin by half-past six, just in time for a talk on "Wives and mothers of great men."

And now gee whizz! . . . We are right over the Atlantic, pelting for all we are worth to Pittsburg (U.S.A.), and we are there by 7 p.m. listening to "Roxy's Stroll." The announcer informs us that it is being relayed from New York. He has an American accent, and no doubt of it! . . .

Back across the Atlantic, across the North Sea and on to Bergen, and there by 8 p.m. . . . It takes us a few seconds to fly from America to Norway. We could have done it much quicker had we not run into nasty atmospherics.

Having heard a concert at Bergen, on to Copenhagen, in Denmark, for another concert there.

At 8.30 p.m. Paris, listening to a wonderful concert of French masterpieces.

At 9 p.m. we are hesitating. . . . There is a choice between Prague in Czecho-Slovakia and Rome—concerts at both places. Rome wins, and we are not disappointed by our choice.

By 9.15 p.m. we are at Toulouse, in France, and at 10 p.m. hesitating again.

We have to choose between Pittsburg and Juan-les-Pins (France). Juan-les-Pins has it with dance music.

After a whiff of this famous French bathing resort, we are off again to U.S.A. Schenectady this time, and in a second or so are listening to "Stetson Parade," as performed by the American Legion band of Boston.

From Schenectady to Rabat, in Morocco—the summer garden cinema concert.

Midnight finds us in Schenectady again, where we listen to a National string quartet, and later to the latest baseball scores relayed from New York.

At 1 a.m. . . . We are brought down to earth once more. . . . There is a determined knock at the door and the well-known voice, usually gentle, but at the moment slightly metallic: "Are you coming to bed? It is Monday already!" Ah, well, bed it is. . . . We have had a fine time, have we not? . . . Germany . . . France . . . Italy . . . Latvia . . . Morocco . . . America . . . All round the world . . . Marvellous!

[By courtesy of the B.B.C.

STUDIO NO. 7 AT SAVOY HILL

[*By courtesy of the B.B.C.*

B.B.C.—SAVOY HILL

PART II

THE WHY AND THE WHEREFORE OF THE MAGIC CARPET

CHAPTER I

THE AUTHOR EXPLAINS

THERE are many people who complain that "wireless" is difficult to understand, that it is impossible to grasp its principles unless one has the necessary technical education.

There are others who say that they know all there is to know about "wireless." In the majority of cases, unless they are trained Radio engineers, if you question these "know-alls" you will find that they carry in their mind a great accumulation of disjointed facts, mostly collected from various periodicals, facts that are misunderstood and perverted; an accumulation that is worse than useless. Curiously enough the real expert will never tell you that he knows all about "wireless." The more a man knows about his subject the less dogmatic he is in his statements. He is careful in expressing his opinion because he knows the difficulties too well.

As a rule, the so-called "man in the street" does not know that "wireless" is not a complete subject in itself. It is only a small branch of physics, and what is more—an advanced branch of this vast subject. In order to reach this branch one has to climb a goodly portion of the trunk of the tree of knowledge, and go methodically from branch to branch before the desired fruit is reached.

One has to study the constitution of matter generally and to know something about the physical properties of matter before one can even hope to have a glimmer of an idea on the subject of electrical currents. No man can realise what is happening inside a "wireless" set unless he knows a good deal about magnetism and electricity. *There is no royal road to knowledge.* The work has to be done methodically and systematically if one is to understand the subject under discussion.

It is not impossible for the man in the street, i.e. a man who has had no scientific training whatsoever, or very little of it, to grasp the essentials, and, later on, to master the details of radio engineering, provided he is capable of reading a serious book without going to sleep over it. Previous education is not very material if one has ordinary common sense and is capable of concentrating.

It is always difficult to explain a scientific subject in everyday language. There are many books treating of "wireless" in a popular manner, but the majority of them are either too advanced or too simplified in their treatment. Some authors assume that their readers have had a university education, and others imagine them to be so childish, as far as science is concerned, that they must be talked to in a sort of a scientific baby-language.

The author of this book, writing under a nom de plume, has endeavoured to strike a happy medium. During the war he had the privilege of serving in the Royal Engineers (Signals), having previously had a university training in Electrical Engineering in this country and abroad, and was called upon to lecture to Officers, N.C.O.s and men on electricity and magnetism as an introduction to signal work.

Needless to say the majority of his students had no previous scientific training. As you know, in the army one does not argue. One could not go to an officer commanding and tell him that it is difficult to talk about a scientific subject in everyday language. The job had to be done and done well. And what is more, it was done.

The experience he acquired during his army service was applied later to lecturing at the L.C.C. evening Institutes, while being actively engaged during the day on the manufacturing side of the "wireless" industry. The L.C.C. students are naturally all "men in the street." After three years' training these men in the street obtained experimental licences and some of them became instructors themselves.

He started their first year with a series of lectures which have been embodied in this book, supplemented by practical work.

The contents of this book are therefore a result of practical teaching, thoroughly tested out and tempered by many criticisms and suggestions from his superiors and the students themselves.

His students are thoroughly satisfied that they can follow his lectures without any difficulty. It remains to be seen if the readers of this book will be of the same opinion. The author would like to hear of any difficulties they may encounter in studying it. Every practical suggestion made will be considered by him as a great favour. (See "Conclusion" on page 273.)

silver, mercury, hydrogen and oxygen are all elements. Water, steel, bronze, air are compounds made up of atoms of elements.

It is quite interesting to know the elementary substances or elements and their comparative weights. The weight of an atom of any element is arrived at by comparison with an atom of Hydrogen the weight of which is taken as a unit.

Chemists denote each element by a symbol consisting of a capital letter or a capital and a small letter. These symbols are used like shorthand, to avoid writing in full the name of the element.

The symbol for Hydrogen is the letter H and the symbol for Oxygen is the letter O. Water consists of two atoms of Hydrogen and one atom of Oxygen, and the symbol for water is therefore H_2O, the small 2 on the right of the letter H indicating that there are two atoms of Hydrogen.

If you look at a table of chemical elements you will notice that the precious metals such as Platinum and Gold are amongst the heaviest. The most interesting element in the table is Radium (Ra), an atom of which is 226 times heavier than an atom of Hydrogen. But about Radium more anon. . . .

Now comes the question: Does the atom represent the final division of matter?

The Size of Molecules and Atoms.

The internal construction of an atom is the most wonderful thing on earth! In order that you may be able to appreciate better the beauty of the atom let us try to visualise the size of a molecule and the atom. Since molecules and atoms of different substances vary in size with the substance, we will talk about an average molecule and an average atom. A molecule may contain anything from two to two thousand atoms! 125,000,000 average molecules laid side by side will cover an inch. So that assuming the molecule to be roughly circular, its diameter is 1/125,000,000 of an inch! Such a molecule may contain, say, 1,000 atoms. Considering that there are empty spaces inside the molecule, since the atoms are not closely packed together, you may imagine how small an atom is! And yet in spite of its almost incredibly small size it is built practically on the same plan as our solar system!

In our solar system a number of planets rotate round the sun in regular and definite paths, being held in their paths by the gravitational pull of the sun. The Earth which we inhabit is 92,000,000 miles away from the sun, so that there is plenty of empty space in the solar system. The atom, taking into consideration its small size, has just about as much empty space inside it, relatively to its tiny "sun" and its still tinier "planets."

Electrons and Protons.

Every atom has a nucleus around which in definite paths and at high speeds rush small particles of electricity called *Electrons.* It is really difficult to imagine the size of an electron. Inside the nucleus there are other different particles of electricity, still smaller than the electron, but much heavier, called *Protons.* In every atom there is an equal number of protons and electrons, but while all the protons are concentrated in the nucleus, some of the electrons are also in the nucleus, cementing the protons together, while the remaining electrons carry out the duty of "planets" and rotate round the nucleus. *The protons and the electrons have an affinity for each other and attract each other, while an electron will repel an electron and a proton will repel a proton.*

Owing to this attractive force between a proton and an electron the nucleus is well cemented together, while enough of the protonic force is left to hold the free rotating electrons in their respective paths. The electrons and the protons are particles of two kinds of electricity which we usually distinguish by the names of negative and positive electricity. *The electron represents negative electricity, and the proton positive electricity.*

As we already know, the proton is smaller than the electron but much heavier. The electron is comparatively so light that all the weight of the matter seems to be concentrated in the protons. If we could make a solid golf ball of nothing but protons it would take a prodigious golfer to move it—it would weigh roughly 6,000,000 tons!

An atom of Hydrogen has a nucleus consisting of one proton and one revolving electron. This is the simplest arrangement in nature at present known. The free revolving electron travels at the rate of 1,300 miles a second, according

CHAPTER III

MATTER AND ENERGY

WE can see from the previous chapter that since all matter is finally made up of protons and electrons and that the only difference between various substances is the number of these protons and electrons and the manner of their arrangement in the atoms, these two particles of electricity are the materials of which all matter is built. We cannot destroy a proton or an electron. We cannot create them. Therefore it is clear that matter cannot be created. There is a definite number of electrons and protons created once and for all by the Creator, and all that can be done now is simply to arrange and re-arrange these existing particles of electricity the best we can.

Matter cannot be created, and it cannot be destroyed. Matter is therefore indestructible. *This is the law of conservation of matter.*

Now, we all know what work is, at least we ought to know. There are all kinds of work. A labourer digging a trench is performing work. A watch-spring driving the mechanism of a watch is performing work. A stone falling from a height and hitting somebody on the head is performing work.

It is quite a common thing for a husband to say to his wife when she wants him to roll the lawn that he has not the energy to do it. What is energy?

It looks as if energy is the ability to perform work. And so it is. Energy is the ability or capacity to do work.

Work is a measurable quantity. The unit of measure is a *foot-pound.*

If you lift a pound weight one foot from the ground you have performed one foot-pound of work. If you lift 50 pounds to a height of 10 feet you have performed 500 foot-pounds of work.

Energy, being nothing but ability to perform work, is also measured in foot-pounds.

There are two kinds of energy. A stone placed on the ledge of a roof possesses energy in virtue of its position. A wound-up spring will unwind itself and thus prove to possess energy in virtue of the displacement of its parts and its elasticity. Such energy due to position is known as *potential energy.* The stone placed at a certain height, or a wound-up spring, possesses potential energy and can perform work.

A bullet fired from a rifle possesses energy thanks to the explosion that has taken place inside the rifle. It will travel at a great speed and will perform work. Such energy is called *kinetic energy.*

Just as matter is indestructible, so energy is indestructible. We cannot create or destroy energy. All we can do is to transform one kind of energy into another kind.

This is the law of conservation of energy.

Let us go back to our labourer.

A labourer when working uses his muscles. After a while his muscles will get tired and he will stop and rest, breathing hard. He is pumping as much air as he can. Why does he do so?

In order to be able to do work the labourer must have a certain amount of energy. This energy is stored in his muscles and comes from the food he eats and the air he breathes. The energy supplied to his muscles is heat energy and is due to the various chemical processes going on inside the body.

When a man is tired, his muscles have developed large quantities of a chemical substance called lactic acid. Oxygen is required to get rid of it. This is the reason why the labourer stops working and breathes hard. The blood stream carries away from the lungs as much oxygen as possible in order to convey it to the muscles and burn away all the waste products.

As soon as this is done, the man feels himself rested, his energy is restored to him and he is capable of performing more work.

Thus you see how the heat energy of the body is transformed into ordinary mechanical energy.

In friction we have another example of the transformation of energy. Here mechanical energy is being transformed into heat energy. In electrical engineering we transform heat energy directly or indirectly into electrical energy. If we burn coal in the furnace of a boiler, and convey the steam thus obtained to a steam engine, we can cause the engine to rotate a dynamo and thus generate electricity.

Here we have transformed heat energy first into mechanical and then into electrical energy.

If we take two dissimilar metals and solder them together at the ends, and then heat one end while the other remains cold, we shall have an electric current flowing in a wire connecting the two joints. Such an arrangement is known as a thermo-junction. In this case we are converting heat energy directly into electrical energy.

When a current is flowing in a wire it heats the wire. Here is an example of the transformation of electrical energy into heat energy.

It should be clear by now how one kind of energy is transformed into another. The greatest source of energy we have is the Sun. The energy of coal, which is nothing but preserved wood, comes from the Sun. The energy of human beings and animals is obtained from the Sun. The sun supplies energy to plants and makes them grow. Animals eat the plants, and we eat the animals as well as the plants. The food we eat gives us the heat energy which makes our muscles capable of performing work.

The rate at which work is performed is called power.

CHAPTER IV

MAGNETISM *

THERE exists in nature a mineral called Magnetite which consists of two elements: Iron and Oxygen. A molecule of Magnetite is made up of three atoms of pure Iron and four atoms of Oxygen. Its chemical symbol is Fe_3O_4. Magnetite or magnetic iron ore has very curious properties which baffled the early scientists considerably. A piece of Magnetite would attract and lift small pieces of iron. It would not attract, with the same force, any other material.

Later it was noticed that the influence exerted by Magnetite on Iron differed from that exerted by it on steel. It would attract iron, and the piece of iron clinging to it would in turn attract other smaller pieces of iron, thus apparently having acquired magnetic properties itself. But these acquired magnetic properties did not last. As soon as the iron was removed from the immediate neighbourhood of the Magnetite it ceased to attract other pieces of iron. Steel, on the contrary, not only became a magnet when attracted by Magnetite but it kept its magnetic properties for a considerable time afterwards.

Ordinary iron, therefore, does not possess the properties of Magnetite although the latter contains it. Oxygen also does not possess any magnetic properties. . . . Why then should a combination of these two elements suddenly exhibit something new?

Well, we do not know. As a matter of fact we do not know even now what magnetism really means, although we know the effects of it very well, and use the magnetic properties of iron and steel to a very large extent in everyday engineering.

* For further information see "Ralph Stranger's Wireless library" book IV—*Magnetism and Electro-Magnetism.*

Magnetite must indeed have puzzled the early scientists considerably, and as to the man in the street, well . . .

There is a story about a Swiss shepherd who, wearing hob-nailed boots, happened one day to step on an exposed patch of Magnetite in the mountains. You will guess what happened. . . . Yes, he stuck fast and strong with both feet, and only got away by unlacing his boots and leaving them there. He naturally blamed the devil and ran home fast, barefooted, to spread the wonderful tale of the latest exploit of the evil one.

The Magnetic Compass.

You will realise that the earth, containing, as it does, large quantities of Magnetite and iron ore, must have magnetic properties itself, and can be considered as a huge natural magnet. The ancient Chinese apparently discovered Magnetite long before our history began, and learned to magnetise iron. They also discovered that if a small arrow or needle is fashioned out of Magnetite and suspended free to rotate, it will always point in one direction, from North to South. As a matter of fact a magnetic needle does not point exactly in the direction of the geographical North and South poles, but somewhat to one side, so that the geographical poles of the earth and the magnetic poles do not coincide.

The Chinese having discovered this property of the magnetic needle made it guide them in the right direction across the seas, the magnetic needle thus having become a compass for navigational purposes.

Modern compass needles are not fashioned out of Magnetite, but are made of steel, and are arranged to rotate on a needle point over a dial indicating the four points of compass and their subdivisions. It is important when using a compass to make sure that there is no iron or steel present near it. In fact, on board the modern ship, which contains a large amount of steel in its hulk, a correction has to be made for the deviation of the compass under the influence of this material.

The end of the compass needle which points towards the North Pole is called the North-seeking pole or simply the North pole of the needle, while the opposite end goes under the name of South pole.

We say, therefore, that every magnet has two poles, a North and a South one.

Natural and Artificial Magnets.

Magnetite can be considered as the only natural magnet in existence. Having learned the properties of Magnetite, we soon started to make artificial magnets out of iron and steel.

As we already know, steel can be readily magnetised, and will keep its magnetism for a considerable time. Artificial magnets made of steel can be obtained either in the form of a bar or a horse-shoe.

Iron, not being able to retain its magnetism, is used in the manufacture of temporary magnets which can be magnetised whenever required. The iron horse-shoe core is, therefore, surrounded by a coil of wire through which an electric current is made to flow. As soon as the current flows the iron becomes magnetised. Why? We shall see this later when we know a little more about electricity. Such a magnet is called an electro-magnet.

Permanent magnets and electro-magnets are used extensively in the manufacture of Head Telephones and Loudspeakers as well as a number of other instruments, and it is as well, therefore, to know something about them. To conclude this section we will notice that steel retains its magnetism for a long time unless it is maltreated. Thus it will lose its magnetism if it is subjected to violent mechanical shocks or if, having been made red hot, it is suddenly cooled. We know now that we should not throw our seven-guinea Loudspeakers about or subject them to red heat and sudden cooling.

Magnetic Fields.

Now, here are a few interesting experiments which you can perform yourself. There are shops all over the country where artificial bar and horse-shoe steel magnets are sold.

Obtain two bar magnets and two horse-shoe magnets together with a quarter of a pound of iron filings.

If you inspect your magnets you will find that one end has a letter N stamped on it. This is the North pole, the other end being the South pole. Take a bar magnet and put it on the table. Bring another bar magnet near it and touch the North pole of one magnet with the South pole of another. You will find that they will attract each other.

Now touch a South pole with a South pole and you will find that there is no attraction, but repulsion takes place instead. The same thing will happen if you bring two North poles together.

Thus it is clear that *unlike poles attract each other and like poles repel each other.*

To carry our experiments a little farther, take a bar magnet and place it in the middle of a table. Cover the magnet with a sheet of white paper and sprinkle the paper with iron filings, all round and over the magnet.

Tap the paper gently with a pencil and see what happens. . . . You will notice the iron filings have placed themselves in rows along definite curved lines forming a curious pattern.

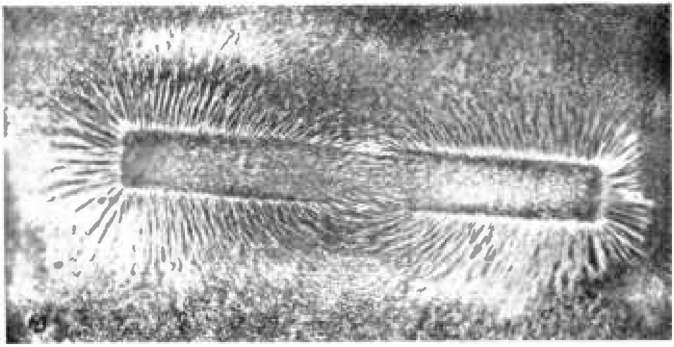
To make sure that this is not an accident, pour the filings back into the bag and replace the paper over the magnet. Sprinkle the iron filings over the paper again and you will find that the same pattern is faithfully reproduced.

The reason for this is that every magnet possesses *a magnetic field made of lines of magnetic force.* This field exists in space all round the magnet, i.e. on the sides, below and above, and the iron filings placed on paper over the magnet simply follow these lines and reproduce the field visibly.

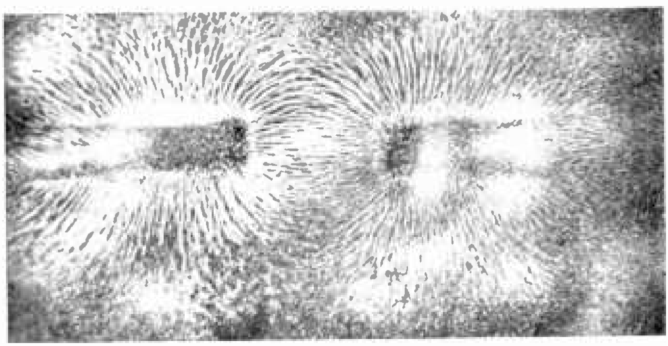
In this case you do not have to take anything on trust, because you can see the field for yourself, as well as its lines of force.

Repeat the same experiment with the other bar magnet and you will find that the field is still of the same character. Now try the horse-shoe magnet, which is nothing but a bar magnet bent to shape. The field is somewhat different. It looks as if a horse-shoe magnet concentrates the lines of force in a smaller space. Does this make the field stronger or weaker? Well, we compare two fields, or rather the strength of two fields, by the number of lines of force in a square inch or square centimetre of space. The field that has more lines per square inch is the stronger of the two.

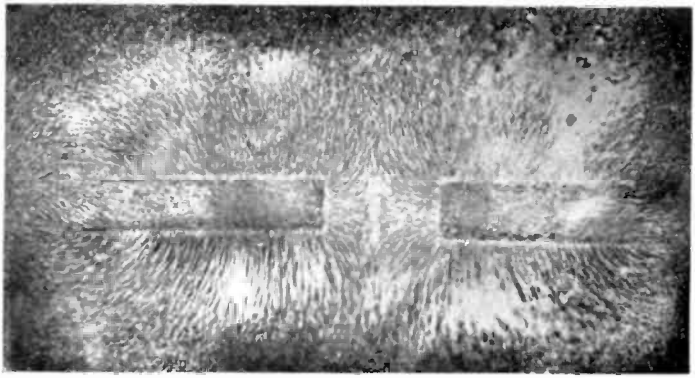
If you explore in this way the magnetic field due to a bar magnet you will find that its magnetic field is not



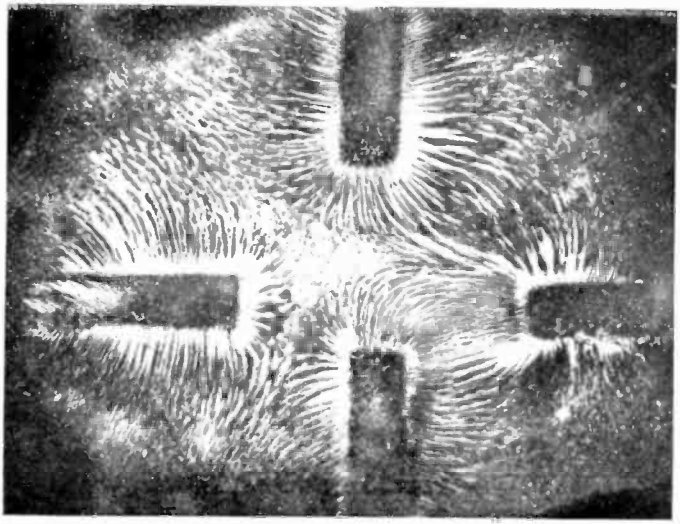
THE MAGNETIC FIELD AROUND A BAR MAGNET



THE MAGNETIC FIELD BETWEEN TWO DISSIMILAR POLES



THE MAGNETIC FIELD BETWEEN TWO SIMILAR POLES



THE MAGNETIC FIELD BETWEEN FOUR POLES OF WHICH THREE ARE SIMILAR AND THE ONE ON THE RIGHT DISSIMILAR uniformly strong. In some places it is stronger than others.

Place two magnets about an inch apart, with their North poles facing. Bring your paper and iron filings into play and observe the resultant magnetic field. It is different in character from the field of a single magnet, but how instructive! We said that a North pole repels a North pole. The lines of force of their combined fields show this clearly. . . . See how they sweep away from each other between the poles!

Try the same thing again, with the two opposite poles facing each other, and you will find still another field, this time the lines of force flowing into each other. Repeat this experiment with two horse-shoe magnets facing each other, and observe the resultant field.

By the way, it is possible to make a permanent record of these fields if, instead of ordinary paper, you use paper dipped in paraffin wax. As soon as the iron filings have arranged themselves to your liking, pass a lighted match over them; the paraffin wax will melt and in cooling will retain the iron filings in position. This pattern of iron filings on paraffined paper can be placed in a photographic printing frame over a sheet of sensitised paper and be printed and fixed in the ordinary way.

The lines of force of a magnetic field are said to spread from the North pole to the South pole.

Magnetic Induction.

We saw that iron when attracted by Magnetite became, on contact, a magnet itself. It can also be magnetised without being touched, just by influence at a distance.

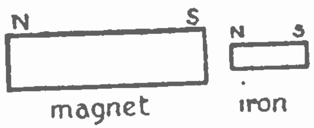


FIG. 2

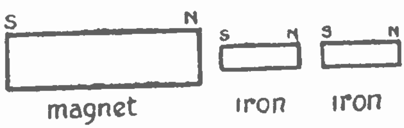


FIG. 3

Take a permanent magnet and place it on a table, in line with and half an inch away from a piece of soft iron. Now test the iron by bringing a few iron filings near it. You will discover that the piece of iron under the influence of the permanent magnet has temporarily also become a magnet and will attract iron filings. If you test out the polarity of the ends of the iron approaching a compass to the end farthest away from the permanent magnet, you will find that that end is a South pole and the opposite end is a North pole, so long as the permanent magnet is placed with its South pole next to the iron. Thus if you bring the South pole of the compass needle towards the outer end of the iron it will be repelled.

Now remove the permanent magnet and the iron will lose its magnetism.

Such influence at a distance is called *induction*, and when it is magnetism that is being induced it is called *magnetic induction*.

As you have seen, therefore, during the process of induction the South pole of the permanent magnet induced the opposite pole (North) in the near end of the soft iron, and a pole similar to itself (South) in the far end.

We shall come across this phenomenon later on in connection with other things, when we shall find that there is a good deal of similarity between various scientific happenings.

Now take a permanent magnet and place two pieces of soft iron as shown in Fig. 3.

You will find that the magnetic induction is still being carried on and that both pieces of iron have become magnets. The sequence of poles is quite logical, and is as shown on the sketch.

Now let us try to picture what is happening inside the magnet and the pieces of iron.

The Molecular Theory of Magnetism.

Mark you, we do not know definitely what is happening inside the magnet, but there is a theory that explains more or less the happenings which have been described in the previous pages.

This theory says that the molecules (old friends of ours) of iron and steel are complete little magnets in themselves.

Each molecule being a magnet, it naturally possesses two poles and its own magnetic field.

Before magnetisation the molecules are arranged, at least from the magnetic point of view, with their poles pointing in all directions.

As soon as the magnetising influence comes along, it acts like a Sergeant Major on parade. . . . "Molecules! . . 'Tshun! . . North poles! . . North Turrrrn! . ." and here you are.

This theory explains the phenomenon of magnetisation. In Magnetite the molecules are arranged by nature in such a way that all their North poles are facing one way and all the South poles another way.

In steel, the molecules, having been turned from raw recruits into good soldiers, remain so, i.e. keep their magnetism. But the molecules of iron are hopeless. . . . As soon as the Sergeant Major turns away, off they go in their old ways and face anyhow. . . .

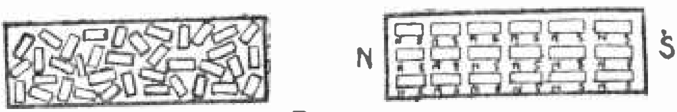


FIG. 4

Since the molecules of a magnetic substance have to be turned the right way, a force is required to make them do so. This force is brought into play by the magnetic field of the permanent magnet or some other magnetic field and is called the *Magnetising Force.* Up to the present we have considered the magnetic field as existing in air. The lines of force have shown themselves to spread in the air fairly widely, but if we introduce in their path a piece of soft iron, we shall notice at once that they will crowd into the iron, as if it were much easier for them to pass through iron than air. We therefore say that iron is more "permeable" to the lines of force than air, and we talk of the permeability of materials, i.e. the ease with which they let these lines of force go through.

The number of lines of force of a magnetic field in air per square inch or square centimetre, gives us the measure of the magnetising force. The number of lines of force per square inch or square centimetre passing through iron, gives us the measure of the ***flux density***, the ***Flux*** being the total number of lines of force passing through the iron.

There is a definite relation between magnetising force, flux and permeability, namely:

$$\text{Permeability} = \frac{\text{Flux Density}}{\text{Magnetising Force.}}$$

This is by the way, just to show you that we have not by any means exhausted the subject of magnetism. There are shelves of books written on magnetism alone. Whether you read them all will depend on how interested you are in the matter. If you intend to design and make your own components, the material here is insufficient, and you will have to read a great deal more, but if you are aiming at just a general understanding of the "mystery" of "Wireless," it will prove to be ample, especially as it is intended to dive a little deeper into the subject when we are discussing practical wireless problems.

But there is one thing in connection with magnetism that it is necessary to mention to you now, and that is

Magnetic Hysteresis.

If we take a piece of iron and first magnetise it, and then demagnetise it by some means or other, we shall find that two things will happen: The iron will not demagnetise in the same way as it was magnetised, and it will not demagnetise completely . . . there will be some "residual magnetism" left. That it is so, you will have to take on trust, as the experiments are rather complicated, and require a little more knowledge than we possess at present.

This dissimilar magnetisation and demagnetisation of iron, is called *Magnetic Hysteresis.*

Magnetic hysteresis in iron involves no little waste of energy, especially when it occurs in the iron core of transformers used in wireless. Not only does it cause loss of energy, but also a good deal of distortion of "wireless" signals. Well-designed and reasonably priced transformers have the hysteresis in their iron reduced to a minimum. Such a procedure requires first class raw materials, which are naturally expensive, and obviously cannot be put into a transformer that is sold to the public at a ridiculously low price. It is well, therefore, to spend a little more money on a transformer and to make sure that it will not distort.

It should be noted, in conclusion, that apart from iron and steel, the following metals exhibit magnetic properties, though to a very much lower extent: *nickel*, *cobalt* and *manganese*.

CHAPTER V

ELECTRICITY AT REST (ELECTROSTATICS) *

Electric charges.

The Greeks discovered, as far back as 600 B.C., that if a piece of amber is rubbed with some suitable material it will manifest an unusual property in that it will attract small pieces of light matter.

It is clear that this phenomenon is not a question of magnetism, since amber is not a magnetic material. The attraction must be due to some other cause.

You can repeat this experiment yourself, in the absence of amber, by rubbing a glass rod with silk, or a stick of sealing wax with flannel. You will find that the glass rod, after it has been rubbed with silk, will attract small pieces of paper or cork.

The Greeks called amber "elektron," and when other materials subjected to friction exhibited properties similar to those of amber, they said that those materials were electrified.

Hence the word—electricity.

What happens when two bodies are rubbed? Why should an electrified body attract other bodies?

We already know that all matter is made up of molecules. We also know that molecules are made up of atoms, and that an atom consists of a nucleus around which revolves a number of free electrons. The nucleus consists mainly of protons cemented together by a number of electrons. There are as many protons as there are electrons in an atom, and thus each proton must be balanced by its respective electron if the balance is to be preserved and the atom is to be normal.

We know that there is an affinity between electrons and protons—they will attract each other—while an electron will repel an electron and a proton will repel a proton. This

* For further information see "Ralph Stranger's Wireless library" book II—*Electrified Matter*.

is the reason why the protons in the nucleus are so solidly cemented by the nuclear electrons and why the free electrons outside the nucleus are kept in their paths.

We cannot make a proton move from its nucleus without destroying the atom, but it is quite easy to make a free revolving electron jump from its "native" atom to another.

Thus *electrons can travel from atom to atom.*

The force required to do this is not very great; ordinary friction is sufficient for the purpose.

When we rub a glass rod with silk we take away a number of electrons from the surface atoms of the glass and transfer them to the surface atoms of the silk.

Every atom has a definite structure, and a definite number of free electrons outside the nucleus.

If some of these electrons are taken away, or there is a surplus of electrons in the atom, the atom ceases to behave in a normal manner and becomes "electrified."

Let us consider an atom that has lost some of its electrons. There are as many protons left unbalanced in the nucleus as there are electrons missing. The unbalanced protons will show, therefore, a preponderance of positive electricity on the atom, and will do their best to attract some electrons to replace those that vanished, so as to establish a normal state of affairs once more. If another atom comes near, and if this atom is normal, there will be a tussle between the protons in the rival nuclei. The protons of the "impoverished" atom will do their best to pull over the electrons from the other atom, while the protons of the normal atom will do their best to retain them. But the exposed protons of the "impoverished" atom have no electrons to keep balanced, and can therefore concentrate the whole of their forces on the desired electrons. The electrons in the normal atom will obey the superior force, and will continue to leave the normal atom till the pull between the rival nuclei is equalised.

The "impoverished" atom does not get all the electrons it wants, but it does obtain some at the expense of the normal atom. The normal atom, as soon as it loses some of its electrons, ceases to be normal, since now it also has a deficiency.

If an atom with a *surplus* of electrons comes near an "impoverished" atom, the interchange is easy. The atom

Thus if you electrify a copper rod by holding it in your hand and give it a positive charge, i.e. rob it of some of its electrons, it will compensate itself immediately from the earth (through your body) and will become normal again. If you give it a negative charge, it will get rid of its surplus electrons in the same way. In the first case the electrons will flow from earth to the copper rod and in the second case they will flow from the copper rod to earth.

If you refer to any text-book you will find that what we call here a positive charge, the text-book will call a negative charge. Do not be alarmed at this discrepancy, since the text-books are still using the old-fashioned meanings for positive and negative charges arbitrarily chosen before the electron theory was developed. The latest developments compel us to revise somewhat our original ideas on the subject and to introduce a new way of thinking. Since this is not supposed to be a text-book, and you have probably

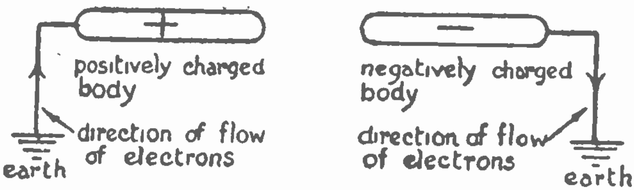


FIG. 5

passed all your examinations long ago, you are free from the necessity of answering set questions on paper in a certain established way, and there is therefore no harm in being modern, provided that you can follow this book more readily than the average text-book.

Having discovered that a copper rod cannot be electrified if it is held in the hand, it is necessary for us to discover an alternative method of electrifying it.

Somehow or other we must isolate our copper rod from earth.

We know that we can electrify glass when holding it; unlike copper it will not let its electrons flow away to earth nor will it accept any electrons from earth.

Conductors and Insulators.

It seems that, for some reason or other, glass and copper have different properties as far as the flow of electrons is concerned.

Copper seems to be able to conduct electrons, while the glass seems to act otherwise. *If we charge a glass rod at any point of its surface the charge will remain at that point* and will not spread all over the rod, while *if we charge a copper rod the charge will spread immediately all over the surface* and will leak away to earth through the experimenter's body. Copper and glass do not hold their charges in the same way.

For this reason we divide all substances into two classes: Conductors and Insulators.

A conductor will pass electrons more or less freely, while an insulator will offer such a resistance to their passage that they will not come through in any appreciable quantity.

Therefore, if we want to electrify a copper rod by friction we must attach to it an insulating handle made of glass or some other non-conducting material. It is then easily electrified in the ordinary way. It is very useful to know which substances are conductors and which are insulators. The following table will give all the required information:

TABLE OF CONDUCTORS AND INSULATORS

Conductors	*Insulators*
Acids	Air (dry)
Aluminium	Amber
Brass	Cotton
Bronze	Ebonite
Charcoal	Glass
Copper	Gutta-percha
Gas Coke	Indiarubber
German Silver	Ivory
Gold	Jet
Graphite	Leather (dry)
Human body	Linen
Iron	Marble
Lead	Mica
Manganin	Oils
Mercury	Paper
Metallic salts	Paraffin wax
Nickel	Porcelain
Platinum	Resin
Platinum Silver	Sealing wax
Platinoid	Shellac

There are other more elaborate models for laboratory work, but this will do for ordinary experimenting. In absence of gold, the leaves can be fashioned out of tin foil.

The two missing sides of the box can be replaced by glass, thus making the box dust-proof yet not obscuring the view of the leaves.

The action of the electroscope is as follows: When a charged body touches the top disc of the electroscope, the disc, the rod and the leaves acquire the same charge. The two leaves being similarly charged will repel each other and thus form an angle.

The stronger the charge the greater is the angle between the leaves. If there is no charge the leaves will not diverge.

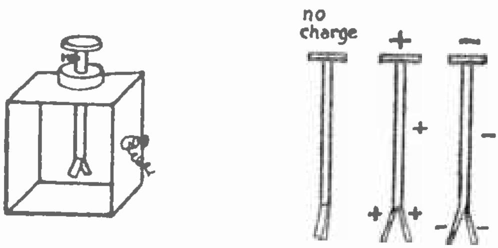


FIG. 7

In this manner a ready means is provided for finding out if a body under test has a charge or not.

We saw that if a conducting body, such as a copper sphere, is charged positively, i.e. if it has a deficit of electrons, it will draw its missing electrons from the earth if connected to it.

If it is negatively charged and connected to earth it will get rid of the surplus electrons by conducting them to earth.

In both cases electrons will flow either from earth to the conductor or from the conductor to earth till the normal state of affairs is established.

Why should this happen?

Well, the natural state of affairs is for the body to have neither a deficit nor a surplus of electrons, but just the normal number allotted to it by nature. When a body is robbed of some of its electrons, some of the protons become unbalanced, and these protons do their best to re-establish the normal state by pulling in all the electrons within reach, till the loss is compensated.

On the other hand when a body has a surplus of electrons there is nothing to hold that surplus—the electrons are unbalanced because all the protons are already fully occupied in their routine work. This unbalanced surplus will therefore escape at the first opportunity, and the unwanted electrons will leave the body as soon as an avenue of escape presents itself.

Hence there is always some force present that is urging electrons to move.

Electric Potential.

Just as heat will pass from a body at a higher temperature to a body at a lower temperature; just as gas will flow from a chamber having a high pressure to a chamber having a lower pressure, or no pressure at all, so the electrons will flow from a body having a higher *degree of electrification* to a body with a lower degree of electrification.

The degree of electrification of a body is usually called the electric *potential* of that body.

The earth being a vast reservoir of electrons has no electrification, no potential at all. *The electric Potential of earth is said to be zero.*

Electrons will flow from a body with a higher potential to a body with a lower potential. Thus electrons will flow if there is a *difference in Potential.*

A positively charged body, i.e. one having a deficit of electrons, must therefore have a potential below that of earth, since electrons will flow to it from earth. A negatively charged body must have a potential higher than the earth potential, since the electrons will flow from it to earth.

Thus *the potential of a positively charged body is always below the earth potential, while the potential of a negatively charged body is always above it.*

Here we are at loggerheads again with the text-books.

Let us take two copper spherical conductors insulated from earth and placed in air. Let their sizes be equal and let them carry equal but opposite charges. (Fig. 8.)

As you see, the electrical meaning of capacity is not so mysterious after all, it is just ordinary common sense.

Thus we find that each conductor has a capacity of its own which allows it to gain or to lose so many electrons and no more.

The capacity, naturally, depends on the size of the body. As a matter of fact *if the spherical conductor is placed in air its capacity is numerically equal to its radius.*

If we have a spherical conductor isolated in air, and it has a radius of, say, 10 centimetres, its capacity of gaining or losing electrons is 10 units.

A sphere having a radius of 20 centimetres has double the capacity of the sphere with a 10-centimetre radius.

If the same amount of charge is applied to each of these two spheres, the sphere with the smaller capacity will have a larger degree of electrification, i.e. a higher potential.

This is the reason why the two spheres A and B, having equal negative charges, but different sizes, will have different potentials, and the electrons will flow from A to B, A having the higher potential.

As soon as the flow of electrons has taken place the potentials become equal, and the charges distribute themselves in proportion to the capacities of the spheres.

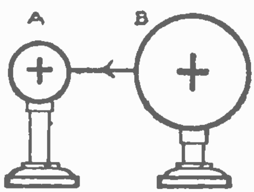


Fig. 12

Now let us consider two spheres A and B, this time having equal positive charges. We must be very careful here in our reasoning, as we are dealing now not with a surplus of electrons but with a deficit of them. (Fig. 12.)

We must be careful because if two conductors have a deficit of electrons it means that they both have a preponderance of protons. The protons are unbalanced, and show therefore an excess of positive electricity, an abnormal excess.

The protons cannot leave the nucleus. If they did this they would destroy the atom. The only thing that is capable of moving from atom to atom is the free electron. Thus we see that electrons moving from an atom will leave in it an unbalanced number of protons, and it is therefore the flow of electrons that causes a positive charge.

This positive charge will grow or diminish as electrons disappear from a body or return to it.

Thus really it is the electron that is responsible for the positive charge.

The sphere A has a certain positive charge. Let us assume that there are 50,000 electrons taken away from it and thus 50,000 protons (positive particles of electricity) are left predominant. The larger sphere B also has 50,000 electrons missing. From the point of view of the protons, the sphere A has a higher potential than B because its capacity is smaller. And so it is, from the protonic point of view.

So, in accordance with our previous reasoning, electricity should flow from the sphere A to the sphere B, i.e. from a conductor having a higher potential to the conductor having a lower potential.

But the protons do not travel, only electrons do that. *If a positive charge should happen to diminish it means that some electrons have arrived from somewhere.* If the positive charge increases it means that some more electrons have left the body.

If there is any flow of electricity between our spheres at all, and there must be some, since conditions alter, it can only be a flow of electrons.

Now, the smaller sphere A, having already lost 50,000 electrons, can afford to lose much less than the larger sphere B. The whole capacity of A for losing electrons is practically exhausted, while the larger sphere can still lose a few more.

Therefore when the two spheres are connected, *electrons will flow from the sphere B to the sphere A*, till a common potential is established.

The positive charge on A will diminish, since A has gained a number of electrons and there will be fewer protons predominant. The positive charge on the sphere B will increase, since B has lost some more electrons, and therefore the predominance of protons has increased. This increase of positive charge on B and the decrease of positive charge on A is in proportion to the capacities of the spheres, and is in accordance with our previous reasoning.

From *the point of view of the electrons* the sphere B has a higher potential, since it has not lost all the electrons it is capable of losing, but as far as final results are concerned the charges will distribute themselves in the same way as in all previous cases.

Relation between Charges, Capacities and Potentials.

There is a definite relation between the amount of charge (i.e. the number of electrons present or absent on a body), the capacity of the body and its degree of electrification or potential.

These relations are as follows:

Let us call the charge "quantity of electricity."
Quantity equals Capacity multiplied by Potential.

or

$$\text{Quantity} = \text{Capacity} \times \text{Potential} \qquad \text{(i)}$$

This also means that

$$\text{Potential} = \frac{\text{Quantity}}{\text{Capacity}} \qquad \text{(ii)}$$

or

$$\text{Capacity} = \frac{\text{Quantity}}{\text{Potential}} \qquad \text{(iii)}$$

From the above we can see that if we know the numerical values of Capacity and Potential we can find the value of the Quantity by simple multiplication.

Similarly if we know the numerical values of Quantity and Capacity we can find the numerical value of the Potential by simple division.

Knowing the numerical values of Quantity and Potential we can find by division the numerical value of Capacity.

Let us try it.

Let the Capacity be 10 units and the Quantity be 1,000 units. What is the Potential?

We know from the above that:

$$\text{Potential} = \frac{\text{Quantity}}{\text{Capacity}}$$

$$\text{Therefore Potential} = \frac{\text{Quantity}}{\text{Capacity}} = \frac{1{,}000}{10} = 100 \text{ units}$$

Let the Quantity be 1,000 units and the Potential be 100 units, then

$$\text{Capacity} = \frac{\text{Quantity}}{\text{Potential}} = \frac{1{,}000}{100} = 10 \text{ units}$$

Let the Potential be 100 units and the Capacity be 10 units, then

$$\text{Quantity} = \text{Capacity} \times \text{Potential} = 10 \times 100 = 1{,}000 \text{ units.}$$

You see how easy it is.

By the way, we can write the above formulæ in a shorthand of our own, i.e. instead of writing in full the words Potential, Quantity, and Capacity we can use symbols or letters instead.

Let us call Potential V
Quantity Q
Capacity C

Then the expressions: Quantity=Capacity × Potential becomes $Q = C \times V$

$$\text{Potential} = \frac{\text{Quantity}}{\text{Capacity}} \text{ becomes } V = \frac{Q}{C}$$

$$\text{Capacity} = \frac{\text{Quantity}}{\text{Potential}} \text{ becomes } C = \frac{Q}{V}$$

It is so much quicker than writing every word in full.

This method is adopted universally in a modified form of arithmetic known under the name of algebra.

Now that we know the relation between Capacity, Potential and Quantity let us return to our spheres A and B and charge them negatively, and then see if with the help of arithmetic we can discover what precisely is happening on these spheres when the flow of electrons takes place.

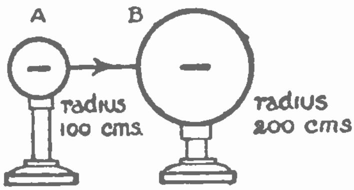


FIG. 12A

A	B
Quantity=50,000 units.	Quantity=50,000 units.
Capacity= 100 units.	Capacity= 200 units.

We can now find the Potential of each sphere, as we know their respective charges (Quantities) and Capacities:

$$\text{Potential of A}=\frac{50{,}000}{100}=500 \text{ units}$$

$$\text{Potential of B}=\frac{50{,}000}{200}=250 \text{ units.}$$

Thus we see at a glance that the potential of A is double the potential of B.

The potential of A being larger the electrons will flow from A to B till a common potential is established.

Let us call this common potential v.

When the two spheres are joined by means of a thin wire they can be considered as one body.

The total charge on this new body will be the sum of the two charges, i.e. 50,000+50,000=100,000 units.

The capacity of the new body will be the sum of the individual capacities i.e. 100+200=300 units.

Therefore the new common potential will be:

$$\text{Common potential } v=\frac{\text{Common quantity}}{\text{Common capacity}}$$

$$=\frac{100{,}000}{300}=333\cdot 333 \text{ units}$$

Compare the new potential of A with its original potential and you will see that it has dropped from 500 to 333·333 units. Compare the new potential of B with its original potential and you will see that it has increased from 250 to 333·333 units.

What has happened to the charges?

The new potential of A is 333·333, its own capacity is 100 units, therefore its new charge is $Q=V\times C=333\cdot 333\times 100=$ 33,333·3 units.

Similarly the new charge of B is 333·333×200=66,666·6 units.

Thus again we see that the charge on A has diminished from 50,000 units to 33,333·3 units while the charge on B has increased from 50,000 to 66,666·6 units.

With the help of the above formulæ check the results obtained with two spheres A and B both having an equal positive charge of 50,000 units, their respective capacities being as before: 100 and 200 units. (Fig. 12A.)

Electrification by Influence.

If we bring an electrified body near a normal body that has no electric charge whatsoever, we can displace its electrons in such a way that although the normal body has not been actually touched by the electrified body, this normal body will show on itself two equal and opposite charges.

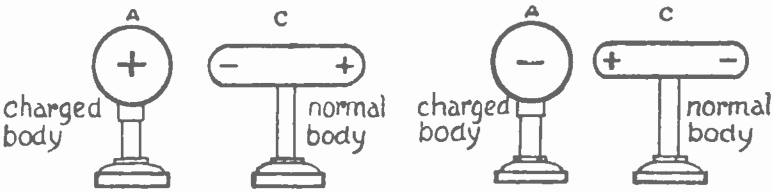


FIG. 13 FIG. 14

The body A is a spherical conductor having a positive charge, i.e. a number of electrons have been taken away from it. The body C is a normal body having no charge. As soon as the body A is brought near the body C, the latter will show (via electroscope) that it has a negative charge at the end nearer to A and an equal positive charge on the far end. (Fig. 13.)

What has happened?

The protons on the body A, being predominant, try to pull in any electrons that are near, so as to compensate for the deficit. Therefore when they are near enough to the body C they will attract the electrons on C as near to themselves as they can, and thus the electrons on C will mass themselves on the near end and form a negative charge.

The other end of the body C being deprived temporarily of its electrons will show a predominance of protons, i.e. a on their outer surface. Remove A and C, test B and you will discover that the charge on B has disappeared, while A and C each show a positive charge, equal to half of the orginal charge on B.

What happened is that B being originally charged positively had a certain deficit of electrons. When the cups A and C were fitted over it, the sphere compensated its deficit from the inner surface of A and C. The inner surface in its turn compensated itself at the expense of the layer of atoms above it, and so from layer to layer till the outer surface of the cups gave up its electrons and developed a positive charge.

Thus in the final stage the electrons are missing from the outer surface of the two cups and they show a deficit of electrons, i.e. a positive charge. Each of them will have half the original charge of B.

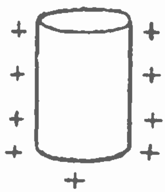


FIG. 17

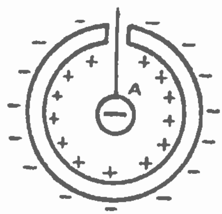


FIG. 18

If we take an insulated hollow conductor such as a metal cylinder closed at one end and give this cylinder a positive charge the charge will distribute itself on the *outside* and there will be no charge inside. (Fig. 17.)

Now take a hollow sphere in a neutral state, i.e. having no charge on it, and suspend inside this hollow sphere a negatively charged spherical conductor. (Fig. 18.)

You will find that inductive displacement will take place, and the outside of the hollow sphere will show a negative charge while the inside of the sphere will show an equal positive charge.

It has been found by experiment that the positive and negative induced charges on the hollow sphere are not only equal to each other but each of them is equal to the inducing negative charge.

This is quite clear. If the inner solid sphere A has a surplus of 10,000 electrons it will repel 10,000 electrons from the inside surface of the hollow sphere to its outside, thus exposing 10,000 unbalanced protons inside.

Electric Fields.

We already know a little about fields existing in space from Magnetism. The space around an electrically charged body is also in an abnormal state. There are definite lines of force around the conductor, and these lines of force are responsible for the formation of the electric field. An electric field will manifest itself in several ways. The lines of force play an important rôle in the attraction and repulsion of charged conductors; they are also responsible for the phenomenon of inductive displacement of electrons.

FIG. 19

Fig. 19 shows lines of force around a charged sphere. These lines of force radiate in every possible direction around the sphere, so that if we could see this electric field its lines would surround the sphere like the bristles surround a hedgehog when the animal is frightened and has rolled itself into a ball. Fig. 20 shows lines of force between two equal spheres bearing equal but opposite charges.

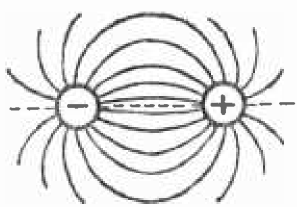


FIG. 20

The lines of force do not pass through the conductor but end on its surface. These lines start from the positively charged body and end on the negatively charged body.

CHAPTER VI

ELECTRICITY IN MOTION

We have already considered the behaviour of electrons when they are in surplus on a conductor, and we already know that if this conductor is connected to another conductor that lacks electrons there will be a rush to equalise things.

It is clear that there must be two necessary conditions to cause a flow of electrons: (i) a difference of potential between the two conductors, and (ii) a ready conducting path.

The difference of potential simply means that one conductor must have a surplus of electrons and the other conductor a deficit of them in order to provide a force capable of bringing the electrons into motion.

This can be achieved, for instance, by ordinary friction, and there are friction machines capable of producing such difference of potential. The description of these machines you will find in any text-book on electrostatics.

There are several ways and means of establishing a difference in the number of electrons at the two ends of an electrical *circuit.*

The easiest way to achieve this is by chemical means.

Primary Cells.

If two plates, one of Copper and one of Zinc, are immersed in dilute sulphuric acid (H_2SO_4) a chemical action will take place as soon as the copper and zinc plates are joined on the outside by means of a copper or other wire.

Owing to the action of the acid, the zinc plate will be made rich in electrons while the copper plate will be made poor in electrons. When the two plate terminals are joined on the outside, electrons will flow from the zinc terminal to the copper terminal, and inside the cell from copper to zinc, thus completing a round of flow of electrons.

When the two outside terminals are joined together by means of a wire, there being a difference of potential between the two plates, the electrons will be set in motion in order to wipe out the difference in the number of electrons at the two ends and thus establish a normal state of affairs. But as fast as the electrons are doing this, the acid will work just as fast and maintain the difference, forcing the electrons to flow constantly while the circuit is closed and the materials in the cell are not exhausted.

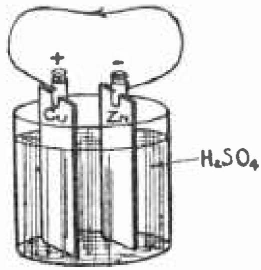


FIG. 29

Electric Current.

You should remember that the flow of electrons is from the zinc plate to the copper plate, and therefore it is the zinc plate that is originally rich in electrons. For this reason the zinc plate is labelled — while the copper plate is labelled +, therefore the current flows from — to +.*

The complete circuit from the copper plate, through the acid (acid is a conductor), through the zinc plate, through the outside wire and back to the copper plate, is known as an *electrical circuit.*

An electrical circuit is therefore a series of conductors forming a complete chain.

While this chain remains unbroken the flow of electrons will take place, but should there be a break anywhere the current will cease.

The Flow of Electrons is known as the Electric Current.

A vessel filled with dilute sulphuric acid and containing two metal plates of zinc and copper is known as a *Primary Cell.*

The plates immersed in acid can be made of other materials such as lead or carbon, but this is immaterial at the moment.

* For further information see " Ralph Stranger's Wireless library " book VI—*Batteries and Accumulators.*

Not all conductors offer the same amount of resistance to the passage of electric currents; each material has its own *specific resistance.*

Specific Resistance.

Tests have been carried out to determine this specific resistance of different conductors. Little cubes were made of different materials of 1 centimetre side, and their resistances were measured.

It is rather interesting to see how this specific resistance varied with different substances, and a useful table is included here for this purpose.

By the way, the specific resistance has to be measured in every material at the same temperature, as the higher the temperature the higher is the resistance of the conductor.

Insulators behave differently: the higher the temperature of an insulator the lower is its resistance.

Table of specific resistances of various conductors measured in microohms (one microohm is one millionth of an ohm) per cube centimetre at a temperature of 18 degrees Centigrade.

Name of Conductor	*Specific Resistance*
Aluminium	2·94 microohms
Antimony	40·50
Bismuth	119·0
Cadmium	7·54
Copper, drawn	1·78
Copper, annealed	1·69
Gold	2·42
Iridium	5·30
Iron, wrought	12·00
Lead	20·80
Magnesium	4·35
Mercury	94·30
Nickel	11·80
Platinum	11·0
Silver	1·66
Tantalum	14·5
Thallium	17·6
Tin	11·3
Tungsten	5·0
Zinc	6·10

The foregoing table shows how the specific resistance of various conductors varies.

You have noticed that the specific resistance is measured in units called microohms. One microohm is a millionth of an ohm. One ohm (a name given after a German scientist) is the unit by which we measure resistance. This unit has been chosen according to a definite standard. *The resistance of a column of Mercury of certain dimensions has been measured at a certain temperature and this resistance was taken as a unit of resistance—one ohm.*

Therefore *one ohm is the resistance of a column of Mercury* 106·3 *centimetres long and weighing* 14·4521 *grammes (thus having a cross section of* 1 *sq. millimetre), measured at* 32° *F. (or* 0° *C.).*

Now we know two units for electrical measurements, the *Volt* for measuring the E.M.F., and the *Ohm* for measuring resistance.

Once we know the material of which the conductor is made and the dimensions of the conductor we can calculate the resistance of this conductor.

If a cube of copper has a certain resistance, two cubes of copper placed side by side will have double the resistance, three cubes three times the resistance and so on. So that *the longer the conductor, the greater is its resistance.* Also, the thinner the conductor, the greater is its resistance, as, naturally, the electrons will have more difficulty in getting through a narrow passage than a wide one.

The precise way of finding the resistance of a conductor is to multiply its specific resistance by the length of the conductor and to divide it by the cross-sectional area.

$$\text{Resistance of Conductor} = \frac{\text{Sp. Resist.} \times \text{Length}}{\text{Cross-sectional area}} \text{ in microohms.}^{*}$$

Since the specific resistance is given per centimetre cube, the length and the area must be measured also in centimetres.

There may be no occasion for you to have to calculate yourself the resistance of a conductor (it can be measured with the help of measuring instruments and deduced from Ohm's law which is described further), but the above shows how the thing can be done.

* See also "Ralph Stranger's Wireless library" book V—*The Mathematics of Wireless.*

red heat by the electric current. We also have, in the same way, electric cookers, electric irons, etc.

Fuses which protect our lighting circuits from damage are designed in such a way that any excessive current that might damage our lamps or set the house on fire will melt the fuse and thus interrupt the circuit. Once the fuse is melted the circuit is broken, as the fuse forms part of it, the current will no longer flow through our lamps and the light will fail.

If you find that any wires in your wireless receiver are getting hot, something is radically wrong. At once disconnect the accumulator and the H.T. battery and then look for the fault. There must be a short circuit somewhere.

We give the name short-circuit, or simply "short" to the conditions obtaining when a piece of metal comes incidentally in contact with two wires at once which are carrying current from an accumulator, a battery, etc.

Your circuit is naturally designed so that it contains a certain amount of resistance in order to obtain a certain current with a given E.M.F. When a piece of metal or wire comes in contact with two wires at once, it connects them or "shorts" them and thus eliminates a good deal of the resistance that should be active. The resistance having become smaller the current will increase at once and will start to heat up the wires excessively and do other damage. A short is therefore a dangerous thing.

A maid is perfectly capable of placing a metal tray on top of an H.T. battery—thus short-circuiting it. The voltage of the H.T. battery may be anything from 60 volts to 180 volts. The resistance of the tray is comparatively small and therefore a large current will flow through the tray, rapidly discharging the battery and damaging the tray. When the circuit is broken we say that it is disconnected or simply "dis."

The Magnetic Effect.

If you bring a compass near a wire in which a current is flowing, the needle will move, showing that there is a magnetic field present around the wire. Thread a wire through a sheet of paper so that the paper is at right angles to the wire. Let a current flow through the wire. Sprinkle some iron filings on the paper, close to the wire, and you will find that the iron filings have placed themselves in concentric circles or rings all round the wire, thus forming a magnetic field.

There is always a magnetic field present around a conductor in which a current is flowing.

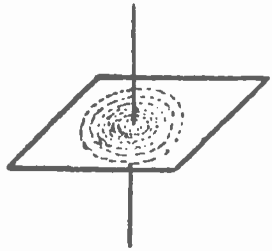


FIG. 31

The magnetic effect of the current is highly important, since it has made our modern electrical machinery possible.

Without this effect we could not have had our dynamos and our motors, we could not have had our transformers, and our coils would be useless. Wireless would have been impossible.

The Chemical Effect.

When an electric current flows through certain liquids, curious phenomena happen.

Hydrochloric acid (HCl) will be split up by the current into Hydrogen (H) and Chlorine (Cl).

Water with a trace of sulphuric acid in it will be decomposed into its constituent parts, Hydrogen and Oxygen.

This process is called *Electrolysis*, and the liquid through which the current passes is called the *electrolyte*.

It was thanks to the chemical effects of electric current that our modern accumulators became possible and electroplating was invented. Now that we know something of the chemical effect of electric current, we can consider the definition of the unit with which we measure the current, i.e. the ampere.

One ampere is the current which deposits 1·118 *milligrammes of pure silver per second when passed through a solution of silver nitrate.*

Thus we know the three most important units, viz. the Volt, the Ohm and the Ampere.

Insulation of an Electrical Circuit.

Look at your leads from the set to the Loudspeaker, the accumulator and the H.T. battery; they are all covered with in numbers till again they reach the same maximum as before, after that, diminishing in numbers till all motion stops again. At the beginning of the third fraction of a second the whole cycle of events begins all over again, a few electrons appearing on the left side of the conductor and proceeding to the right.

If you could count the number of electrons at each small fraction of a second passing a given point of the conductor you could show what is happening on paper.

The sketch below shows pictorially the happenings in a conductor in which an alternating current is flowing. A line is drawn to represent the length of time of some fraction of a second. This line is divided into a number of parts, each division giving the time of our counting the electrons. The upright lines are drawn, as shown, to represent in height the number of electrons flowing at that particular instant. These perpendicular lines convey clearly the idea

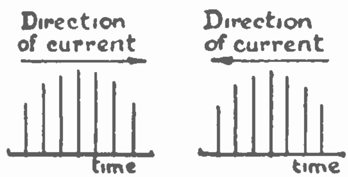


FIG. 32

of how the number of electrons that takes part in each instantaneous flow gradually grows, having started from nothing, till their number reaches a maximum and falls off again to nothing.

If we draw the same picture after the electrons have changed their direction and are flowing from right to left you will notice that the pictures are identical. At the same interval of time the same number of electrons is going through, whatever be the direction of flow.

If we draw a curve over the top of our perpendicular lines, this curve itself, although we rub out the vertical lines, will still clearly represent how the number of electrons varies.

To make this more pictorial still let us join the two curves together, and, to show that the current is flowing in two alternative directions, let us draw one curve above the line representing time and the other curve below this line. Now we can see clearly how the direction is changed.

Looking at such a curve (known as a sine curve) you can see at a glance that you have a complete cycle of events, or period, that happened in one small fraction of a second. At the

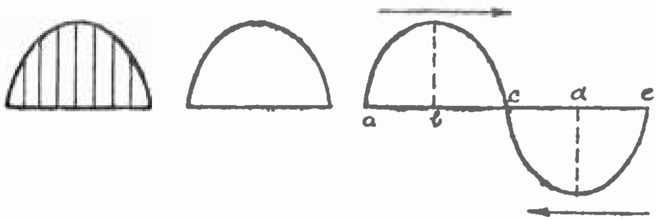


FIG. 33

time indicated by the letter *a*, no current is flowing; from *a* to *b* the strength of the current is gradually growing till it reaches its maximum at the point *b*. From *b* to *c* (still flowing in the same direction) it starts to fall in strength till it dies down to nothing at *c*. At this moment a *half-cycle* has been reached.

Reversing its direction, it starts to grow again from *c* to *d* till it reaches a maximum again at *d*, and then falls off to nothing at *e*. Here it changes its direction again. One complete cycle has occurred between *a* and *e*. Two complete cycles would look as the sketch below.

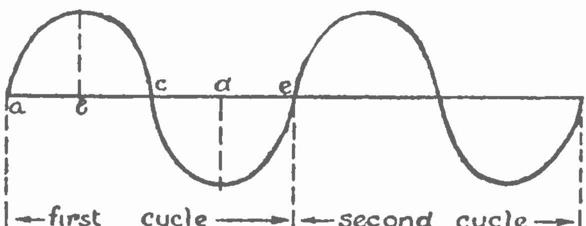


FIG. 34

You notice that Fig. 34 looks like a wave. The curve we have drawn to represent the variations in the strength of current is called *the current wave*.

Alternating E.M.F. which gives rise to alternating current must itself undergo similar variations. As a matter of fact

CHAPTER VII

ELECTRO-MAGNETISM

LET us now go a step farther in our studies of the magnetic field around a conductor that carries an electric current.

Please remember that *whenever an electric current is flowing there is always a magnetic field around the conductor.*

We already know that the magnetic field around a straight wire is a series of concentric circles.

If you bring a compass near such a magnetic field and reverse the direction of the current in the conductor (we are dealing here with direct current) you will notice that the North pole of the magnetic needle does not point the same way when the current is reversed.

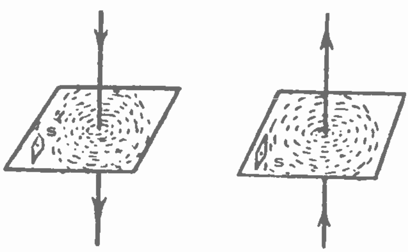


FIG. 38

If the current is flowing down the wire, then the South pole of the needle will point as shown, and the lines of force of the magnetic field will be going clock-wise. If the current is flowing up the wire, the lines of force will flow in the opposite direction and the South pole of the magnetic needle will reverse its direction.

Let us carry out another experiment. Let us bend the wire into a loop and the magnetic field will dispose itself as shown in Fig. 39.

We should not forget that a magnetic field exists not only in the plane of the paper but all around the loop, above the paper, below it and at the sides.

A magnetic field around a coil of wire will look as shown in Fig. 40.

Let us now make two identical coils and cause a current of the same strength to flow in each one of them. If you

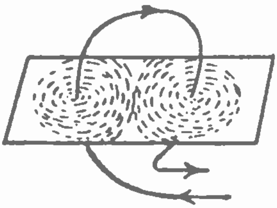


FIG. 39

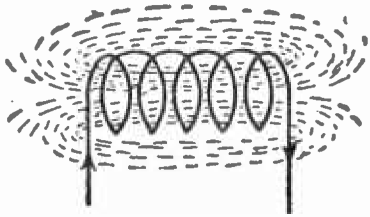


FIG. 40

bring the ends of such coils near to each other, you will discover that they possess polarity, in the same way as magnets, and will repel and attract each other. If you look at the end of the coil, and the current is flowing in it in the clockwise direction, then you are facing the North pole of the coil. If the current is flowing anti-clockwise, you are facing a South pole.* To remember this, use a mnemonical method as shown.

FIG. 41

Electro-Magnetic Induction.

We already know something about the inductive displacement of charges when electricity is at rest. We also know something about magnetic induction. Therefore the word ***induction*** is not exactly strange to us.

* The old fashioned text-books, assuming that current flows from + to − give diametrically opposite polarities.

circuit in such a direction as to form an opposing South pole on the "threatened" end of the coil, and thus try to repel the invasion.

And yet when the danger is over and the "enemy" is retreating, the electrons, seemingly thinking that the foe has turned tail and that it would be a good thing to stop him, move in the opposite direction and form a North pole so as to prevent the magnet from moving away.

We must remember that the *induced current is always opposing the influence of the cause of induction.*

We will now try to cause a magnetic field to move in space without a magnet. Let us place two coils side by side and close to each other, as shown.

Let the left hand coil be the primary cause of induction, giving rise to the magnetic field, provided with a cell and a

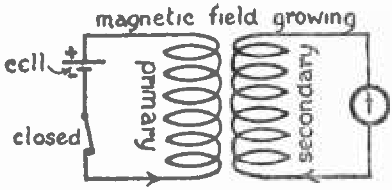


FIG. 45

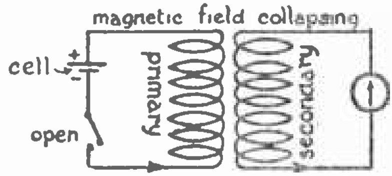


FIG. 46

contact key which will enable us to close or open the circuit at will (an engineer would have said "to make or break the circuit"). The right hand coil in which we wish to induce a current, we will call the secondary coil, and it has a galvanometer in circuit.

When we press down the contact key of the primary circuit we shall start a current in it; electrons will flow from the negative terminal of the cell to the positive terminal. As we shall realise a little later, the current will not start at full strength but will grow gradually, and the magnetic field will therefore also grow gradually. The magnetic field, in growing gradually, will gradually spread out in space, and its lines of force will move so as to cut the turns of the secondary coil rapidly at right angles. This will induce in the secondary circuit a current flowing in the *opposite direction* to the primary current, and giving rise to a magnetic field of its own which will oppose the primary field.

Now let us open the contact key of the primary circuit. The primary field will start collapsing, because its current is collapsing. Thus the primary magnetic field will now move back, away from the secondary coil. The current in the secondary coil will reverse, trying now to prevent the collapse of the primary field.

Mutual Induction.

It is interesting to observe that, as we have already discovered, the induced current in the secondary circuit causes a field of its own, which is also moving in space since it is also growing or collapsing in accordance with the influence of the primary field. The magnetic field due to the secondary circuit will cut the turns of the primary coil and induce in it a current in the opposite direction to its own current, i.e. strengthening the primary current, which will in turn strengthen the secondary current. This effect is known as *mutual induction*, and is used in "wireless" in many ways.

Self-Induction.

During electro-magnetic induction there is, however, another effect in a coil, which will appear to us rather curious and is also based on induction.

When we start a current in a coil, the magnetic field will start building up around the coil as a whole and also around each individual loop of wire or each turn of the coil. Therefore, each turn in the coil will have a small magnetic field of its own, also moving in space during the process of growth of the main field. These small fields will, naturally, cut the next turn of wire of the coil, and will induce in each turn a small additional current over and above the already existing current. This small current, by all the rules and regulations of electro-magnetic induction, must be such as to oppose the current that gives rise to it, i.e. try to reduce the main current while it grows, and try to increase it

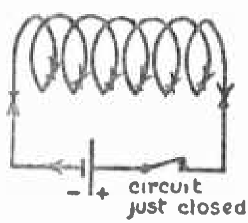
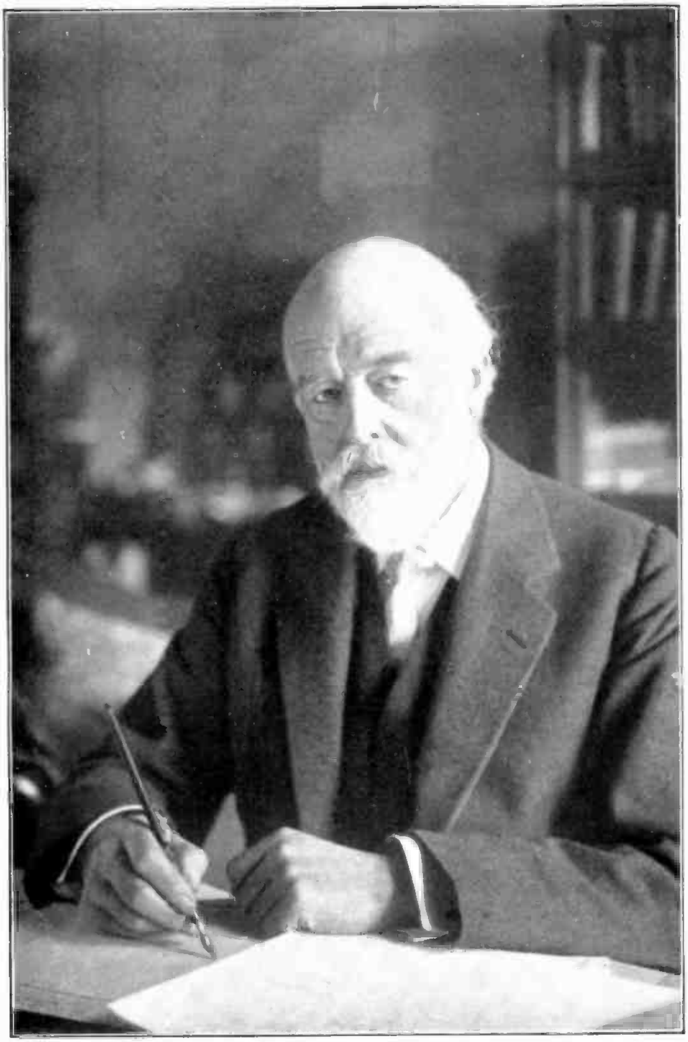


FIG. 47



[*Photograph by E. O. Hoppe*

SIR OLIVER LODGE

[By courtesy of the Marconi Company

MARQUIS G. MARCONI, G.C.V.O., D.Sc., LL.D.

PART III

THE WEAVING OF THE MAGIC CARPET

A WARNING

Nothing in this book should be taken as an encouragement to infringe any existing patent.

The appended diagrams represent theoretical circuits, merely illustrating the principles involved in wireless reception, and are not intended for constructional purposes. Those who wish to build their own sets should, in their own interest, periodically consult the following technical constructional journals, enumerated in alphabetical order:

Amateur Wireless, 3d. weekly.
Modern Wireless, 1s. monthly.
Popular Wireless, 3d. weekly.
Wireless Constructor, 6d. monthly.
Wireless Magazine, 1s. monthly.
Wireless World, 4d. weekly.

Advanced students should read

Experimental Wireless, 2s. 6d. monthly.

For British programmes see

Radio Times, 2d. weekly.

and for Foreign programmes

World Radio, 2d. weekly.

also the B.B.C. Handbook, 2s. annually.

The *Stations Identification Panels* book, 1s.

The talks are printed in *The Listener*, 3d. weekly.

CHAPTER I

THE RIDDLE OF THE ETHER

LET us take, a bottle of champagne. Let us drink the champagne and celebrate the fact that we have reached Part III of the book. Now, when we have drunk the wine what is left in the bottle?

Nothing? . . . Wrong! . . . Air? . . . Yes, but let us pump all the air out. . . . Nothing? . . . Wrong again! . . . There *is* something left in the bottle, although it is not apparent to our senses. That something is ether. No, not the stuff the chemists sell in bottles, but the medium that pervades the whole of the Universe.

Ether is a mysterious medium of which we know very little, and which we cannot yet isolate. This much we do know: there must be such a medium in existence, otherwise we should have been unable to obtain any light or heat from the sun, and our planet would be dead.

Ether is a medium filling the whole of the universe, the space between molecules and inside atoms. Like any other medium, it possesses *density* and *elasticity*.

Having density, it can be compressed or stretched. Having elasticity, it will not remain deformed, but will assume its normal state as soon as the stress or the strain is removed.

Thus, it is possible to disturb the ether, to make it feel a shock, and, what is more, to make it transmit that shock a long way off. It is possible to disturb the ether say, in Australia, and, by suitable means, discover the character of this disturbance in London.

The sun is 92,000,000 miles away from our planet. The light that reaches us from the sun is nothing but a disturbance in the ether, a disturbance which spreads with a speed of 186,325 miles a second!

Just try to imagine such a speed. Our fastest man-made machine has a world's record of 318 miles an hour. Herr Fritz Von Oppel hopes to reach a speed of 350 miles per hour with his rocket car, but 186,325 miles a second or 670,770,000 miles per hour, just think of it!

Sunlight takes 8 minutes 13·7 seconds to reach us from the sun. There are stars from which light takes 1,000 years to reach the earth. Thus you may realise that a disturbance in the ether will persist for a very long time if the cause of the disturbance is strong enough. The ether is therefore a very sensitive and a very persistent medium.

It was thanks to the fact that the ether could be disturbed that "wireless" became possible, as soon as we had discovered the means.

There is a close connection between the ether and the electrons.

While electrons in an atom are in their normal state, the ether remains undisturbed, but as soon as an electron is kicked out of its path and starts moving elsewhere, the ether becomes strained all round it and that strain is felt throughout the medium.

Here is cause and effect. All we have to do is to set electrons in motion in a conductor and thus disturb the ether, and people miles and miles away will know not only that we are disturbing the ether, but also the way in which we are disturbing it.

The disturbance in the ether will affect every conductor in the way of this disturbance, simply by inducing E.M.F.s across each conductor (see Part II) and causing the electrons in it to oscillate.

Thus all we have to do is to erect a conductor, i.e. a wire, high in the air, say, in Australia, and another say, in London, provide some means of making electrons dance to our Australian fiddle, and the London electrons will dance in the same way.

A disturbance in the ether spreads in every possible direction in space, and therefore such a disturbance can be discovered by millions of stations at the same time. There is no secret about it, everybody can hear it if they want to.

The beauty of the whole thing is that by means of sound waves we control the way the electrons will jump about or oscillate in the sending wire, and thus make them disturb the ether in quite a definite manner having a relation to the sounds emitted.

To every sound emitted by a speaker, a singer, a piano or an orchestra, the electrons will respond in a particular way of their own. This will cause in the ether numerous very rapid disturbances, in sequence, which will in their turn disturb electrons elsewhere, and the electrons will cause by means of suitable apparatus the reproduction of the same sounds.

Not very complicated, is it?

By the way, many people think that "wireless" means sending out sound waves. As you see, this is not so; the sound is simply used to control the electrons. Try to shout to a friend of yours a mile away and see how much of your sound will reach him.

We already know that light, being a disturbance in the ether (the sun supplies the disturbing electrons and our skin and eye provide the receiver) spreads with a speed of 186,325 miles a second or, in French measures, universally adopted in radio measurements, 300,000,000 metres a second. "Wireless" signals being also a disturbance in the ether and of the same nature will spread with the same speed.

The circumference of the earth at the equator is roughly 24,902½ miles. A wireless signal, therefore, travelling at 186,325 miles a second, will take about ·13 of a second to go right round! Thus Big Ben will be heard in America before the passer-by on Westminster Bridge hears it, as sound waves travel much slower than ether waves.

We have a special name for disturbances in the ether; we call them electro-magnetic waves. The term electro-magnetic is used owing to the fact that each disturbance in the ether is a sort of a twin disturbance, it has a double effect; one half of it affects a conductor electrically, and the other half magnetically.

An ether disturbance is not really a wave in the same sense as the sea wave; it is rather a rapid and periodic series of compressions and rarefactions in the ether, a sort of continuous shiver going on in every possible direction, and thus shiver after shiver is being caused by the transmitting station.

metres long. If there are a million waves a second each wave must be 300 metres long.

Since a distance of 300,000,000 metres must be covered each second, it stands to reason that the more waves there are covering that distance the shorter each wave is going to be.

As you see, there may be one wave a second or there may be a million waves a second, so that the frequency with which each waves occurs is important.

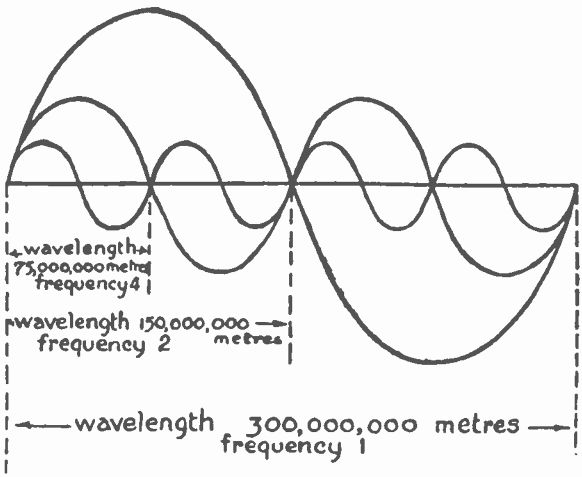


FIG. 49

If a wave 300 metres long occurs with a frequency of one million times a second, the distance of 300,000,000 will be covered in one second. We can see at a glance now that the relation between the speed with which a wave travels, its length and its frequency is:

$$\text{Wavelength} = \frac{300{,}000{,}000}{\text{Frequency}} \text{ metres.}$$

Now let us try this formula: If a wave has a frequency of 1,000 cycles in one second, what is the wavelength?

$$\text{Wavelength} = \frac{300{,}000{,}000}{1{,}000} \text{ or } 300{,}000 \text{ metres.}$$

You have probably noticed already that the product of wavelength and frequency must always come to 300,000,000 metres.

One complete wave represents one complete cycle of events, as already explained on page 79. Thus frequency means that so many complete cycles have occurred in one second. We therefore measure frequency in cycles. We talk about a frequency of 60 cycles, 1,000 cycles or 1,000,000 cycles.

Engineers have found it convenient to talk of batches of 1,000 cycles at once, and called that figure a kilocycle. A kilocycle is thus simply a name for a thousand cycles. So that an engineer, instead of writing down 1,000,000 cycles will write down 1,000 kilocycles, or simply 1,000 Kc.* You see how such a unit shortens the row of figures.

Up to last year we all talked about wavelengths of Stations, i.e. the length of the wave which they send out, but recently engineers came to the conclusion that for their purpose it is more convenient to talk of frequencies instead of wavelengths.

For this reason you will find in *World Radio* against each station its wavelength in metres and the equivalent figure of kiloherz, i.e. frequency.

Here are the most important equivalent wavelengths and frequencies:

Wavelength metres.	Frequency kiloherz.
100	3,000
200	1,500
300	1,000
400	750
500	600
600	500
700	428·57
800	375
900	333·33
1,000	300

Thus you see that as the wavelength increases the frequency decreases. Please check the above figures with the help of the formula given on the opposite page.

* One cycle per second is called herz. One kilocycle per second is therefore one kiloherz. This is a new name given quite recently.

These two fields would alternate in volume, i.e. increase in strength, and reach a certain maximum and then die down to nothing, then start travelling back again; in other words they would behave in the same manner as the wave we have described previously.

If you could see a little way from the aerial you would notice that the wave has started off in real earnest and is going away from the aerial, in all directions, bending as it follows the curvature of the earth and weakening a bit every time it passes a conductor. In passing a conductor the wave is deflected, and a little of its energy is dissipated in causing electrons in that conductor to oscillate. If the conductor happens to be not an aerial but just an obstacle, or a "screen" as it is called, because it screens aerials from the wave, it does no useful work, as far as reception is concerned, but just eats up the precious energy.

Such screens exist in various localities either in the form of high hills containing metallic ores, or tall buildings with a steel skeleton. In such localities reception is bad if the screening obstacle happens to be between the transmitting station and the receiving aerials.

When the electro-magnetic wave reaches a receiving aerial it affects the aerial, and the electrons in the aerial circuit start oscillating up and down the aerial and thus provide the necessary conditions of reception in the set.

As we have already said, the electro-magnetic wave is reflected by conductors. This is rather fortunate, as otherwise "wireless" reception would be impossible, since every wave would simply leave us and disappear in space.

Around the earth, high up in the atmosphere, there is a large layer of negatively charged atoms of frozen atmospheric gases (you know that the higher you go up the colder it becomes), i.e. atoms which have a surplus of electrons on them. The reason for these atoms having a surplus of electrons is that in day time they are being constantly bombarded by electrons from the sun. This layer, known as the Heaviside layer (named after a scientist of that name) forms a very effective conducting surface, covering the whole of the earth like a blanket.

This layer reflects the "wireless" waves, and prevents them from leaving our planet, in fact it causes them to follow the earth's curvature.

A good deal depends on the angle at which the waves start spreading into space from the transmitting aeriel. The shorter the wave the more acute is the angle, and the more sharply it is reflected by the Heaviside layer. Long waves bend around the earth's surface more readily than short waves. While a long wave, i.e. a wave exceeding 100 metres in wavelength, will be well received at a considerable range, i.e. in a wide radius all round the transmitting station, a short wave will be received within a small radius and then travel as if it were a billiard ball flying from side to side of the billiard table. The Heaviside layer forms the sides of the billiard table and the short wave is the ball. On being reflected it might pass close to the earth's surface at some point influencing a number of receiving aerials and pass close to it again somewhere at the antipodes.

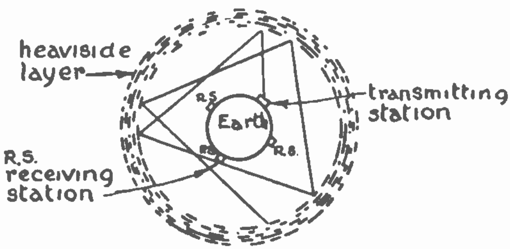


FIG. 50

When receiving on short waves you may fail therefore to receive any signals one hundred miles or five hundred miles away from the short wave transmitting station, while it is being very well received thousands of miles away, just because it happens to pass there close enough to the earth's surface. In short wave reception we therefore speak of "blind spots" or "dead zones" where reception is impossible. Short waves can therefore be used for signalling at much greater distances and with much less power.

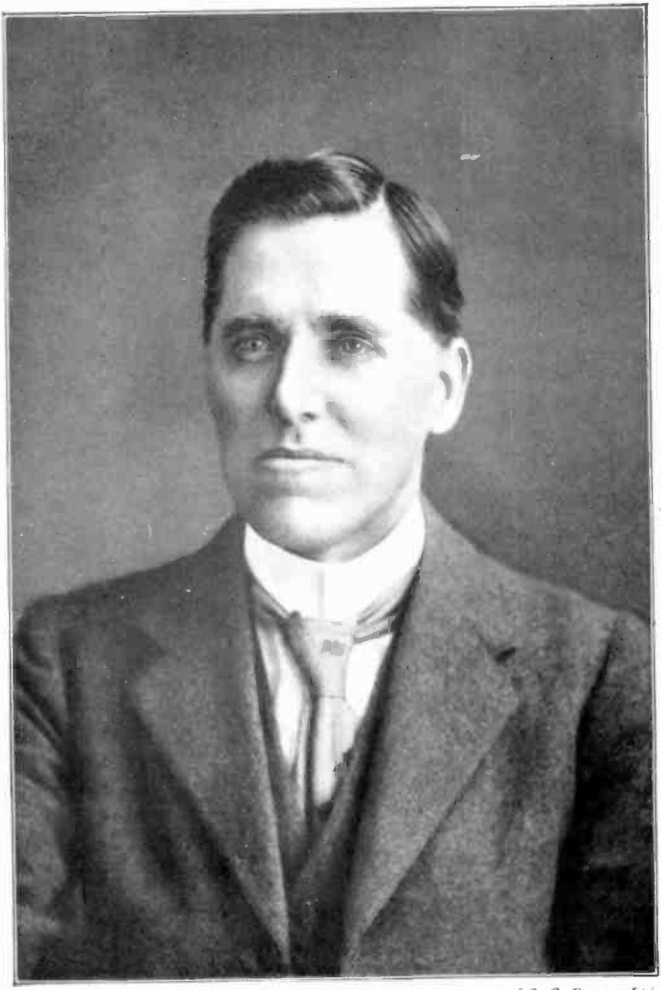
It is interesting to observe here that the Heaviside layer apparently does not stop the sun's rays from reaching the earth. As we have seen from our table of various waves, light has a very high frequency, and consequently its wavelength is very short. We know, therefore, that very short wavelengths will penetrate the Heaviside layer readily enough, and it has been stated that reflection begins only after 1 meter.

Thus if we want to communicate with Mars, provided that there is somebody there to communicate with, we should use wavelengths below 1 metre. And yet a few years ago a number of "amateurs" sat up all night listening solemnly on a large valve set in case any signals came through from Mars, as Mars happened to be at its shortest distance from the earth. Unfortunately they were listening on very long waves, and therefore, even had there been any signals sent, they would have had no chance of receiving them.

One must assume that the Martians are intelligent enough to know that they have to use very short waves.

There is a good deal of research to be done in connection with short wave work, as very little is yet known on the subject. Designs for short wave receivers often appear in the t chnical Press, and such receivers can be easily constructed at a very moderate cost. There are a number of short wave sets on the market.

When working on short waves we notice another phenomenon that is seldom observed with long waves. The intensity of signals may vary considerably from time to time. One can describe such variations only in one way: The signals appear to fade away and then come up to full strength again. This is called "fading."



[By courtesy of S. G. Brown, Ltd.

S. G. BROWN, F.R.S., M.I.E.E.
A Pioneer in Radio Acoustics

original position, they will continually alter the resistance of the circuit of which they are a part.

The more resistance there is in the circuit, the smaller the current is going to be, as we already know from Ohm's law, and the less resistance there is, the stronger the current.

When a microphone is active a current is caused to flow through it all the time. When you speak in front of the microphone your vocal chords move and produce a series of sound waves in the air. These air waves beat on the diaphragm of the microphone and make it vibrate in the same way as the vocal chords are vibrating.

The diaphragm, therefore, alternately presses on the carbon granules when it moves towards them, or releases them when it flies back.

Thus while the diaphragm is vibrating it continuously alters the resistance of the circuit and therefore the strength of electric current in it.

The resistance and the current vary in accordance with the variation of intensity of the sound waves in the air caused by the vocal chords.

This means that we are actually transforming the sound of our voice into electrical currents.

It also means that by our voice we can control the current in the circuit.

Thanks to the microphone we can control not only the strength of the current in a telephone circuit, but also the manner of oscillation of electrons in a transmitting aerial, and thus control the "wireless" waves which are being radiated.

The microphone described above represents the most simple form of such an instrument, but in actual practice more complicated microphones are used.

For Broadcasting purposes the microphone currents or electrical impulses are too weak and have to be amplified.

It must be clearly understood that during speech the current flowing through the microphone varies its intensity absolutely in accordance with the variations of intensity of the voice. Each slight shade in intonation, each sound pronounced has an electric impulse to itself.

If the microphone currents are brought into a telephone circuit, as they are in an ordinary telephone, they will make another diaphragm vibrate in exactly the same way as the microphone diaphragm is vibrating under the influence of our voice. Therefore the person who listens at the other end will hear exactly the same sounds as those emitted in front of the microphone.

How this second phase is performed, viz., transforming electric currents into sound again, we will consider in the next chapter.

CHAPTER V

HEAD TELEPHONES

We already know from Part II of this book that if a current flows through a coil there will be a magnetic field around that coil. If the coil is suitably wound on a core of soft iron, whenever a current is flowing in the coil the magnetic field due to the current will magnetise the iron core and it will become a magnet which will attract other pieces of iron. Such a temporary magnet is called an electro-magnet.

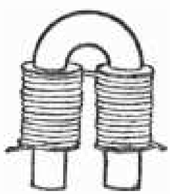


Fig. 52

Now let us imagine such an electro-magnet made up of a horseshoe-shaped soft iron core with two coils wound on it, the coils being joined together so that a current will flow through the pair of them and will magnetise both ends of the horseshoe core, making one of them the North pole and the other the South pole.

We also know already that the intensity of the magnetic field round a coil and therefore the intensity of magnetisation of the iron will vary with the strength of the current which is flowing through the coils. Thus the stronger the electric current in the coils, the stronger will be the electro-magnet, i.e. the greater will be its attraction for other magnetic bodies.

If in front of such an electro-magnet we can place a thin soft iron diaphragm, and if the electro-magnet is active, i.e. a current flows through its coils, the thin diaphragm will also become a magnet by magnetic induction and will be attracted by the electro-magnet.

If a pulsating current is flowing through the electro-magnet, the magnetic field will also pulsate, and the pull on the diaphragm will also be of a pulsating character and the diaphragm will start to vibrate.

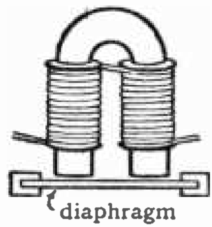


FIG. 53

Now, we know that we can take a thin soft iron diaphragm, place it in front of an electro-magnet through which a pulsating current is flowing and the diaphragm will vibrate.

You have already probably said to yourself: "How convenient! If we let the microphone currents pass through an electro-magnet we can make the iron diaphragm vibrate in the same way as the microphone diaphragm and make it reproduce the same sounds."

Precisely. Lead the microphone current into the coils of such an electro-magnet. The current will vary in accordance with the varying resistance of the carbon granules, or in other words, in accordance with the variation of sound agitating the microphone diaphragm. This current will impress the same variations on the magnetic field of the electro-magnet, and thus vary the pulling power of the magnet, causing the iron diaphragm to vibrate in exactly the same way as the carbon diaphragm has been vibrating. The iron diaphragm will beat on the air and will produce sound waves identical with those emitted by the vocal chords of the speaker at the other end.

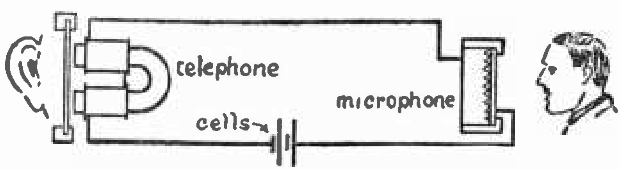


FIG. 54

The human ear cannot hear all the sounds emitted in nature. There are sounds that the ear cannot catch because there are limits to human audibility. Many people, for instance, cannot hear the hum of a mosquito. If you turn to your piano you will find that the higher the note the faster the string vibrates, i.e., the higher is the frequency of its vibrations. The audible range of frequencies lies between 10,000 and 50 cycles a second.

This is the reason why in "wireless" we distinguish High Frequency and Low Frequency. An electro-magnetic wave having a frequency of 1,000,000 cycles a second will produce currents also of high frequency in our aerial. If we brought these currents to this electro-magnet of ours, then the diaphragm, assuming it could overcome its own inertia and could vibrate at such a tremendous speed, would produce so high a note that no human being could hear it. Therefore before we can use the currents in our aerial for audition purposes, we have to alter their character so that they exert a comparatively slow pull on the telephone diaphragm.

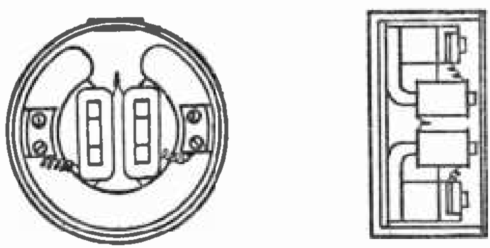


FIG. 55

Such an electro-magnet, with a soft iron diaphragm in front of it, as we have described above, is called a telephone receiver (do not confuse it with a "wireless" receiver).

The contraption shown in Fig. 53 is rather crude, and represents the simplest form of a telephone receiver. In actual practice the construction is somewhat more elaborate.

To make the telephone receiver more sensitive, the soft iron core of the electro-magnet is clamped to a permanent steel magnet in the shape of a ring. Thus we have an initial magnetic field to start with, which is being either strengthened or weakened by the temporary magnet. (Fig. 55.)

The permanent magnet, causing the initial magnetic field, holds the soft-iron diaphragm in a state of tension. As the additional magnetic field due to currents flowing in the electro-magnet coils weakens and strengthens the resultant field, the tension on the diaphragm is also, naturally, weakened or strengthened, and thus the diaphragm begins to vibrate. Again, since the variations in intensity of current flowing through the telephones are controlled by the vibrations of the microphone diaphragm, the telephone diaphragm will reproduce the same vibrations, and the same sound waves will be produced at the receiving end as those emitted at the microphone end.

There is one thing we have to consider in connection with telephones, before concluding this chapter, and that is the question of their resistance.

We talk of telephones having a low resistance or a high resistance. By resistance of telephones we mean the resistance of the coils on the magnets, or rather the resistance of the wire in the coils.

The resistance may be as high as 4,000 ohms. It may be as low as 120 ohms. A high resistance instrument is connected directly to the anode of the last valve (we shall know all about it in the next few chapters), while a low resistance instrument is connected to the anode through a telephone transformer.

When the output is high it is safer to connect the telephones through a telephone transformer. (See Fig. 114.)

CHAPTER VI

HOW BROADCASTING IS DONE

A Broadcasting station consists of two main parts: The Studio where the microphone is found, and the Transmitter with its aerial.

The studio and the transmitter are not necessarily in the same building. While the studio may be in the middle of a town the transmitter with its aerial may be a few miles outside that town, or still farther afield.

To the studio is attached a control room where operators are able to connect the studio, or in other words the microphone, to any transmitter in the country through the ordinary Post Office telephone lines.

The first step in Broadcasting transmission is to cause electrons to oscillate in the transmitting aerial in alternate directions and in a continuous manner so that the ether is periodically disturbed, an alternating wave, having a high frequency, being all the time radiated by the aerial. This wave is called the *carrier wave.* (Fig. 56.)

In an ordinary telephone circuit, where we have a microphone at one end and a telephone receiver at the other end, a current is made to flow as soon as you lift the telephone receiver from its hook. This current, flowing in a continuous manner, does not produce any impression on the telephone diaphragm and you cannot hear anything until somebody begins to speak at the other end, and thus starts to vary the resistance of the circuit. So that this initial current is really the carrier current which serves as a foundation to the microphonic variations.

The "wireless" carrier wave serves the same purpose. It "carries" the microphonic variations across the ether. If you try to listen to a carrier wave, unless it is modified in character through suitable apparatus, you will hear nothing. Its frequency is too high, and the telephone diaphragm is unable to respond to such rapid vibrations, which have the effect of a single steady pull on the diaphragm.

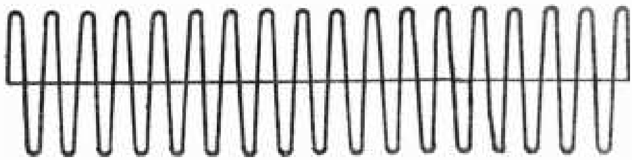


FIG. 56

In Fig. 56 we have shown a regular wave representing the variation of current in the aerial, causing the emission of the carrier wave. When a performer speaks in front of the microphone in the studio and thus varies the resistance of the microphone circuit, currents of varying strength begin to flow in the circuit.

The microphone currents are now amplified, and are passed through the transformer (the word "through" is not quite right but it will do for the present).

These amplified microphone currents are made to influence the aerial carrier currents, and the character of the resultant current and therefore of the resultant wave will look something like the curve shown below.

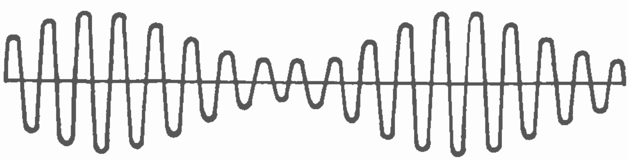


FIG. 57

The action of making the microphonic currents influence the carrier current, is called "modulation."

You will no doubt realise that by altering the character of final currents in the aerial we are altering the character of the wave we are sending out, so that the carrier wave in the ether will also alter its character and will become a modulated wave, being the result of the carrier current and the microphonic currents. Since the microphonic currents represent sound waves interpreted in terms of electrical impulses, the altered carrier current will also represent the characteristics of these sound waves and will pass on these characteristics to the emitted wave. Thus the ether wave radiated by the aerial bears the characteristics of the sound waves emitted in front of the microphone. Having understood this, we can now follow out the whole sequence of events in Broadcasting.

The singer, the speaker or the whole orchestra, is singing, speaking or playing in front of the microphone. The microphone diaphragm vibrates in accordance with the variations of intensity of the sounds emitted and, by varying the resistance of the circuit through which a current is passed, varies the intensity of that current, which begins to change in strength in accordance with the variations of sound.

The microphone currents are amplified, and, on passing through the transmitter, influence the already flowing carrier current in the aerial. A modified final (modulated) current will flow in the aerial and cause the aerial to radiate the final modulated wave.

Thus, when the microphonic currents are absent, only carrier currents flow in the aerial, and only the carrier wave is being radiated. As soon as the microphonic currents come into existence, the carrier current alters its character, and a modulated carrier wave starts to travel in space.

This modulated wave, on passing any receiving aerial, will induce in it currents of the same character as those that were flowing in the transmitting aerial a small fraction of a second ago. Thus the receiving aerial will have currents bearing the speech or music characteristics as passed from the studio. These currents, after passing the various stages in the receiver, will be brought to the coils of the telephone or loudspeaker as *a series of comparatively slow impulses* capable of causing the telephone or loudspeaker diaphragm to vibrate in the same way as the microphone diaphragm was vibrating in the studio. We shall look into this a little closer in Chapter XV.

To put it all in a nutshell, in Broadcasting we have to do four things:

(i) To convert sound waves into electrical impulses, (ii) To convert the electrical impulses into electro-magnetic waves, (iii) To convert the electro-magnetic waves into electrical impulses again, and (iv) To convert electrical impulses into sound waves.

The first two things are done by the Broadcasting station and the last two by the receiving set.

It is not of the slightest use for the transmission to be perfect unless the receiving set is also working perfectly. Otherwise we can start with the best of music at the studio, and, if the receiver is badly designed, finish off at the receiving end with an unseemly cacophony.

If the receiver is not properly adjusted it will cause distortion, and may alter the sounds to such an extent as to make them unrecognisable. You may be sure that everything is well at the B.B.C. end as far as transmission is concerned, unless the transmitting station has broken down, but this happens very seldom indeed.

Therefore if you notice that your signals are distorted, have a look at your receiver and you will probably find that your valves are not being properly treated or your set is oscillating (see Chapter XXI).

You will no doubt realise that you are not getting all the power from the Broadcasting station. The waves spread themselves in all possible directions, and are energising millions of aerials. Therefore, the amount of energy you can receive is very small indeed, and if you happen to be screened from the Broadcasting station you will receive still less.

If you are screened, you may receive a more distant station much better than the one that is nearest to you provided that there is no screen between your aerial and this distant station.

CHAPTER VII

THE AERIAL

An aerial is a conductor completely insulated from earth before it reaches the receiving set, but connected to earth by the tuning circuit of the receiver.

Its function is to interpret the passing electro-magnetic waves radiated from a Broadcasting station in terms of electrical impulses or oscillations in the aerial wire.

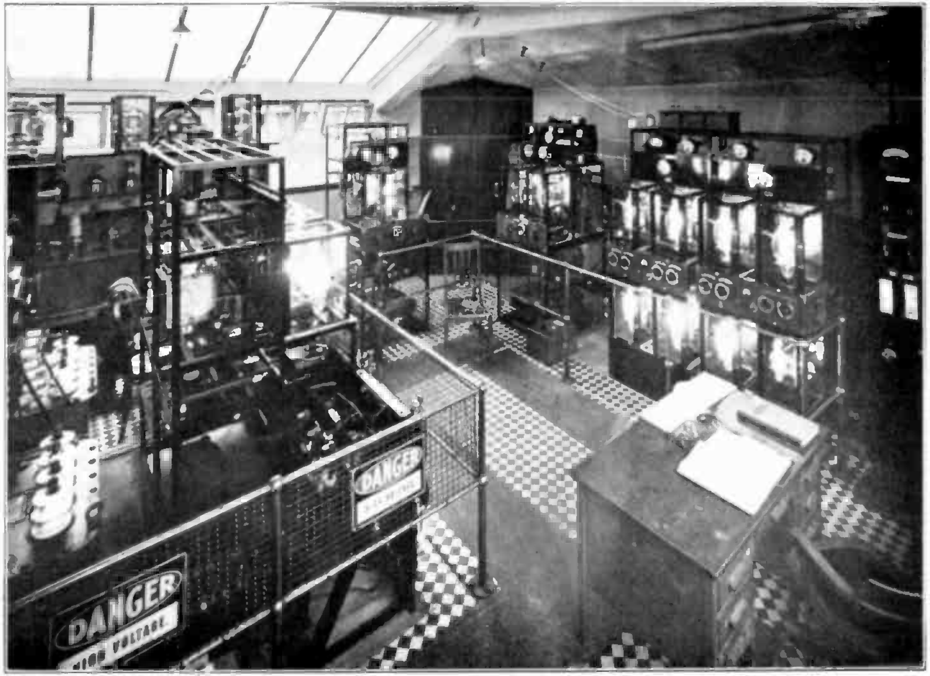
What happens is that when an electro-magnetic wave passes the aerial it promptly influences the electrons in the wire and causes them to move up and down the aerial in exactly the same manner in which the electrons of the transmitting aerial were moving only a small fraction of a second previously.

The aerial is connected through a "down lead" wire to the aerial terminal of the set, and so to the "Tuning circuit" of the set, the other end of this tuning circuit being connected direct to earth.

Thus we have two problems in front of us: completely to isolate from earth the aerial wire and to make a good connection to earth of the "earth side" of the receiver.

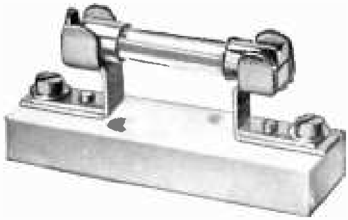
The aerial wire should be erected as high as possible and clear of all obstacles. Its position will depend, naturally, on the position of your house. If you have a garden, the problem is simple. The aerial can be stretched between the base of a chimney pot and a convenient tree at the end of the garden. (Fig. 58.) If such a tree is not available a mast should be erected and the aerial fixed to it.

What is important is not the actual height of the aerial but its effective or average height. If an aerial is 20 feet above the ground at one end, and 50 feet above the ground



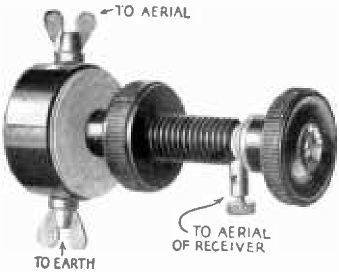
[By courtesy of the B.B.C.

THE TRANSMITTER OF 2LO



Marconiphone
Lightning Arrester

Dubilier Series-
Parallel Switch



Marconiphone Lead-in
and Earth Switch

Dubilier "Ducon"
Aerial Eliminator

at the other, its effective height is neither 50 nor 20 feet, but $\frac{50+20}{2}$, i.e. 35 feet.

A house, from the point of view of the aerial, is a continuation of the ground, and therefore if an aerial is erected 10 feet above the roof, and the roof is 60 feet above the ground, the effective height of the aerial is not 70 feet but only 10 feet.

The best wire to use for an aerial is the so-called: "7/22 copper wire." This simply means that the copper wire has seven strands and each strand is of 22 gauge.

You will require for your aerial system the following components: One hundred feet of aerial wire, two aerial insulators, a leading-in insulator and a single-pole double-throw

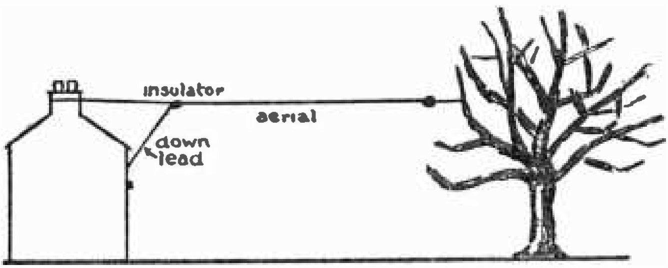


FIG. 58

switch on a porcelain base. These are arranged as shown in Fig. 59.

When erecting the aerial the following precautions should be taken: See that the aerial wire is clear of such objects as roofs, trees, etc. Make sure that the aerial wire, when passing through the insulator, is clear of the rope securing the insulator to the support. Do not cut the aerial wire but use the remaining loose end for leading in. See that the leading-in wire is about 5 feet clear of the wall of the house.

Finish the leading-in wire at the outside end of the lead-in insulator. See that the insulated wire passing into the room from the lead-in insulator to the switch does not go all round the room. Place the set as near as possible to the window or door on which the lead-in insulator is fixed.

Connect your switch as shown in Fig. 59.

As you see, the switch will connect the aerial to the set for reception and to earth when the aerial is not in use.

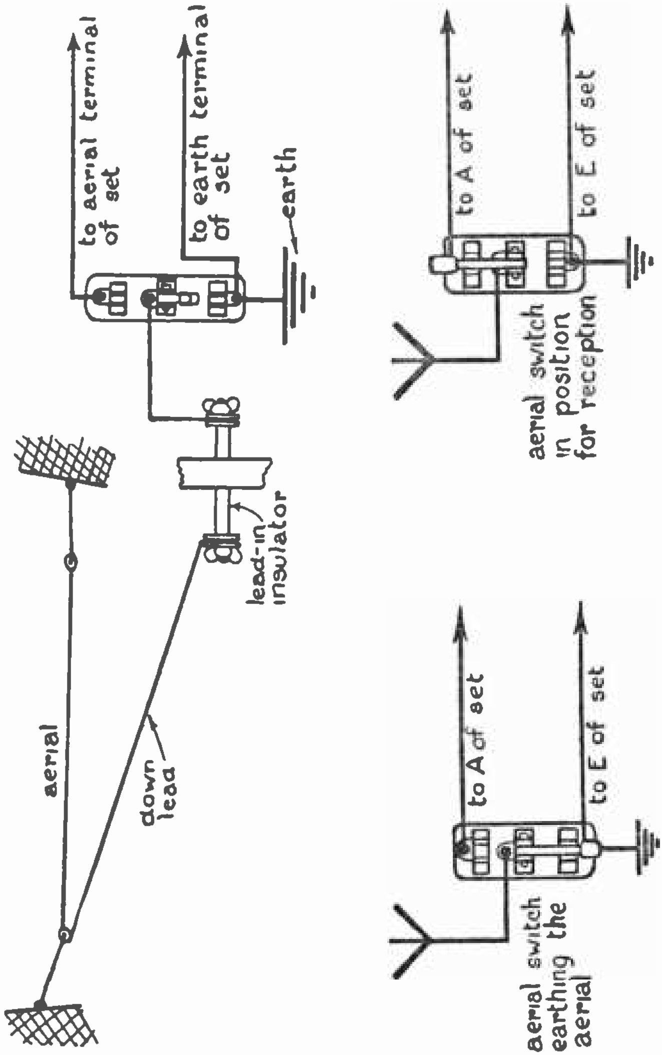
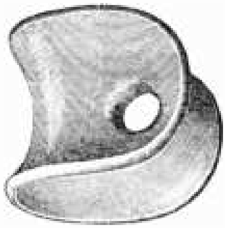


FIG. 59

To make an efficient earth, procure a large metal biscuit tin, and scrape off the paper. Sandpaper the tin, solder to it a stout insulated wire made of copper, and bury the tin about three feet in the ground, again as close as possible to the window or door through which the lead-in passes. *The shorter your earth wire the better.* The earth wire can come into the room through a hole in the woodwork. Connect it direct to the switch. A good earth can also be obtained by soldering or clamping the earth wire to a convenient water tap. Gas pipes should not be used for this purpose.

Your aerial and the lead-in wire should not exceed 100 feet in length. This is a Post Office regulation.



AN AERIAL INSULATOR
FIG. 60

As a rule, a single-wire aerial is sufficient for all ordinary reception, but if space is a consideration a twin or two-wire aerial can be used to a good advantage. The two wires should be at least 5 feet apart and fixed via insulators to light wooden spreaders. (Fig. 61.)

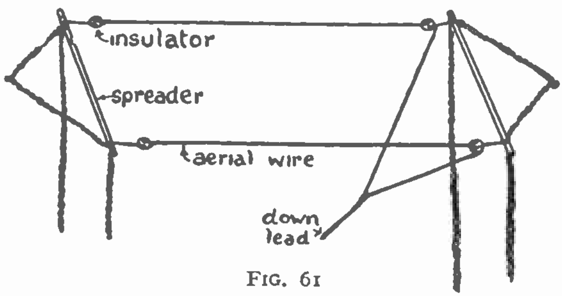


FIG. 61

There are people who think that it is more imposing to have a whacking big twin aerial over their garden, but it may involve spending a good deal more money than necessary.

The lightning arrester does not influence wireless reception, but it will provide the lightning surge with an easy path to earth.

An aerial erected outdoors is known as an outdoor aerial.

An aerial can also be erected indoors. Indoor aerials are used when people live in a flat or the landlord is crusty. Pirates, i.e. people who won't pay for their licence, also use indoor aerials for preference and for obvious reasons.

An indoor aerial can be stretched in a loft, along a corridor, or made to zigzag on the ceiling. Such an aerial is best insulated throughout its length (rubber covered wire is generally used) and suspended on small indoor insulators. The earth can be made in the usual way or a *counterpoise* can

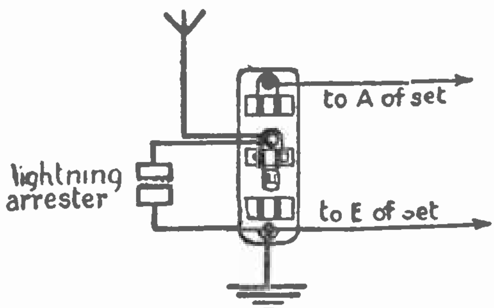


FIG. 63

be used. A counterpoise is simply a similar zigzag on the floor, each wire on the ceiling being exactly opposite its corresponding wire on the floor. The counterpoise replaces earth.

Indoor aerials and counterpoise aerials are, naturally, not as efficient as a good outdoor aerial, but sometimes one has no choice.

With powerful sets it is possible to use a small indoor aerial consisting of a coil of wire wound on a frame. These are known as frame aerials. (Fig. 66.)

Such aerials have directive properties, and have to be turned round till maximum signals are obtained from a given station. In portable sets the frame aerial is inside the case and no outside aerial and earth is required.

It is also possible to obtain satisfactory reception with an aerial buried in the ground and insulated from it. Such an aerial also has directive properties.

Outdoor aerials are of various types, but the most commonly used for reception purposes are the inverted L aerial and the T aerial.

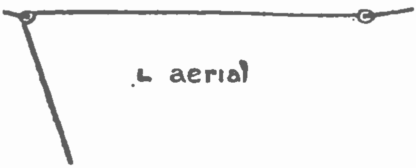


FIG. 64

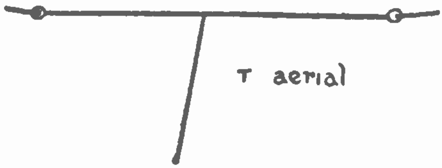
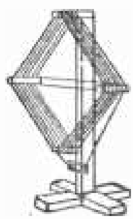


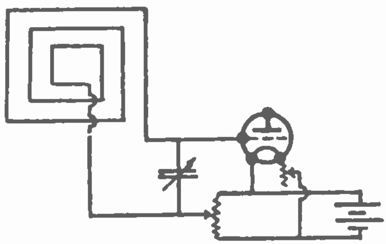
FIG. 65

In the case of a frame aerial, no earth connection is necessary, and the frame aerial is connected across the aerial and earth terminals of the receiver.



FRAME AERIAL

FIG. 66



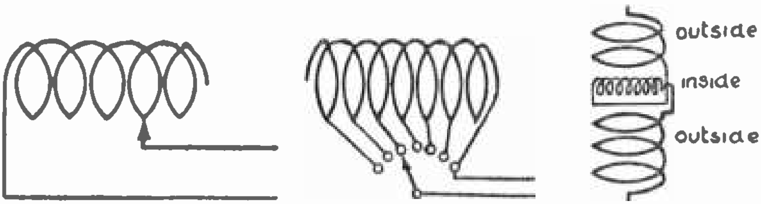
METHOD OF CONNECTING THE FRAME AERIAL TO THE SET

FIG. 67

slider. Thus the slider is always in contact with the bare wire of the turn it happens to rest against. With the help of the slider we can therefore include in our circuit as many turns as we want.

The tapped inductance offers a somewhat less exact adjustment, and is used for preliminary rough work. Every few turns of the coil are tapped, and each tapping is brought to a metal stud. A switch is used to obtain contact with each stud. Here one end of the circuit is connected to the end of the coil, and the other end of the circuit to the switch, so that again the inductance of the circuit can be varied.

A variometer or a vario-coupler is another form of variable inductance, consisting of two coils joined in series, i.e. end to end, and one coil is capable of rotating within the other.



SLIDER COIL TAPPED COIL VARIOMETER

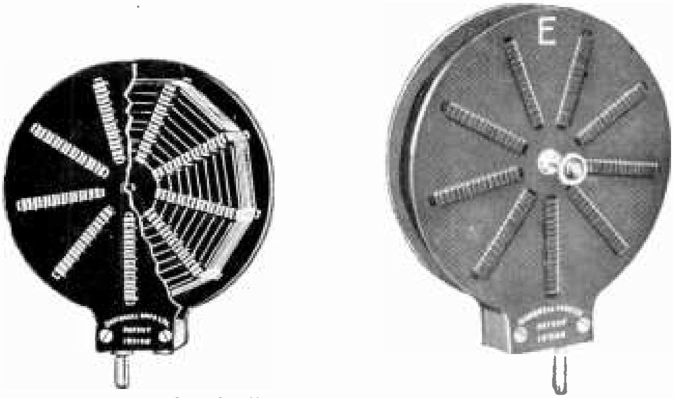
FIG. 71

When a current is flowing through the two coils, as the coils are being rotated their magnetic fields either help each other or oppose each other. Thus we have a variable magnetic field, and therefore in effect a variable inductance of the coils, since *inductance depends on the number of lines of force linked with one turn of wire.*

The plug-in type of coil has a fixed inductance, and such coils are usually made in sets of different values so as to provide a more or less wide range of inductances. There are various types of plug-in coils named after the manner of winding them: Honey-comb coils, basket coils, pancake coils, etc. The type used most is the honey-comb coil, as it is more efficient than most of the other types.

In the chapter dealing with tuning we shall discover the use of coils in wireless work and will go into the subject a little further.

COILS



Gambrell Coils (Plug-in-Type)

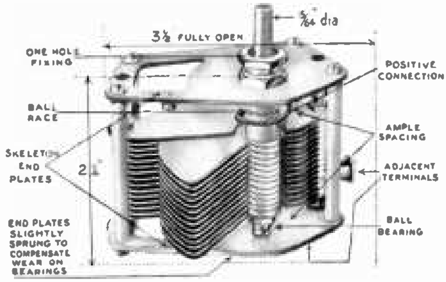
Dubilier
Toroid Coil

"Polar" Aerial-
Reaction Unit

Met-Vick
A.N.P. Coil
(Astatic Non-Parasitic)

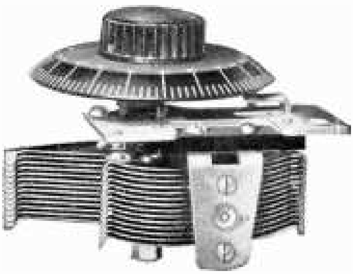
for High
Frequency
Amplification

VARIABLE CONDENSERS



"Polar" No. 3 Model

Gambrell "Neutrovernia" Stabilising Condenser



Marconiphone Variable Condenser

Marconiphone Ganged Condensers

CHAPTER IX

CONDENSERS

Two parallel metal plates, separated from each other by a dielectric, constitute a condenser. If by some means or other we charge the plates of the condenser, i.e. establish a deficit of electrons on one plate and a surplus of electrons on another, there will be a difference of potential between the two plates, and when the plates are joined together an instantaneous current will flow between them until the difference of potential disappears, and the surplus and deficit of electrons is wiped out.

Thus we can charge a condenser by connecting it across some appliance having a difference of potential, such as a cell, and then discharge this condenser by putting it across a closed circuit.

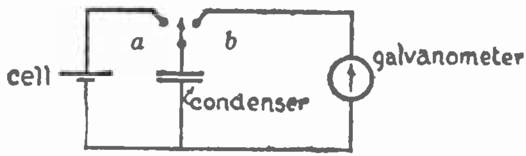


FIG. 72

The diagram above shows a rough means of doing this. If the switch is moved to the stud *a* the condenser will be placed across the cell and will charge up. If then the switch is moved to the stud *b*, the condenser will discharge itself and the galvanometer in the circuit will show that a momentary current is flowing. You notice that having charged a condenser we can keep the charge on it for some time, i.e. store electricity till we require it again. This property of a condenser is very useful in wireless work. Imagine a

Thus if we want to add capacities we join them in parallel, and if we want to diminish the resultant capacity we join them in series. If the natural wavelength of an aerial is too high, we drop it by diminishing the capacity of the aerial. This is done by putting between the aerial and the aerial terminal of the set a condenser of a certain value, in other words, by joining the capacity of the aerial with another capacity in series. Condensers, when joined together, behave in quite a different way from resistances and cells. If we want to obtain the sum of a number of resistances or of a number of cells we join them, as you will see later, *in series*, while if we join condensers in series we shall diminish the capacity instead of increasing it.

Condensers can be divided into two classes: *fixed condensers* and *variable condensers*. Fixed condensers, as their name implies, have a fixed capacity. They consist of a number of plates separated by mica, paper or other dielectric, the plates being divided into two sets, and each set joined to its appropriate outside terminal. The whole is sealed in an insulating case, usually of moulded ebonite.

Variable condensers are capable of varying their capacity between certain definite limits. A condenser of this type consists of two sets of plates or vanes, one set being fixed and the other set capable of rotation about a central spindle. The spindle is on ball bearings, in the better type of condensers, and a knob is fixed to the spindle for ease of manipulation. A graduated dial is also provided for noting the position of the vanes. The dielectric is usually air.

Some of the condensers have additional small vanes at the end of the spindle in order to provide a fine adjustment, i.e. small variations of capacities; this is called a vernier adjustment and the condenser is called a vernier condenser. There are also variable condensers with slow motion adjustment enabling the operator to move the vanes in respect to each other slowly and thus obtain a very uniform and gradual variation. The idea of using moving vanes for varying the capacity of a condenser has been applied owing to the fact that the capacity of a condenser depends on the size of two parallel plates placed opposite each other. Thus the amount of overlap determines the active area of the plates and therefore the active capacity in circuit.

Variable condensers are manufactured with a number of different characteristics depending on the shape of the vanes, and bear such names as: square law condensers, straight line frequency condensers, etc. The type of the condenser for any particular circuit is named by the designer in the specification. The discussion of the use of these various types is outside the scope of this book.

When buying fixed condensers it is always safer to buy well-known makes, although they may be a little more expensive. A good deal depends on how the condenser is constructed and how it is tested. The dielectric in fixed condensers must have a very high resistance so that leakage through the condenser is at a minimum.

easy. We will denote the aerial, the earth, a coil and a variable condenser by the following conventional signs:

FIG. 76

Now, there are many ways of making up an aerial tuning circuit.

In speaking of aerial coupling, we are referring to the way the aerial circuit is connected to the remainder of the set.

Aerials are distinguished from the point of view of coupling as (i) directly coupled aerials, (ii) loosely coupled aerials.

Directly Coupled Aerials.

To begin with, it is not necessary always to have in our tuning circuit both a coil *and* a condenser.

A coil, the inductance of which may be varied, will suffice. Remember there are three forms which such an arrangement may take: the slider coil, the tapped coil and the variometer.

The methods of using these are as follows:

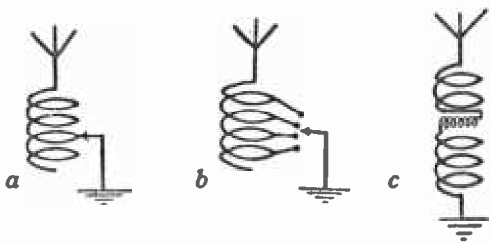


FIG. 77

In Fig. 77, *a* represents a tuning arrangement that makes use of a slider coil. The aerial wire is connected to one terminal of the slider coil and the earth wire is connected to the bar terminal of the slider coil. The slider itself is shown as an arrow at the end of the wire. You will see at a glance that as you move the slider you include more and more turns of the coil in your circuit and thus more and more inductance. As you increase the inductance you increase the wavelength till you come to the right one.

b represents an aerial circuit with a tapped coil. The aerial wire is joined to one end of the coil, while the earth is joined to the switch that goes over the studs of the coil tappings. As you turn the switch you include more and more turns in your circuit, and thus increase the inductance. *c* shows a variometer permanently connected between the aerial and earth.

We already know something about the action of a variometer. As we turn the inner coil of the variometer by means of an outside knob we vary the inductance of the system and thus vary the wavelength in our aerial circuit.

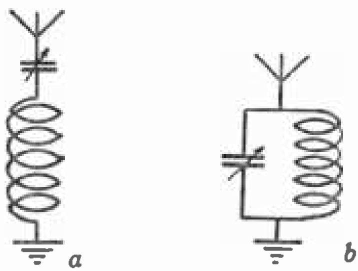


FIG. 78

The most usual way of building a tuning circuit is to use a coil and a condenser together. The coil with its inductance provides, so to say, the foundation of the wavelength, and the condenser serves for final delicate adjustment.

In *a* in the above Fig. 78, the aerial wire, the condenser, the coil and the earth are all in series, i.e. are joined end to end.

In *b*, the condenser is connected across the coil (in parallel with it) and the aerial and earth across their joints.

In the first case we say that we are using a series condenser, in the second case—a condenser in parallel.

CHAPTER XI

CRYSTALS

In the early days of Broadcasting, "Crystal" receivers were very popular with the general public on account of their comparative cheapness and ease of construction.

As a matter of fact a crystal receiver is the most simple form of wireless receiving apparatus, and, although having a limited range, is hard to beat from the point of view of purity of reproduction.

A crystal detector consists of the familiar piece of crystal and a wire contact, commonly known as a "cat's whisker." The "cat's whisker" is sometimes omitted, and two crystals are used with very good results. The main defect of a piece of wire as a contact is its instability. Everyone who has used a cat's whisker for listening knows how often it is necessary to readjust this tiny wire, which will lose its contact at the slightest provocation, even when somebody walks across the room.

The two-crystal combination is much more stable, provided that the crystal holder is of good design.

It was discovered some years ago that, if certain natural minerals are placed in a circuit carrying an electric current, the current will pass in one direction only. If a voltage is applied in such a way as to make the current flow in the reverse direction, the mineral or the "crystal" will offer such a resistance that the resultant current will be negligible.

The property of allowing an electrical current to flow in one direction only is known as *rectification*, and the crystal therefore is referred to as a "rectifier" or detector (of "wireless" signals).

There exists a great diversity of opinion as to the nature of the rectifying property of crystals, but this lack of definite knowledge does not preclude us from using crystals for the purpose of "wireless" reception.

Some of the crystals are, so to say, born rectifiers, and will rectify on their own without any additional batteries, but others will do their work best if they have a small polarising battery *in series*.

For the keen experimenter, crystals offer an enormous field for original research, because their real properties are very little known as yet, and there is a good deal that requires clearing up.

Natural and Commercial Crystals.

A Japanese scientist, Mr. Wichi Toricata, in his paper, "Commercial Wireless Telegraphy in Japan," published in the *Electrician* on the 16th of September, 1910, gives the following table of detectors:

1. *Ores quite sensitive with perfect contact.*

Oxides	*Sulphides*
Zincite	(b) Simple Sulphides
Tenorite or Melaconite	Molybdenite
Cassiterite	Galena
Anatase	Zinc blende
Arkansite	Chalkosite
Pyrolusite	Iron pyrites
Wad	Pyrrhotine
Complex Oxides	*Complex Sulphides*
Micacious	Magyagite
Ilmenite, iserine, hystatite	Tennantite
Magnetite	Enargite
Psilomelane	Boulangerite
	Schwatzite

(c) *Metallic combinations*
Lolingite
Meteorite
Smaltite

2. *Ores sensitive with light contact.*

(a) *Sulphides*	(b) *Metallic combinations*
Simple sulphides	Niccolite

Silicon. Silicon is highly sensitive in its pure state, but the commercial silicon contains a certain amount of metallic calcium, and as this metal is quickly attacked by air a film of calcium hydroid soon covers the silicon surface, and then practically all detector action ceases.

"*Perikon, Zincite and Chalcopyrite.*" The Perikon detector is a combination of zinc oxide (ZnO) and copper pyrites ($CuFeS_2$). It is twice as sensitive and more easily adjusted than the silicon detector. These two crystals, used as a detector, require a polarising battery, but considerable rectifications may be obtained without it. This combination is desirable for use where adjustments may be frequent, due to vibrations or similar disturbances which may be present as in the case of portable receiving equipment.

*Cerusite** (American trade name). Cerusite is a better rectifier than carborundum. No polarising battery is required.

Zincite. Red oxide of zinc. Zincite and brass point contact form a reliable and sensitive detector.

Tellurium-Aluminium. Tellurium-Silicon. These are sensitive detectors with or without polarising batteries.

The Good Points of a Detector.

It is rather a difficult matter to judge the comparative sensitiveness of two detectors because many factors have to be taken into consideration, and the tests carried out under exactly the same conditions, but the following are the general properties which a good crystal detector must possess:

(a) It should be mechanically strong and well constructed. This means that it should be able to hold its adjustment and not be easily disturbed.

(b) The crystals should be sensitive, that is, should possess good rectifying properties, if their setting is properly adjusted. Too great a sensitivity is not desirable, as satisfactory adjustment is usually obtained with difficulty. Also it may be difficult to retain the sensitive adjustment.

(c) The crystal should be easily adjusted. It is a distinct disadvantage if any marked difficulty is found in adjusting the setting for good reception, as valuable time may be lost in this way if a signal is coming in and the detector is not operating properly.

* This is also the mineralogical name for native lead carbonate, the pure white crystals of which are practically insulators.

(d) The crystal should possess self-protecting characteristics, to prevent itself from being burnt out and the setting destroyed if abnormally powerful radiations are received, such as atmospheric disturbances.

Ordinarily all points on a crystal are not equally sensitive, and it is necessary to adjust for maximum sensitivity. The adjustment of the detector can be made either while receiving signals or before actual reception, by exciting the receiving set by means of weak local oscillations from a buzzer.

Crystal Circuits.

Crystal circuits are very simple, and the following few examples will enable you to understand how a crystal set is put together.

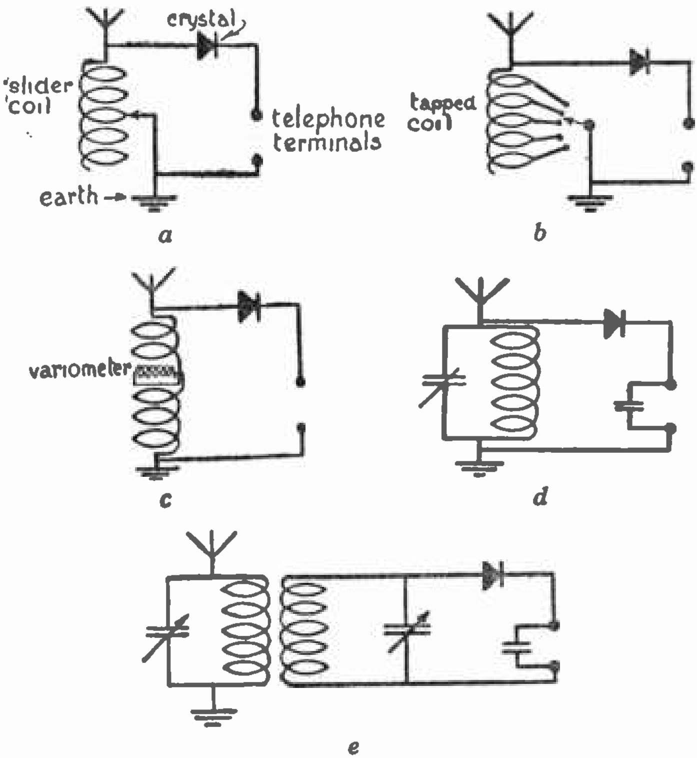


FIG. 80

A crystal circuit means simply a crystal holder and a pair of telephone terminals across a tuner.

In the above circuit you will notice that the only difference between these circuits is the method of tuning.

a uses a slider coil, *b* a tapped coil, *c* a variometer, *d* a coil in parallel with a condenser, *e* is a loosely coupled aerial rather interesting from the experimental point of view.

The values of the variable condensers and the right coils can be easily chosen with the help of a manufacturer's table.

The types *a* and *b* are not recommended unless they are used from a purely experimental point of view. The slider coil and the tapped inductances have a so-called "dead end" effect. This means that part of the coil is not being used for reception, and energy is being wasted at that "dead end."

The variometer type is pretty efficient, but it is preferable to start with a coil-condenser tuner, as it makes it so easy to convert this crystal set into a valve set later on. Please note that the telephones should always be connected between the crystal and the earth.

Try out all sorts of crystals for reception, and see if you can find some new combination or some new material that will give better results than the known crystals.

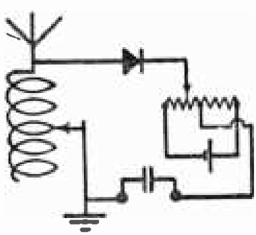


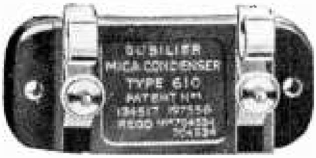
FIG. 81

As regards the crystals that require a polarising battery, W. Greenwood, B.Sc. (Eng.), A.M.I.E.E., A.C.G.I., in his text-book *Wireless Telegraphy and Telephony*—University Tutorial Press (5s. 6d.), gives the following diagram of connections. (Fig. 81.)

You will notice that the potentiometer (a variable resistance) is wired in such a way as to offer either a positive or a negative potential.

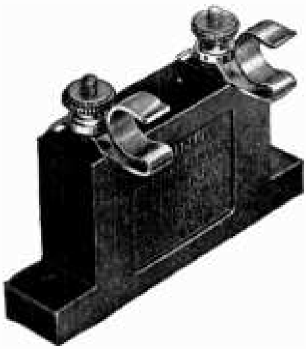
Why not start experimenting with crystals straight away?

FIXED CONDENSERS



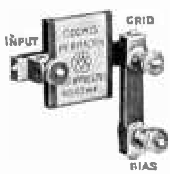
Dubilier, Type 610

Marconiphone Condensers



Dubilier, Type 620

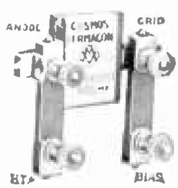
Ferranti Condenser



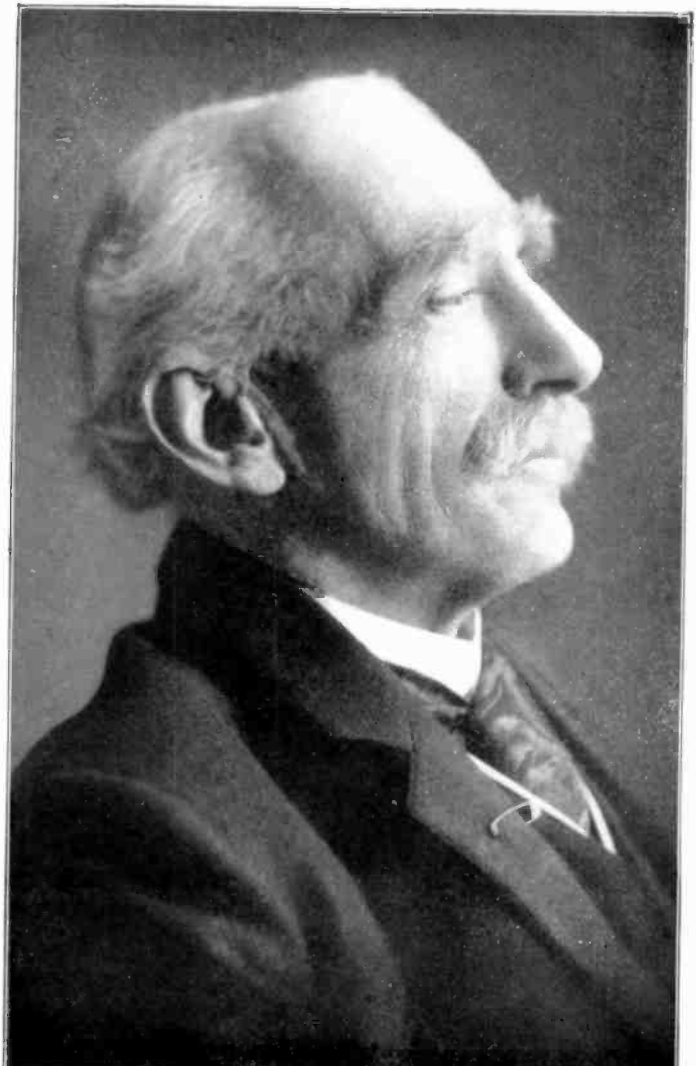
Met-Vick Grid Condenser and Grid Leak

Ferranti Condenser

Lissen Condenser



Met-Vick R.C. Coupling Unit



[*Photograph by Maull & Fox Ltd.*

SIR AMBROSE FLEMING, KT., M.A., D.Sc., F.R.S., M.I.E.E., ETC.
THE INVENTOR OF THE VALVE

CHAPTER XII

THE VALVE *

THE "wireless" valve can serve in two ways: either as a rectifier (i.e. take the place of a crystal) or as an amplifier or device for increasing signal strength.

Externally the valve looks like an electric lamp, although somewhat different in shape, and has four "legs" coming out of the base.

Placed on supports inside the glass bulb, which is completely exhausted, (i.e. there has been produced a vacuum), are three "electrodes" or metal pieces called as follows:

(1) the plate or anode,
(2) the grid,
(3) the filament.

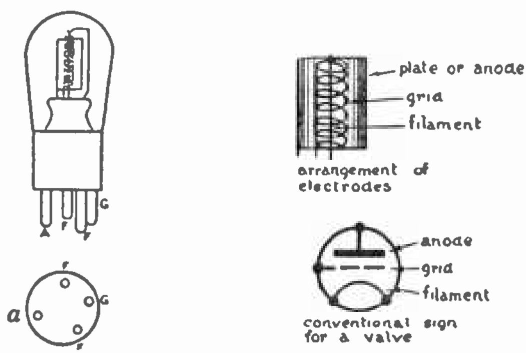


FIG. 82

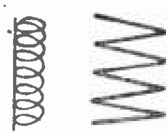
The shape of the electrodes varies with various makers, but the most simple arrangement is to have the plate in the shape of a tube or cylinder with open ends. Inside the plate or anode is a spiral wire which is called the grid, and right

* For further information see "Ralph Stranger's Wireless library' book X—*Modern Valves.*

in the centre of the grid, between two supports, is stretched a thin wire called the filament.

The three electrodes are not in contact with each other and there is a certain definite distance between them.

DIFFERENT SHAPES OF ANODES



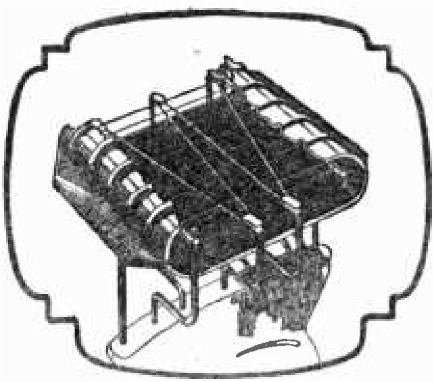
DIFFERENT SHAPES OF GRIDS

DIFFERENT SHAPES OF FILAMENT

FIG. 83

Each electrode has supports which are embedded in a glass projection inside the bulb, and each of them is connected to its respective "leg."

Of the four "legs," one belongs to the anode, one belongs to the grid and two belong to the two ends of the filament. Please note that the "legs" are not symmetrically placed—



A MULLARD VALVE ELECTRODES

FIG. 83A

an important point when inserting a valve into a valve-holder. (Fig. 82.)

When valve "legs" are inserted into a valve-holder which is connected to the rest of the circuit, the valve is also connected provided that the "legs" of the valve are making good contact with the sockets of the valve-holder.

When buying a valve ask the "wireless" dealer to test it out in front of you, so as to make sure that it works properly. See that the base of the valve is securely fixed to the glass.

In order to understand the working of a valve we shall have to call to our aid our old friends the electrons.

When a wire is brought to a certain temperature its molecules will vibrate with such terrific speed that electrons will be thrown off the atoms and hurled from the filament into space. This is known as *electron emission*.

All the early valves used, for the emission of electrons, a white hot filament which gave a good deal of light. For this reason they were called "*bright emitters*." The design of valves has progressed since then, and bright emitters are very little used nowadays. There is no light to be seen on the filaments of modern valves. They do not rely on high temperature for electron emission, but have a thoriated filament instead, i.e. a filament coated with thorium which gives an electron emission at a comparatively low temperature. This means that less current is required to heat the filament and therefore great economies are effected in the discharge of the heating accumulator commonly called L.T. accumulator. Such valves having thoriated filaments and working at a comparatively low temperature are called *dull emitter* valves.

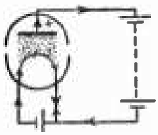
A HOT FILAMENT THROWING OFF ELECTRONS INTO SPACE FIG. 84

Thus, under certain conditions, electrons are thrown off the filament into space.

You will remember that electrons are particles of negative electricity and are attracted by the protons or particles of positive electricity.

Therefore, if we place a plate close to the filament and make this plate poor in electrons, i.e. have a preponderance of protons, this plate will attract all the electrons that come near it. In this manner we can obtain a flow of electrons from the filament to the plate. The plate is made poor in electrons by connecting it to the positive terminal of a large battery (H.T. battery).

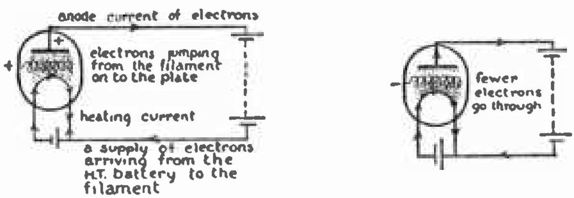
The plate or anode (let us always call it anode) will thus exert a pull on the filament electrons and they will rush into space much more readily in order to reach a place where they are wanted. However, there is one thing to be observed: the electrons are so keen on leaving the uncomfortable filament that they try to rush in a big "cloud" into the space between the filament and the anode. You know what it is when a crowd tries to get anywhere; people get into each other's way and impede one another. The electrons, whose nature it is to repel each other, are worse than any crowd, and very few of them would ever reach the anode unless they were helped on their way. This cloud of electrons is known as *space charge.*



ELECTRONS FLOWING FROM FILAMENT TO ANODE FIG. 85

In order to help the electrons on their way to the anode, a grid is introduced between the anode and the filament. Now, if we charge the grid positively it will also be poor in electrons and will assist the anode to attract the filament electrons. Thus, with a positively charged grid more electrons will pass from the filament to the anode than in the case where there is no grid.

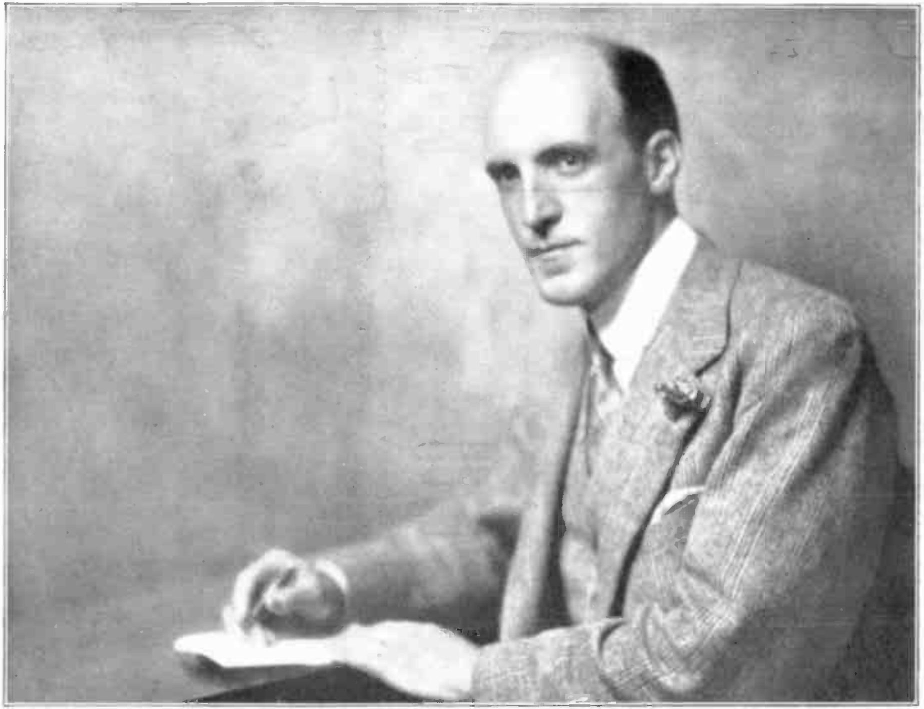
If the grid is charged negatively, the electrons in surplus on the grid will repel the filament electrons and obstruct their flow to the anode. Since the grid is a spiral and not solid like the anode, its opposing area is much smaller than the attracting area of the anode, and a number of electrons will go through in spite of the negatively charged grid.



A POSITIVE GRID A NEGATIVE GRID

FIG. 86

The stronger the charge on the grid the more that charge will influence the flow of the filament electrons, i.e. either increasing or decreasing the flow of current through the



[By courtesy of Arks Publicity Ltd.

S. R. MULLARD, M.B.E., A.M.I.E.E.
THE MAKER OF THE VALVE

Five Electrode Valve

Screened Grid Valve

MULLARD VALVES

General Purpose Valve

Screened Grid Valve

MARCONI VALVES

valve in accordance with the nature of the grid charge. Thus it is possible to make the grid act as a traffic policeman and make it regulate the flow of electrons. This is very convenient because it gives us the means of controlling the electric current flowing through the valve from the filament to the anode and in the anode circuit.

You have no doubt already noticed that the electrons can flow in one direction only, i.e. from the filament to the anode, and not from the anode to the filament. Thus the valve will act in a similar way to the crystal and will serve as a rectifier. We shall deal a little later with the phenomenon of rectification, but for the time being we will agree that this property is within the province of the valve.

The "traffic policeman" on the grid does not need to be a very hefty fellow, he can be quite a midget. This means that a very small force is required on the grid to control a large flow of electrons. We already know that our aerial receives precious little energy, and that the aerial currents are quite small. For this reason, the differences of potential impressed across our tuning circuit are also very small. When these differences of potential are impressed across the grid and the filament of our valve (as you will see later to be the case) we shall find that the grid will receive a series of positive and negative charges.

The potentials applied to our receiving aerial are varying in accordance with the variations of the electro-magnetic wave (which causes these potentials) emitted by the transmitting aerial. But the variations in the currents in the latter are in accordance with the variations of the intensity of sound in front of the microphone. Therefore our variations in the charges on the grid are of the same character. You see the beauty of it?

The sound waves in the studio are converted through the microphone into electrical impulses; these electrical impulses are magnified and are impressed upon the transmitting aerial and therefore upon the carrier wave. The carrier wave, being thus modulated, causes identical impulses to be impressed on the receiving aerial, provided that the latter is properly tuned. The receiving aerial impulses are impressed on the grid of the first valve, and are made to control a much larger flow of electrons from the filament to the anode.

Being policed by the aerial potentials the filament electrons will pass through in varying numbers, the variations still being of the same character as the microphonic variations, and thus we get a magnified, i.e. an amplified effect.

The valve in this case acts as an *amplifier.*

There are three important things to be observed in working a valve.

The filament voltage, i.e. the filament current must be right, in order to obtain the correct temperature of the filament.

The anode voltage must be right, so that the attractive force of the anode is of the correct value.

The initial grid potential must be right, as on it depends the strength of the anode current.

Let us take these three items in turn.

If the filament voltage is too high the filament may melt, and thus the valve be completely spoilt. If on the other hand the filament voltage is too low the filament current will be low, and the temperature of the filament, which is due to the heating effect of the current, will also be low, thus reducing the electron emission.

The anode voltage, if too high, will introduce distortion. With a given valve, the anode voltage cannot be increased indefinitely. There is a certain definite number of electrons that can leave the filament at any given instant. A time will be reached when all the available electrons will take part in the flow from the filament to the anode, and once this happens it does not matter how you increase your anode voltage you will not increase the electronic emission. The valve has reached its *saturation point*, and a saturation current is flowing through it. If, on the other hand, your anode voltage is too low, the strength of signals will be reduced or signals will disappear altogether because the electron emission in this case is not sufficient for the proper working of the valve.

It is usual to give the grid of a valve an initial steady potential as a foundation for the small aerial potentials to work on. If an initial potential is applied to the grid the potentials due to the aerial will be alternately strengthening and weakening it. In such a case the valve is said to be biassed (in favour of some kind of potential) and the valve is said to have a positive or a negative *grid bias*, as the case may be.

It is quite usual to have a negative grid bias on one of the L.F. valves or on a number of them, of anything from 3 to 30 volts.

It seems absurd at first glance to bias a grid negatively, as apparently a negative potential on the grid will stop all the electrons from coming through. This, however, is not the case. The valve that requires a large negative grid bias will still have a considerable flow of electrons from the filament to the anode. For our purpose it is not the maximum electronic emission that matters but the *right* electronic emission.

Every valve gives the best possible performance under certain conditions. Best working conditions mean stability, and stability of a piece of apparatus is important in our work. In order to obtain the best possible conditions, we adjust our filament voltage, and our anode voltage, and also the initial potential of the grid in such a way as to obtain the best possible emission. If we do this we are sure of having the best of signals. Certain combinations of filament voltage and anode voltage happen to require a large initial negative potential on the grid (grid bias) in order to obtain steady conditions of reception.

There are no two valves, even of the same make, that will behave in the same manner, and for this reason we should treat each valve individually in the same way as a doctor has a special treatment for each patient.

Therefore it is much better to investigate, in the case of each valve, the best possible H.T. and L.T. voltages and the right grid bias. Each filament should have a separate filament regulator in series with it.

You will find that the makers will specify all these points on the carton in which the valve is sold.

Treat your Valves properly.

Various valves have various oppositions to the flow of electrons from the filament to the anode. That such an opposition should exist is apparent, as the electrons have to traverse an "empty" space. This opposition is called *impedance* of the valve.

The impedance of the valve is rather important, as on it depends the value of our transformers and anode resistances used in resistance capacity coupling.

There are many valves on the market built somewhat differently for various duties, but these different kinds of valves are of no interest to us at this stage of our wireless education, because all we want to do now is to grasp the essential principles.

In conclusion, here is a piece of good advice. When you are inserting valves into valveholders of your set, disconnect the H.T. battery before you do so. It often happens that you may touch the filament "legs" against two wrong sockets, which will connect the filament to the H.T. battery. If the battery is connected to the set, you may thus apply as many as 180 volts across the filament of your valve and . . . good-bye the price of a good valve.

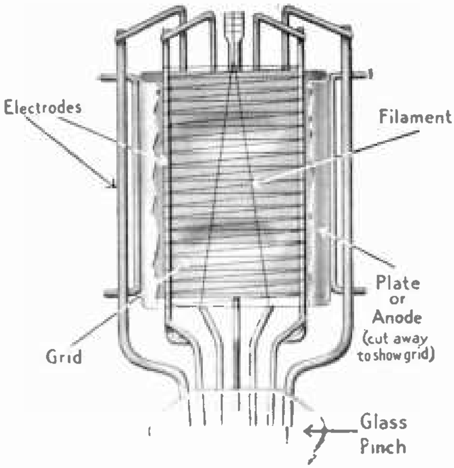
You may be wondering why a glass bulb with three electrodes inside—anode, grid and filament—should be referred to as valve.

In mechanical engineering we call a piece of apparatus a valve because it will let a fluid go in one direction only. The "wireless" valve has a uni-directional flow of electrons from the filament to the anode, hence the name.

The "wireless" valve is also called a "thermionic valve."

NOTE.—Vacuum valves as described above are called "hard" valves in order to distinguish them from the old-fashioned gas filled or "soft" valves.

VALVES



Marconiphone Valve Electrodes

Marconiphone
Valve Holders

RESISTANCES

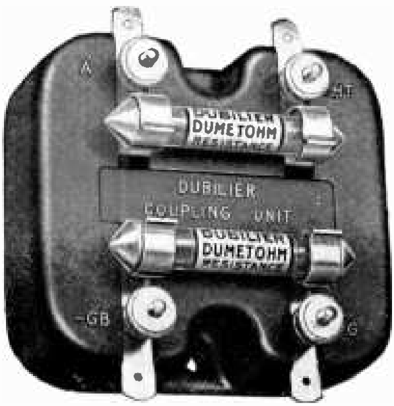
Marconiphone
Rheostat

"Polar"
Fixed Potentiometer

Dubilier Grid Leak

Dubilier Anode
Resistance

Dubilier Filament
Resistance



Dubilier Resistance Capacity
Coupling Unit

Ferranti Resistance for
Eliminators

CHAPTER XIII

RESISTANCES

We already know that every material has a specific resistance of its own and therefore every conductor has a certain amount of resistance. We also know that the resistance of a conductor depends on the length of that conductor and its cross-sectional area. As the temperature of a metallic conductor increases, its resistance will increase.

In a "wireless" receiver space is naturally valuable, and therefore we cannot use very long conductors when we require a large amount of resistance. For this reason filament regulators and other high resistance appliances have a long wire wound around a fibre former in order to concentrate as much wire as possible into a small space. A sliding contact is provided, just as we had a sliding contact in the slider coil, and thus the necessary length of wire can be tapped and included in the circuit. For very high resistances thin wire is used, but there is a limit to the thinness of the wire, as it must be robust and should not get unduly overheated by carrying too much current. In order to get rid of the heat that is generated in the resistance by the passage of the current (heating effect) the resistance wire is spread over as large an area as possible and thus has a large radiation surface which disposes of the heat quickly.

There are three kinds of resistances on the market:

(i) Filament rheostats, or filament regulators, made in various ranges from 3 to 15 ohms.

They serve for regulating the current on the valve filament, and are variable resistances.

(ii) Potentiometers, which are built the same way as the filament regulator, except that they have three terminals instead of two. Potentiometers are placed across the

F

Four resistances are joined in parallel. The value of the first resistance is 5 ohms, the value of the second resistance is 4 ohms, the value of the third is 10 ohms, and the value of the fourth is 2 ohms. What is the total resistance? As we already know the rule:

$$\frac{1}{R} = \frac{1}{5} + \frac{1}{4} + \frac{1}{10} + \frac{1}{2} = \frac{21}{20}$$

Therefore $R = \frac{20}{21}$ ohms.

One cannot naturally go on buying resistances every time a new value is required, but if we know the above rules we shall be able to juggle with the resistances we have in hand in such a way as to obtain new value just by series or parallel combination.

Voltage Drop.

If you remember, one of the formulæ of Ohm's Law is expressed as follows: $E = I \times R$. This means that if you have a resistance of value R and a current I is flowing in it, the difference of potential across the ends of this resistance is equal to $R \times I$. Take an example: A resistance of 5 ohms is carrying two amperes of current, the difference of potential across such a resistance is $5 \times 2 = 10$ volts. This the engineers call a "voltage drop of 10 volts across the resistance."

This is rather useful. With an ordinary accumulator we can get voltages in steps of two volts. Now, if we put across an accumulator a suitable resistance we shall drop the whole of the accumulator voltage across that resistance. (The resistance must be fairly high so as not to take too much current from the accumulator.)

Now, if we provide a sliding contact to go across the resistance and measure the voltage between one end and our tapping made by the sliding contact, we shall find that we can tap off gradually any voltage we like within the limits. Thus a potentiometer provides us with the means of obtaining a gradual variation of potential difference from O to a given maximum.

The potentiometer can also be wired in such a way as to enable us to obtain a varying positive and negative potential as we move our slider. Such an arrangement is used for the purpose of providing the grid of a valve with an initial potential (grid bias) either positive or negative, to which the aerial potentials will either add or subtract. (Fig. 90.)

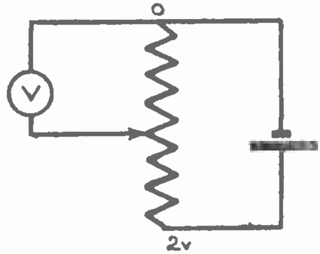


FIG. 88

High value resistances are used for the purpose of providing the electrons with a very high resistance path through which they are required to leak away gradually in the case of the grid leak, and for amplifying purposes in case of anode resistances. The use of anode resistances is explained in Chapter XIX.

Methods of connecting filament regulators, potentiometers and grid leaks.

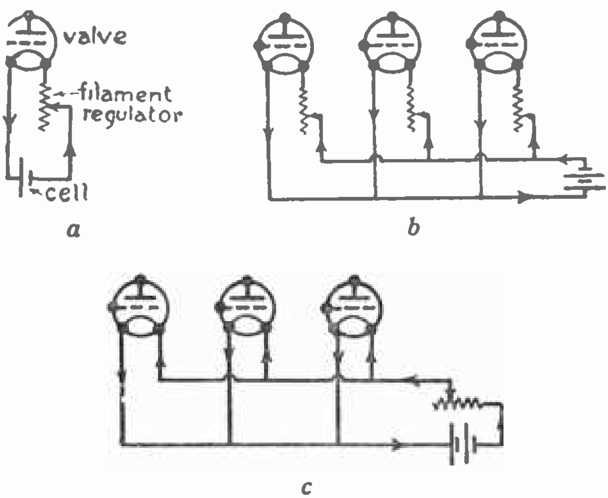


FIG. 89

In Fig. 89 the diagram *a* shows how a filament regulator is connected in series with the valve filament and the accumulator.

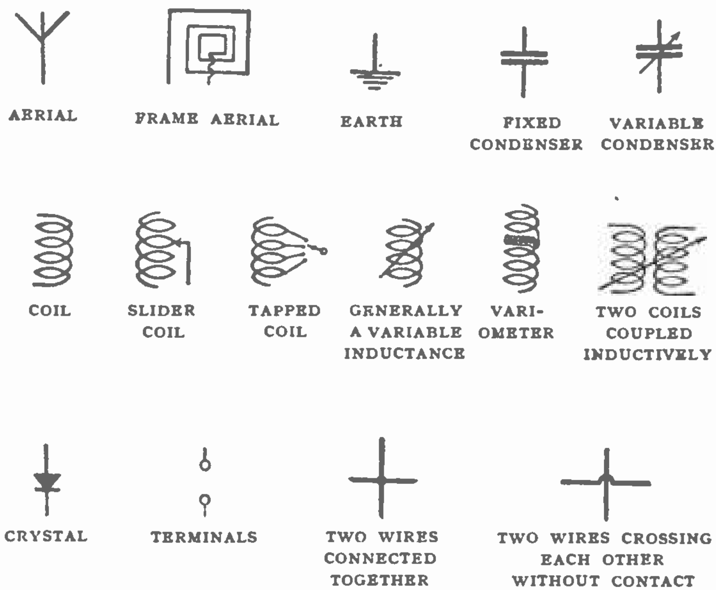
CHAPTER XIV

HOW TO READ DIAGRAMS *

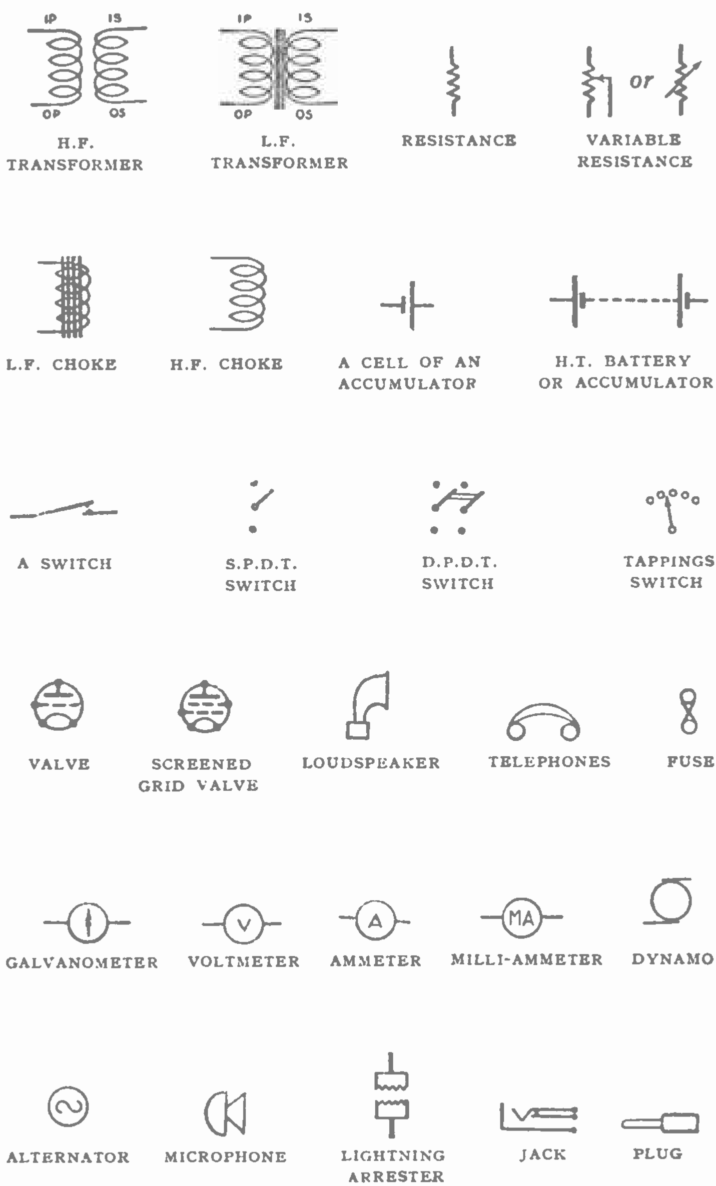
You have noticed, no doubt, how often we have to use diagrams in order to illustrate various points.

Diagrams are easy to read once you know the conventional signs that are used to represent the various pieces of "wireless" apparatus. Here is a list of general conventional signs. Please study it and try to memorise the different items, using a pencil and a piece of paper.

List of Conventional Signs Used in "Wireless" Diagrams.



* For further information see "Ralph Stranger's Wireless library" book XI—*How to Understand Wireless Diagrams.*


IP
IS
OP
OS
H.F. TRANSFORMER
IP
IS
OP
OS
L.F. TRANSFORMER
RESISTANCE
or
VARIABLE RESISTANCE
L.F. CHOKE
H.F. CHOKE
A CELL OF AN ACCUMULATOR
H.T. BATTERY OR ACCUMULATOR
A SWITCH
S.P.D.T. SWITCH
D.P.D.T. SWITCH
TAPPINGS SWITCH
VALVE
SCREENED GRID VALVE
LOUDSPEAKER
TELEPHONES
FUSE
V
A
MA
GALVANOMETER
VOLTMETER
AMMETER
MILLI-AMMETER
DYNAMO
ALTERNATOR
MICROPHONE
LIGHTNING ARRESTER
JACK
PLUG

valve is connected to the aerial terminal through a fixed condenser, and there is a grid leak across this condenser. You will also notice that the filament regulator is connected in the negative side of the accumulator; that the high tension battery is in series with the head-telephones and the anode of the valve, and its negative end is connected to the negative end of the accumulator.

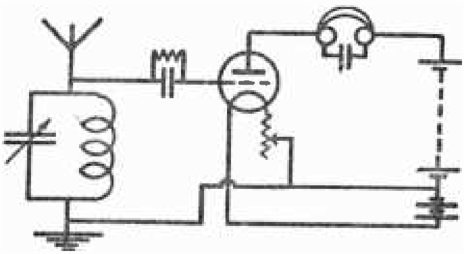


FIG. 95

If you glance at various similar circuits you will find that these methods of connection are common. There is a fixed condenser across the telephone terminals in order to provide a by-path to various unwanted small currents that might affect our reception. With such an arrangement they will pass through the condenser instead of the telephones.

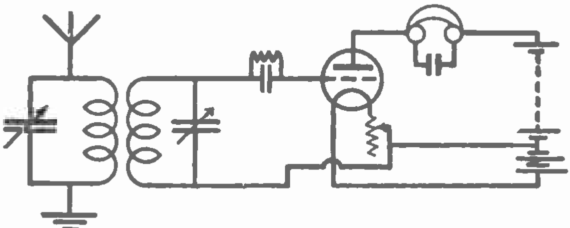


FIG. 96

The same circuit, but with a loosely coupled aerial, will look as shown in Fig. 96.

Here you notice that the grid of the valve is connected to the joint between the secondary coil and the variable condenser, and the valve is therefore again across our tuner.

The negative terminal of the H.T. battery is connected to the negative side of the accumulator as before.

Now let us take this last single valve circuit and add to it another valve and a transformer in order to obtain louder signals.

You will notice that in this circuit we removed the telephones and the H.T. battery and inserted a transformer and a valve, replacing the head-telephones and the battery in the anode circuit of the last valve.

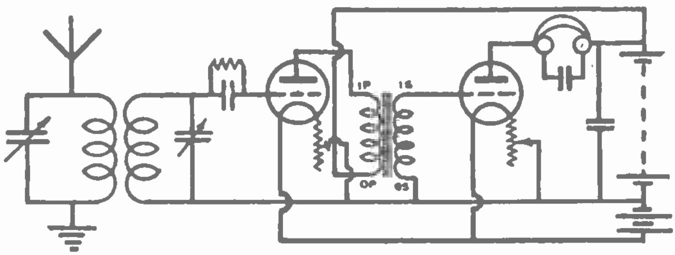


FIG. 97

The anode of the first valve is connected through the primary of the transformer to the H.T. battery, and so is the anode of the second valve, through the telephones. The valve filaments are connected in parallel across the accumulator. The grid of the second valve is connected through the secondary of the transformer to the negative side of the accumulator. This ought to give you an idea of how diagrams are built up, and if you practise reading further diagrams in the book you will soon be able to find your way amongst them.

CHAPTER XV

METHODS OF DETECTING "WIRELESS" SIGNALS

ELECTRICAL oscillations generated in our receiving aerial by the passing of electro-magnetic waves are high frequency oscillations. In the case of a 300-metre wavelength the frequency is 1,000,000 cycles per second. If electrical impulses of such frequency were impressed upon the telephones, the diaphragm would be unable to follow such rapid variations, i.e. it would be unable to vibrate at such terrific speeds on account of its own inertia.

Even if the diaphragm were capable of vibrating at high frequencies the notes emitted would be so high that no human being could hear them. The solution of the problem lies therefore in converting these high frequency oscillations into comparatively slow impulses that would cause the telephone diaphragm to vibrate within the audible range of human beings, which lies between 10,000 and 50 cycles per second.

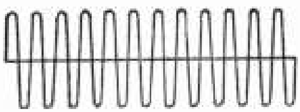
The transmitting station and the receiving stations cooperate in this respect.

The carrier wave, which is a high frequency wave sent out by the Broadcasting station, is "modulated" by the microphonic impulses, and thus the resultant wave leaving the station does not represent a continuous stream of impulses but a series of jerks. The "modulation" is caused by the performer who is speaking, singing or playing an instrument in front of the microphone. Thus, a *train of waves*, or groups of high frequency shivers in the ether, is sent out, and, in passing the receiving aerial, they impress upon it a series of oscillations following each other in groups, but the frequency is still too rapid to become audible.

The receiving set does the next step.

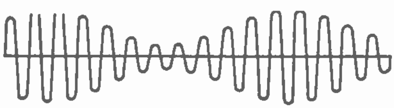
You will not lose sight of the fact that the train of waves, or groups of oscillations in the receiving aerial, is still of an alternating character. If we had some device or other that would pass currents in one direction only, wiping out as it were one half of the wave, the alternating currents would become uni-directional currents, and would flow in a series of jerks at equal "dead" periods (Fig. 98). The alternating currents would thus be rectified, and the device performing such rectification would be a rectifier.

We have at our disposal two kinds of rectifiers in "wireless" work: the crystal and the valve. Both of them are uni-directional conductors, i.e. they will pass current in one direction only.



A CONTINUOUS WAVE
BEFORE RECTIFICATION

A CONTINUOUS WAVE
AFTER RECTIFICATION



A MODULATED WAVE
BEFORE RECTIFICATION

A MODULATED WAVE
AFTER RECTIFICATION

FIG. 98

From the above diagrams we see that once a wave is rectified the pulses become uni-directional and can be reduced to a comparatively slow series of average pulses which arrive slowly enough to affect the telephone diaphragm.

Thus, if a train of waves acts on the aerial, and a rectifier is connected across the aerial tuning circuit, the train of waves will result in a series of uni-directional pulses equivalent to an average direct current of the same form as that flowing through the microphone, and this current passing through the windings of the telephones will give us an audible signal. Therefore, it simply boils down to the fact that we start at the transmitting end with microphonic currents, we strengthen these microphonic currents and disguise them for their journey as an electro-magnetic wave across the ether, and when we get hold of them in our receiver we take off the disguise and lead them to our telephone windings, thus getting the same signals as those emitted at the other end. The crystal and the valve consequently enable us to detect wireless signals; hence they are called detectors, and the particular valve in the receiver that does this work is called a *detector valve.*

Now let us consider how a crystal detects signals.

You will notice that in Fig. 99 a by-pass condenser is provided in the telephone circuit (across the telephone terminals). There is an E.M.F. produced by the electro-magnetic wave across the tuner. Each time the current flows, for example, from left to right, it will charge one plate of the by-pass condenser, say, positively, and the other plate of the condenser negatively. When the E.M.F. is reversed during the next half-cycle, only a very small current will flow through the crystal, and the resultant charges of opposite character on the condenser plates will wipe out only a small portion of the original charge. As the group of oscillations or the wave train arrives, the charge of a certain sign on the condenser will gradually accumulate until the condenser will discharge itself at the end of the train across the telephones, causing a current to flow through them and actuate the diaphragm.

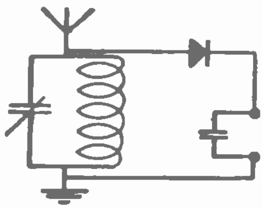


FIG. 99

During the next train the same thing will occur again, and thus a series of currents will pass through the windings of the telephones.

The by-pass condenser is not absolutely essential; the telephones themselves have a certain amount of capacity between the turns of their windings, so that they will act in the same way as if a condenser were connected across them, but a by-pass condenser is advisable.

The action of the valve is somewhat different.

Let us consider the diagram in Fig. 100.

You will notice at once that the grid is connected to the filament through a grid leak having a very high resistance of, say, 2,000,000 ohms. For this reason the grid, when unaffected by aerial potentials, will have the same potential as the filament. The grid, having a small initial potential, will let some of the electrons pass from the filament to the plate, and there will be a steady current flowing from the negative terminal of the H.T. battery to the filament and from the filament to the anode of the valve and back again to the positive terminal of the H.T. battery. Now come into play the alternating potentials due to the passing wave which will impress a train of these alternating potentials across the tuner, or, in other words, across the grid and the filament. The grid is isolated from the rest of the circuit by a condenser, and thus any charge caused on the grid owing to the difference of potential between the grid and the filament can escape one way only, viz. through the high resistance path of the grid leak. For this reason the grid will gradually accumulate a charge while the train lasts. As soon as the train of oscillations is over, the charge on the grid will gradually leak away through the grid leak.

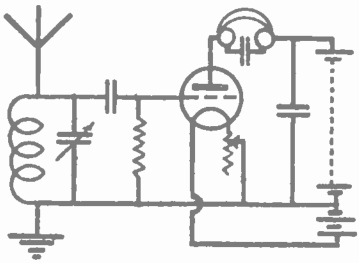


FIG. 100

This will result in a change in the anode current (flowing in one direction from the filament to the anode) which will pass through the telephones and cause the diaphragm to vibrate at an audible frequency.

The above method of rectification is called the grid method. There is another method called the anode bend method. A diagram of connections is given in Fig. 101 for experimental purposes.

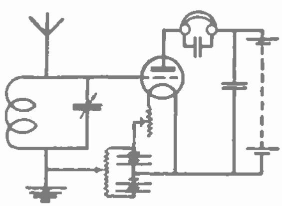


FIG. 101

The anode method is more sensitive than the crystal, but not as sensitive as the grid method, and is therefore less used, although it gives better quality. The grid of the valve is connected straight to the aerial terminal, and the primary batteries, dry cells, batteries, accumulators, secondary cells, secondary batteries, storage batteries, lead accumulators, but for simplicity it is best to regard and describe the wireless battery as an accumulator, if it has to be charged from time to time, and thereby avoid the risk of confusion attending the employment of the term "battery" indiscriminately to primary or dry cells in the one case or to secondary cells or accumulators in the other case.

If we examine an accumulator it will be found that for operating a 2 volt circuit the accumulator has only one compartment, whereas for a 60 volt circuit the accumulator has as many as 30 compartments; each of these compartments is termed a "*cell.*" Each cell when complete with its components and fully charged will deliver an electrical current at an electrical pressure of 2 volts. It is therefore simple to remember that *the number of cells is just half the required voltage of the circuit.* The components of the cell are very interesting, and it is most important to be able to recognise them all and to understand the difference between a healthy and unhealthy component.

Accumulator Parts.

All modern "wireless" accumulators are very similar in principle. A description of the Exide accumulator, which is so universally used, is representative of practically all other types. Inside the cell will be found metal slabs or plates, varying in thickness according to the nature of the service for which the cells are designed. The plates may be ½ in. thick or more if intended for giving out a small intermittent current over a very protracted period between two charges. On the other hand the plates may be very thin if intended for operation in portable sets where weight and space are important considerations. The plates are made of lead, an outer frame or grid of lead-antimony alloy being filled with oxides of lead termed "paste" or "active material." The paste is a gritty composition in which various ingredients have been mixed, making the whole a plastic mass which adheres tightly to the grid.* When the cell is in a fully charged condition the alternate plates will be chocolate coloured, the remaining plates being a light grey colour. The chocolate coloured

* Do not confuse this accumulator grid with the grid of a valve.

plates are termed "positives," and are joined to the positive terminal of the accumulator. The grey coloured plates are termed "negatives," and are joined to the negative terminal of the accumulator. Surrounding the plates is a liquid termed "electrolyte." This is diluted sulphuric acid. Each cell may be regarded as a tank or cistern in which electrical energy can be stored by passing an electric current through it from other storage cells or from an electric generator. *When a cell is receiving current, it is said to be charging; when giving out current, a cell is said to be discharging.* When a cell is standing idle, i.e. neither charging nor discharging, it is said to be on *open circuit.* The effect of passing a charging current through a cell, strictly speaking, is not actually to store electricity in the cell, but to cause chemical changes in the plates, which set up an electrical pressure or potential of different value in the plates, and which enable them subsequently to pass out current again through an external circuit.

The Action of an Accumulator.

The principle upon which the cell functions is that as soon as the terminals are joined together an electric current passes from the positive plates through the electrolyte to the negative plates and across the terminals. If, instead of joining the terminals together, wires are led from them to an outer circuit, such as a lamp, a valve, or other current consuming device, the current will travel round that circuit. The reason for the current travelling is that the sulphuric acid enters into combination with the active materials of the positive and negative plates, and this chemical energy is converted into electrical energy. The discharge from the cell is the consumption of the electrical energy created in the cell on closed circuit by chemical actions. As a very simple demonstration of the action, if one were to take a clean silver coin and a clean copper coin, and place these above and below the tongue nothing would be noticed, but immediately the two coins be allowed to touch a very sharp acid sensation can be noticed on the tongue. In the same way so long as the terminals of a cell are not connected the plates are to all intents lying inactive, but immediately the circuit is closed the plates commence to give out an electrical discharge, because there is a difference of electrical pressure or potential between the positive and negative groups. The electrical pressure of a cell is called its voltage or volts, and is the same irrespective of its size. The voltage of a cell is really the difference of the potential of the positive and negative groups it contains. Unless the path for the current is cut off in the meantime the plates will continue to give a discharge until the potential of the positive and negative groups has levelled up or until the chemical action ceases. The action will continue until the acid can find no active material in one or other of the plates to convert into lead sulphate; or alternatively, until all the sulphuric acid in the electrolyte is exhausted by combination with the active material as lead sulphate.

When a dry cell is exhausted it has no value, and has to be thrown away. The exhausted accumulator if properly recharged can be made equal to new. Examination of the exhausted accumulator shows the voltage to be about 1·8 instead of 2 (when fully charged) and the specific gravity* to be perhaps 100 points lower than that of the electrolyte when the cell was first put on discharge. The colour of the plates has changed, the chocolate coloured positives have become light brown, yellowish or even white; the grey negative plates have also become whitey. In other words, the plates have taken up the sulphuric acid from the electrolyte and the lead peroxide of the positives, and the spongy lead of the negatives has been converted into lead sulphate.

The Selection of a Low Tension Wireless Accumulator.

When selecting a low tension accumulator for a particular "wireless" set it must be borne in mind that the larger the accumulator the greater its capacity† and consequently the longer it will last between charges; moreover during that period the voltage will be much steadier. The question is

* We compare the weight of various liquids with that of an equal volume of water. The ratio of these two weights is called specific gravity.

† The capacity of an accumulator, which is measured in ampere hours (a 40 ampere hour accumulator will give one ampere for 40 hours or two amperes for 20 hours and so on) should not be confused with a capacity of a conductor or the condenser (C).

frequently raised whether it makes any difference in the results obtained according to whether, say, a 40 ampere hour or an 80 ampere hour low tension accumulator be used for a particular set. At first sight one might be led to assume that it would not make the slightest difference, except that the 40 A.H. accumulator would last only half the heating hours furnished by the larger one. Actually the premise is quite incorrect for several reasons. Except on the grounds of higher initial cost and extra weight and volume the larger accumulator has very material advantages over the smaller one; the mean volts on discharge would be higher and the discharge more gradual, so there would be less adjustment and more uniform reception. The bigger accumulator would last longer on one discharge and would therefore not require charging as often as the smaller one. Its life would thereby be longer in terms of years because the wear and tear or deterioration of the plates is greatest towards the end of a complete charge. The larger the accumulator the higher the charging rate and consequently the shorter the period of charge for a given number of ampere hours. The user would therefore have the option of re-charging his 80 ampere hour accumulator after taking out 40 ampere hours, in which case his set would be out of commission only half the time it would have to be with a 40 A.H. set, or alternatively he could take out 80 ampere hours and yet put back the amount in the same time that would be required to put back 40 ampere hours in the 40 A.H. accumulator. Yet another advantage is the fact that the lower the rate of discharge the greater the capacity which the cell will yield; an 80 ampere hour accumulator would therefore give more than double the capacity given by a 40 A.H. accumulator on the same circuit. With all these undoubted advantages it clearly pays the user to put in a much larger accumulator than the size which is just big enough to operate the set for a short period.

The rate at which an accumulator is discharged will determine the capacity which can be obtained from it. High discharge rates will not hurt the accumulator, but will reduce the capacity obtainable on that particular discharge. On no account should an accumulator be left in an exhausted condition; it should be promptly recharged and it will then take no harm for long periods. The capacity of the low tension accumulators is expended in heating the valve filaments. There is a definite relation between the number of hours for which the accumulator would heat the filaments and the current taken by the valve filaments. If the current taken by the valves is definitely known, one can pick out from the Accumulator Maker's Catalogue a suitable accumulator, bearing in mind that *the number of cells is determined by the voltage required for the valves, whereas the size of the cell is determined by the product of the current taken by the valves, and the number of hours for which it is desired to run the accumulators between two charges.*

Unspillable Accumulators.

The increasing popularity of portable "wireless" sets has called for the production of an absolutely unspillable accumulator. This is a problem which is extremely difficult to achieve, because it is not practicable to seal the accumulator hermetically, as free egress must be allowed for the gases evolved in the cells. Although it is not expected that the "wireless" set will be thrown about, or placed in every conceivable position, it is a fact that these unspillable cells are so designed that it is physically impossible to shake out any of the acid. The space occupied by an unspillable accumulator must necessarily be rather greater than that of ordinary cells, and the capacity per cubic inch is therefore somewhat reduced. The durability of the accumulator, however, is not affected. Unspillable accumulators require no more attention than ordinary accumulators beyond the one point that care must be taken to avoid overfilling them, that is to say, at no time must the level of the electrolyte be brought above the acid level mark, always plainly indicated on the side of the cells.

The Selection of a High Tension "Wireless" Accumulator.

The choice of a "wireless" accumulator often depends more upon price, weight, and volume than upon its real suitability. Initial cost is naturally one of the chief considerations of any buyers of high tension accumulators if they do not realise the points of merit, such as stability, noiselessness, performance and durability. The impression that voltage and not capacity is all that is required for a high tension accumulator is quite wrong. No one who has first used a dry battery and then an accumulator can have failed to appreciate the vast difference in results. Then again instances occur where users who have previously employed dry batteries take exception to the size of a high tension accumulator, on the ground that it will not fit their existing cabinet. The user who selects his accumulator to fit existing receptacles need not expect to obtain the best results from his set. Although the high tension current is so minute that it does not depress the open circuit voltage of the accumulator, the capacity is slowly drained, and to avoid the inconvenience of sending the accumulator away to be recharged (unless a home charger is available) the accumulator should have an ampere hour capacity far in excess of that of the ordinary dry battery. For the ordinary 3 valve set a 60 volt 2 to 3 ampere hour accumulator is ample, unless power valves be employed, when the voltage required may be 100–120 volts. For sets with more than 3 valves a larger capacity, say 5 ampere hours, is advisable.

There should be an entire absence of "corrodible" metal fittings to the accumulator. The drilling of lead inter-cell connectors to take metal plugs attached to wandering leads is not altogether advantageous. Acid tends to lodge in the sockets, and when removing the plug it is found that corrosion has set up and there is a tendency to lift the plates or strain the lugs and break the sealing compound. Crackling noises in the set can sometimes be traced to corroded plugs. It seems unnecessary to provide a large number of tapping points on the accumulators of ordinary sets. Screwed terminals—lead covered—are preferable, as they afford a positive grip for the high tension leads. The accumulator selected should be of a thoroughly reliable make, as the plates must be specially designed and manufactured to give complete satisfaction. The amount of active material in the plates should greatly preponderate over the metal in the grid or frame. Such plates are known as the Mass type.

Care and Maintenance in the Home.

The use of pure materials built into plates of correct design working in an electrolyte of suitable specific gravity will enable the accumulator to be held in a charged condition for several months. But although the plates are to all intents inactive when the cell terminals are disconnected, even the best accumulators do lose charge gradually even when standing on open circuit, as indicated by a fall in the specific gravity of the acid and a change in the colour of the plates, due, of course, to the combination of the acid with the active material and the grid or frame, if oxidisable. This particular trouble varies in extent with different types and makes of accumulator. It may be the result of surface leakage, or through the presence of impurities introduced into the cells, (especially by the use of impure acid or unsuitable topping up water) in which case the impurities cause local action—the self discharge of the plates when not doing useful work. It is very important, therefore, to see that the accumulators are fully charged before they are laid aside for any length of time. If the action is not allowed to go too far recharging is readily corrective, whereas should a stage of sulphation be reached in time, it would be very obstinate to remedy by charging in normal strength of electrolyte. In ordinary sets the high tension current is so small that surface leakage and internal local action may actually dissipate more of the accumulated energy than the useful output of the "wireless" set.

No accumulator should be fully exhausted before recharging it. If the plates were allowed to be completely exhausted on each discharge, their life would be shortened. If either element were unduly weak, the cell would give poor results. It is therefore necessary to design a cell and arrange the work of the accumulator so that neither the positive nor the negative is weakened below a safe minimum degree.

There are various ways by which the condition of the accumulator can be gauged. Some of these are too expensive to employ in the home, but are extensively used at the charging stations. In the home, however, one can gauge the condition of the accumulator by the aid of a voltmeter, or by the aid of a hydrometer, or by noting the falling off in the strength of the reception. To be of value the voltmeter must be a really reliable one. One is therefore driven under ordinary circumstances to fall back upon the hydrometer, and even this must be used with caution, as drops of the electrolyte will spoil carpets or clothing. By means of the hydrometer* the fall in the specific gravity of the electrolyte over a given period is noted, and as the fall is in direct proportion to the amount taken out of the accumulator one can gauge fairly closely the amount taken out and the amount which theoretically is still available. The electrolyte loses no virtue in service, and all that is required beyond recharging at sufficiently frequent intervals is to keep the exterior of the accumulator clean and dry, to pay particular attention to the terminals to see that no corroded products are allowed to collect thereon, and to maintain the level of the electrolyte to the correct point by the occasional addition of a little distilled water, not acid. For the protection of the terminals a little vaseline is quite sufficient, but should any corrosion take place the terminal nuts should be removed and be soaked or washed with a little soda solution, and any other parts affected should be similarly washed to neutralise the acid and make the connection surfaces quite clean.

The maximum period between charges which can be relied on is six months, and this period is shortened in proportion to the demand made on the accumulator; for instance, if a high tension accumulator capable of giving 5 milli-amps. for 1,000 hours be employed to serve a super-set taking, say, 160 milli-amps. the accumulator is then being discharged at its 15 hour rate. The life of the accumulator cannot be forecast in terms of months or years, but it is an aggregate of a series of cycles, each terminating with a full gassing charge. The wear and tear is increased if the charging rate be undesirably high or if the cells be allowed to overheat on charge.

In actual service the life of the accumulator is based on an indeterminate combination of two factors—(a) the wear and tear brought about by the erosive or disruptive effects of the gassing, which is unavoidable towards the end of a complete charge, and (b) the deteriorating effect of the sulphation set up in a partially discharged accumulator during the latter portion of the period between two charges. Every recharge is a potential risk of damage, but if reasonable care be taken the risk is remote, and, as mentioned above, the chief risk lies in attempting to rush the charge through at high rates or allowing the cells to overheat.

* A hydrometer is an instrument for measuring the specific gravity of a liquid.

The accumulator is perfectly harmless. Mention has been made of the effect of the electrolyte on clothing and carpets, so care must, of course, be taken not to spill any of the electrolyte. There is not the slightest risk of spontaneous combustion or of an explosion, but naked lights should not be brought near the accumulator, especially after it has just been fully charged, and in particular if the cells are held in *celluloid* containers. The accumulator should be placed in a thoroughly dry position. It should not be kept too hot or evaporation will be abnormal. It should not be left in a dusty location, or surface leakage may arise.

The accumulator should be placed as close to the valves as possible, and *the leads between the accumulator and the valves should be stout enough to carry the current without undue voltage drop.* This is particularly important with dull emitter valves.

Charging accumulators at home as an alternative to sending them to the Service Station presents little difficulty now when reliable so-called Trickle Chargers are available.

The fire risks are remote, but as a precaution when charging direct off the house lighting and power D.C. mains, the accumulator during charge should be placed in a basin or accumulator glass box, or some equally suitable receptacle which affords insulation and would isolate a fire. It is very important to see that the connections to the accumulator are tight during charging, especialy if the cells are charged in series with the domestic power circuit with a possibility of additional electric fires, etc., being switched on during charge.

The colour of the positive plates should be watched, and discolouration or a change from chocolate to a pale yellow or brown and eventually patches of white indicate that the time is approaching for the cell to be recharged. The high tension accumulator requires some special care. Its capacity is measured in milli-ampere hours; any small currents may, therefore, represent an appreciable percentage of its capacity.

It is again emphasised that surface leakage must be guarded against. The tops of the cells must be kept free from dust and moisture, and especially from acid moisture. This is more important than many users appreciate. If the top of the accumulator be wiped over with a rag dipped in weak ammonia or soda this will neutralise any traces of acid, a resulting white precipitate indicates that the acid has been acted upon and the incrustation should be wiped off. Although the plates must be kept covered with electrolyte, the cells should not be over-filled, as this leads to acid being blown through the vent plug. Although the practice is not to be encouraged no harm will arise through accidentally short circuiting the high tension accumulator. An impression exists that such short-circuits will cause the plates to be ruined or at least distorted, but exhaustive tests carried out on Exide High Tension accumulators, type 10 W.J., showed that after no less than 100 short-circuits the plates remained absolutely straight and had shed no active material. The test also showed that even when discharged to zero on short-circuit the cells arose to 2 volts each within half an hour on open circuit subsequently.

CARE AND MAINTENANCE AT THE CHARGING STATION.

We have already seen in the above notes that "Wireless" Accumulators do not require any appreciable amount of attention on the part of the user. Far more attention is required at the Charging Station, as it has been explained that the period of charging is that during which the risk of deterioration is greatest. The most common cause for complaint on the part of the user is loss of charge. This can very frequently be traced to inaccurate adjustment of the set, especially of the grid bias. Any falling off in capacity otherwise is probably the result of one or more of the following causes:

1. Insufficient or incorrect charges. The only stipulation made is that the charge be carried out to completion and at suitable rates. A cell is very like a watch in this respect. If the main-spring will run the watch for 30 hours, and the watch is wound every day, we may know unconsciously that, say, 12 turns will make the spring taut. If one day we forget to wind up the watch it will run down in 30 hours. If we then give only 12 turns as usual the watch may just run 24 hours, but certainly not 30 hours. If an accumulator be charged at a definite rate for a definite number of hours without consideration of the amount of work done by it there is no assurance that it is full, and unless fully charged it cannot give full capacity. Similarly, if we wind our watches roughly, sooner or later there will be trouble, and although an accumulator will stand more misuse than a watch, overheating and disrupted material follow from careless charging or attempts to rush in a full charge in too short a period.

2. Improper adjustment of the specific gravity. The initial specific gravity of the acid must not be higher than 1.240 sp. gr. in Mass type

cells, or an obstinate white sulphate of lead may be formed. If the specific gravity of the electrolyte rises above the working sp. gr. on any charge it should be reduced to the working sp. gr., by drawing off some of the electrolyte and replacing with water. The specific gravity falls during discharge in proportion to the output taken from the accumulator, and to give their full capacity the plates must be completely de-sulphated on each recharge. If the plates be only partially de-sulphated and the electrolyte be brought up to normal working specific gravity by adding more acid or by changing the electrolyte, this does not complete the charge but simply invites trouble on the next cycle.

3. Insufficient insulation. Insulation is of extreme importance. Surface leakage, earths, defective insulation of the leads or double pole switches, etc., run down the high tension accumulator at a disconcerting rate. The surface ought to be kept bone dry, and any trace of acid should be neutralised at once.

4. Leaving accumulator too long in absolutely exhausted condition. The effect of leaving the plates in this condition is to set up abnormal chemical actions, which cause complications, and may lead to a deterioration of the plates.

5. Increasing the rate of discharge and expecting the same capacity as at lower rate. Probably only a small percentage of "wireless" users know what current is taken by the various valves of their set. There is a common tendency to increase the power of the valves regardless of the drain this may impose on the high tension accumulator. The increased rate does not hurt the cells, but it automatically reduces the ampere hour capacity, and consequently the running hours obtainable between any two charges. Table on the opposite page shows how the running hours decrease as the rate of discharge increases.

The Electrician at the Charging Station has it in his power to shorten or protract the life of the accumulator according to his attention to its needs. If the specific gravity of the acid with which the accumulator be filled is too high the acid will combine rapidly with the active material of the negative plate, forming lead sulphate in a finely divided non-adherent powder which will fall to the bottom of the cells. A heavy layer of snow white deposit in a new high tension accumulator usually indicates that the acid has been too strong.

The object of recharging is to de-sulphate the plates, and the rate of charge is only limited by the extent at which the plates can absorb the charging current; the rate of absorption is greater during the early part of the charge provided the plates are in a healthy condition. It is most unwise to try to force the charge into the plates. The thicker the plates the slower will be the rate of charging, otherwise the active material will tend to disrupt. Indications that the plates are not able to absorb the charging current are overheating and evolution of gas bubbles. Towards the end of the charge the gassing will become very pronounced, especially if a high charging rate is maintained. At the end of complete charge the plates should have been brought once more to their original state, lead peroxide in the positives, spongy lead in the negatives, and all sulphuric acid returned to the electrolyte. Unless the charge is completed some lead sulphate will be left in the plates, and unless the plates are thoroughly de-sulphated they will not give their full capacity on the following discharge. This is one of the most important points connected with the results obtained from wireless accumulators. There is no substitute or compromise. If the accumulator is only partially charged, and the acid be poured away and replaced with acid of the correct working specific gravity, this will almost certainly lead to serious trouble and dissatisfaction.

The working specific gravity is not fixed for all types, regardless of make. It is a value determined by the design of the cell, and the nature of the work. The specific gravity must not be unduly high or the plates will shed active material. On the other hand it must not be unduly low or the plates cannot yield their full capacity. On no account, therefore, should the manufacturer's stated working specinc gravity be exceeded, and this value should not be artificially obtained by adding acid or exchanging the electrolyte at the end of an incomplete charge. The electrolyte should not be tampered with in any way. The various "dopes" and quack electrolytes put on the market and widely advertised from time to time should not be employed.

By courtesy of the Chloride Electrical Storage Company Ltd.

A TABLE OF CAPACITIES OF REPRESENTATIVE TYPES OF EXIDE ACCUMULATORS.

Current in milli-amps	2·5	3	4	5	7·5	10	15	20	25
WJ									
Running hours (approx.)	1,000	850	550	440	280	200	125	85	60

Current in amperes	·02	·03	·04	·05	·10	·20	·30	·40	·50
DTG									
Running hours (approx.)	1,000	650	450	350	130	50	27	17	10

CZ4									
Current in amperes	·4	·6	·8	1·0	1·5	2·0	3·0	4·0	5·0
Running hours (approx.)	100	68	50	40	27	20	13	9	7

Points to remember:

(1) *When the voltage of an accumulator cell drops down to 1·8 volts the accumulator should be recharged at once.*

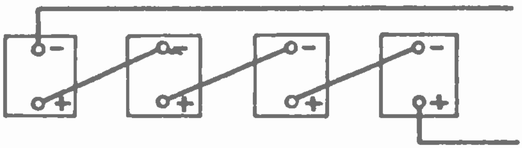
(2) SEE THAT THE ACID IS ALWAYS AT ITS PROPER LEVEL, I.E. COVERING THE TOPS OF THE PLATES.

(3) TEST PERIODICALLY THE SPECIFIC GRAVITY OF THE ACID.

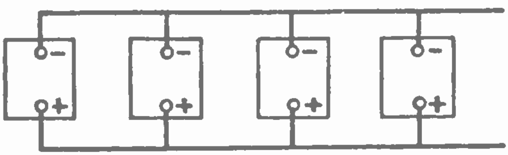
(4) REMEMBER TO BE CAREFUL WHEN HANDLING ACID, AS IT WILL BURN YOUR HANDS AND CLOTHES.

(5) KEEP YOUR ACCUMULATORS CLEAN.

There are two ways of connecting the cells of an accumulator: in series and in parallel. If we join three 2 volt cells



SERIES



PARALLEL

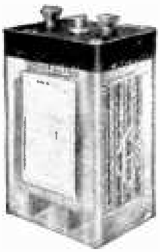
FIG. 102

in series the voltage of the combination will prove to be six volts. If on the other hand we join these cells in parallel the voltage of the combination will be the voltage just of one cell, i.e. two volts. The parallel arrangement has the advantage of discharging each accumulator at the third of the rate. In other words each accumulator is supplying only the third of the total current and therefore they last longer.

When a number of accumulators are joined in series the total voltage of the combination is equal to the sum of the individual voltages.

When accumulators are joined in parallel the total voltage of the combination is the voltage of one single cell.

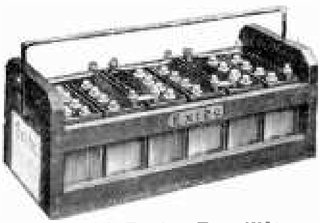
ACCUMULATORS



Exide Cell, Type CZG4, in Glass

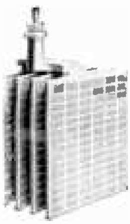
Exide Battery, Type WH, 10-Volts

Exide Celluloid Box and Lid

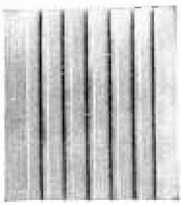


Exide High Tension, Type WJ60, in Crate with Wire Handle

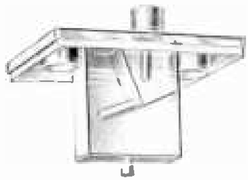
Glass Cell and Ebonite Lid



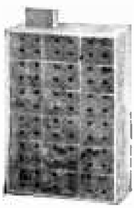
Exide Group



Exide Wood Separator



Cell Lid with Exide Unspillable Device



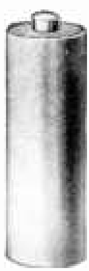
Exide "Mass" Type Plate

Exide Hydrometer Set, Type S.1

HIGH-TENSION BATTERIES

Ever Ready H.T. Batteries

Siemens H.T. Battery No. 913



Siemens
Unit Cell

CHAPTER XVII

HIGH TENSION BATTERIES

You already know that the anode of a valve has to be connected to the positive terminal of a High Tension battery.

The high tension battery is made up of unit cells which are dry primary cells.

The positive "plate" of such a dry cell is a carbon rod surrounded by paste mixed with the following ingredients: zinc chloride, oxide of manganese, sal ammoniac, carbon and water.

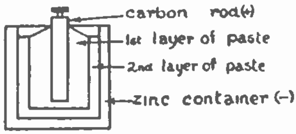


FIG. 103

Around this paste is a layer of another paste consisting of plaster of Paris mixed with flour, sal ammoniac, zinc chloride and water. The whole is enclosed in a zinc container. There is a glass tube inserted into the paste in order to provide an escape for liberated gases.

The E.M.F. of such a unit cell is about 1.5 volts, and the internal resistance is much less than that of a similar wet cell.

These unit dry cells are placed in numbers in one box and are joined in series. A metal socket is soldered to the connection between each pair of cells, so that a tapping can be obtained in steps of three volts after the box is sealed with pitch.

Forty such cells will go into one box to make up a battery of 60 volts. A modern valve receiver as a rule requires a High Tension voltage of 180 volts, so that either three batteries of 60 volts each are required, or one large battery is used.

An H.T. battery should last about nine months from the date of manufacture without an appreciable loss of voltage. Their cost compares favourably with the cost of maintaining accumulators, but they have one drawback: they are like little girls—when they are good they are very very good, but when they are bad they are simply horrid.

Make sure therefore that when you are buying an H.T. battery you buy a well-known make with a guarantee behind it.

When the dry battery becomes old a cell may give out and the performance of the whole thing goes by the board. Crackling noises become apparent in the telephones or the Loudspeaker. When this happens the faulty battery should be disconnected and a fresh one substituted.

An H.T. battery, as explained above, is tapped every 3 volts, and sockets are provided for this purpose. The connection to the set is made by means of "wander plugs" attached to the receiver H.T. leads.

If different voltages are required for the anodes of the valves there may be three wander plugs attached to the set, one for the negative side of the battery and two for different values of positive connections.

If dry grid-bias batteries are used there will be another pair of wander plugs, unless the grid battery is placed inside the set and is connected internally.

The amount of current a battery can supply depends on the size of the individual cells, whose discharge current is measured in milli-amperes.* The batteries as a rule are standardised in a number of convenient units. The table below will show the correct battery to instal for receivers requiring an emission as shown:

Size of Battery		Anode Current
Standard cell units	..	Up to 6 milli-amperes
Medium capacity	..	From 5 to 11 milli-amperes
High Capacity	..	,, 10 to 16 ,,
Super Capacity	..	,, 15 to 30 ,,

You will find the method for measuring anode current in Chapter XXII.

There is no direct ratio between the current consumption and the useful life of a cell. A high tension unit, irrespective of voltage, if discharged at the rate of 6 milli-amperes, will have half the life of an identical unit discharged at 3 milli-amperes.

*A milli-ampere is one thousandth of an ampere.

As soon as a dry battery is connected in circuit the voltage of the battery begins to drop. Large capacity cells will stand up to a heavier discharge, their voltage drop is not so marked, and their recuperative properties are greater than those of small cells.

It is better and cheaper in the long run to buy high capacity batteries. The anode current in modern sets varies considerably with the voltage applied. Tests carried out on typical modern sets consisting of one detector valve, one low frequency stage, resistance capacity coupled, and one power valve gave the following readings at the voltages stated:

Applied Anode Voltage	Negative Grid Bias 1st L.F.	2nd L.F.	Anode Current in Milli-amperes
50 volts	0	1·5 volts	5
75 ,,	0	3·0 ,,	8·5
100 ,,	3	7·5 ,,	9
120 ,,	3	9 ,,	11·5

The application of negative potential to the grid of the power valve helps to save H.T. current, and noticeably improves the quality of reception.

The following table gives the voltages required for the negative grid bias of 2, 4 and 6 volt L.F. valves with the impedances as shown.

H.T. Applied Voltage	Grid Bias Impedance 5,000 to 8,000 ohms	Impedance 10,000 to 16,000 ohms
50	3 volts negative	1·5 volts negative
75	4·5 to 6 ,, ,,	3 ,, ,,
100	6 to 7·5 ,, ,,	6 ,, ,,
125	9 ,, ,,	7·5 to 9 ,, ,,

The above tables are published by the courtesy of Messrs. Ever-Ready Company of Great Britain.

The negative grid bias is as a rule specified by the valve manufacturer, together with the correct H.T. voltage on the anode.

As the voltage of the H.T. battery drops with time, care should be taken to modify the grid bias accordingly, otherwise distortion will take place.

For grid bias purposes small dry batteries are ideal, as the grid does not take any appreciable current. There are convenient grid bias batteries on the market, in units of 4·5, 9 and 18 volts.

Sometimes it happens that a large H.T. battery develops an unsteady voltage that fluctuates a little owing to some internal defect. This can be cured very effectively by placing across the H.T. Battery a large capacity condenser to the value of ½ or 1 micro-farad.

[*By courtesy of the B.B.C.*

CAPTAIN P. P. ECKERSLEY, M.I.E.E., THE FAMOUS RADIO EXPERT AND PIONEER

AMPLIFYING DEVICES

Ferranti L.F. Choke


Marconiphone
"Ideal" Transformer

"Polar" H.F. Choke

Ferranti Telephone
Transformer

Ediswan Resistance
Capacity Coupling
Unit " B "

CHAPTER XVIII

TRANSFORMERS

The Principle of Transformer Action.

In order to be able to understand clearly the action of a transformer let us consider first the action of a low frequency transformer.

A low frequency transformer consists of two coils insulated from each other and mounted on an iron core.

The iron core is laminated in order to eliminate the heating effect due to *eddy currents* in the core. When a magnetic field is rapidly moving near any conductor so as to cut it at right angles, it will induce currents in that conductor. The iron core of a transformer is a conductor, but we do not want any currents in it, as it is not part of our electrical circuit, being there simply in order to concentrate the lines of magnetic force where we want them. If currents are induced in the core they will heat up the core which, on becoming hot, will heat up the insulation of the coils and the conductors, thus reducing the insulating properties of the insulation and increasing the resistance of the conductors. In order to avoid this we cut up the core into a large number of thin plates, i.e. laminæ, and the core is said to be laminated. Such parasitic currents in the core or any conductor are called *eddy currents*. The two coils of the transformer are called the *Primary* and the *Secondary* coils. The Primary coil is so called because we apply to it a potential difference to begin with and thus start the cycle of events in the transformer.

The function of a transformer is to increase the anode voltages variations of a valve before passing it on to the grid of the next valve. Now let us consider how this increase of voltage variation is carried out.

If we have two coils in close proximity to each other, but not connected electrically, it is possible to introduce electrical energy into one coil and to transfer this energy into the other coil by means of the alternating magnetic field existing between the two coils.

When a current is flowing in a conductor there is a magnetic field around that conductor. The field will exist only when the current is flowing, and if this current is not a steady current but an alternating one, the magnetic field will also alternate, and the lines of force will move to and fro in space, expanding and contracting at the same rate as the current.

If such a current is introduced in one of the coils, a magnetic field will come into existence around the coil and, in moving, will cut the conductors of the second coil at right angles, thus inducing in them an E.M.F., and if the circuit of the second coil is closed, a current will flow in it.

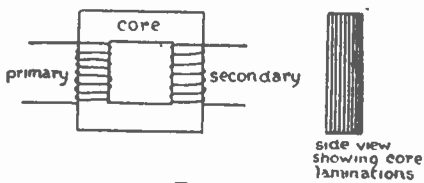


FIG. 104

What will actually happen is that *the magnetic field due to the first coil will induce in each turn of the second coil a certain E.M.F. equal to the E.M.F. of each turn of the first coil that is energised.*

The first coil, which is the primary coil, is thus inducing an E.M.F. in the secondary coil.

Hence we see that the volts per turn in the primary are equal to the volts per turn in the secondary. For practical purposes each turn of a coil can be considered as a little cell having a certain voltage. All the turns are in series, so that the total voltage of each coil is equal to the sum of the voltages of the turns. Therefore, the more turns there are the higher is the resultant voltage. This means that if the secondary coil has 10 times as many turns as the primary coil, the resultant voltage of the secondary coil is 10 times greater than the voltage applied to the primary coil. Mark you, the amount of energy transferred remains always the same. The secondary coil cannot possess more energy than the primary coil. As a matter of fact the secondary coil will possess less energy than the primary coil on account of various losses in the process of transformation.

Electrical power is measured by the product of volts and amperes, i.e. by the product of the E.M.F. and the current. The unit of power is one watt, which represents the power delivered in one second by one ampere flowing at a pressure of one volt. (One watt is, however, too small for ordinary industrial purposes, and therefore a unit of 1,000 watts is chosen and is called one *kilowatt*. The power of wireless transmitting stations is measured in kilowatts.)

Now, the power applied to the primary is: primary applied voltage multiplied by the primary current, in watts.

The power delivered by the secondary is: secondary induced voltage multiplied by the secondary current. (Let us forget about the power factor.)

We will call primary voltage E_P and primary current I_P and also secondary voltage E_S and secondary current I_S; then the power supplied to the primary is $E_P \times I_P$ while the power delivered by the secondary is $E_S \times I_S$.

But we have just said that the powers must be (theoretically speaking, if there were no losses) equal. Thus $E_P\ I_P = E_S\ I_S$.

Let us consider a concrete case.

Apply to the primary a voltage of 50 volts with a current as indicated by the ammeter of, say, 1 ampere. Therefore the power supplied to the primary is 50 × 1 or 50 watts.

The secondary must therefore deliver also 50 watts (provided we conveniently forget the losses). But these 50 watts in the secondary can be made in a number of ways:

2	volts	×	25	amperes	= 50	watts
5	,,	×	10	,,	= 50	,,
10	,,	×	5	,,	= 50	,,
25	,,	×	2	,,	= 50	,,
50	,,	×	1	,,	= 50	,,
100	,,	×	½	,,	= 50	,,
200	,,	×	¼	,,	= 50	,,
500	,,	×	.1	,,	= 50	,,
1000	,,	×	.05	,,	= 50	,,

CHAPTER XIX

HIGH FREQUENCY AMPLIFICATION

A CRYSTAL or a detector valve will do much better work if it has to handle strong oscillations to begin with. For this reason it is more efficient to carry out some of the amplification before the rectifier stage is reached.

Naturally, with the introduction of high frequency amplification, the sensitiveness of the receiver is much increased, as it is then able to pick up much weaker signals and thus receive signals from far distant stations.

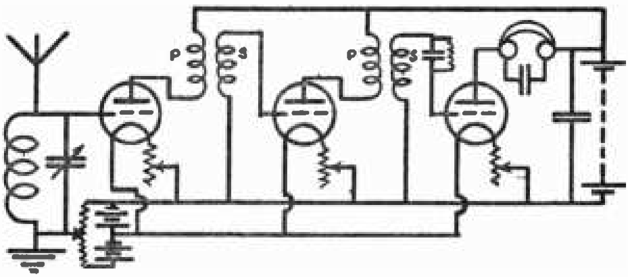
You have probably realised by now that the valve is a voltage-operated device. On the voltages between the grid and the filament depends the value of the anode current. As these voltages are stepped up from valve to valve they result, in the anode of the last valve, in strong current capable of actuating a Loudspeaker.

In amplification we have to face the problem of converting current variations into voltage variations, and this can be done by the following three means: (i) transformers, (ii) chokes, (iii) resistance capacity coupling.

In the case of transformers we can use either aperiodic (untuned) or periodic (tuned) transformers. The H.F. chokes, which are nothing but inductances, i.e. coils, can also be tuned or untuned. In case of resistance capacity coupling we use high resistances in the anode circuit for the purpose of voltage variations.

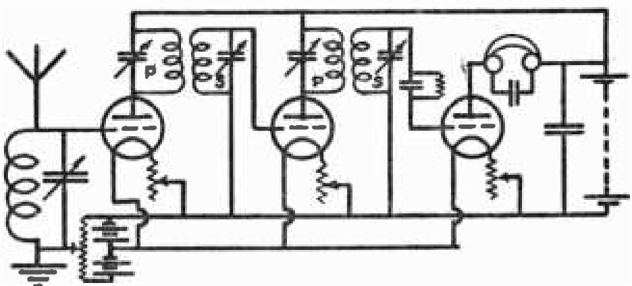
Let us consider all these methods in turn:

Amplification is obtained owing to the fact that any small variation of potential on the grid will result in a large change in anode current. The valve when acting as an amplifier will act as a relay, i.e. enable a small force to bring into play a large force.



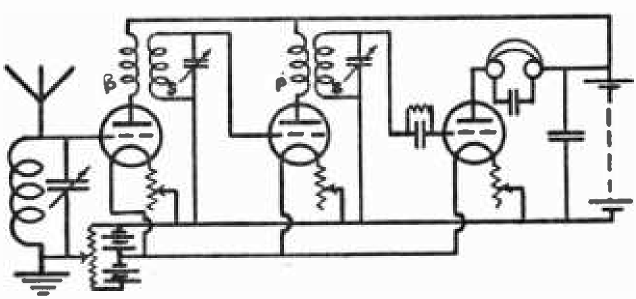
AMPLIFICATION BY MEANS OF APERIODIC H.F. TRANSFORMERS

Fig. 105



AMPLIFICATION BY MEANS OF H.F. TRANSFORMERS WITH PRIMARIES AND SECONDARIES TUNED

Fig. 106



AMPLIFICATION BY MEANS OF H.F. TRANSFORMERS WITH SECONDARIES TUNED

Fig. 107

is applied across the grid and the filament of the first valve there will be a large current variation through R_1; therefore there will be a variation in the drop of voltage across R_1. The voltage of the H.T. battery remaining unchanged, the potential of the upper end of the resistance R_1 will be impressed across the filament of the second valve, while the grid of the second valve is already at the potential of the lower end of the resistance. Therefore the difference in potential across R_1 will be impressed across the grid and the filament of the second valve. The same cycle of events will be repeated with the second valve. Resistance capacity coupling on the high frequency stages is not efficient for low wavelengths, but can be used on very long waves. The best method to use for Broadcasting reception is the tuned anode method, while for very short waves, H.F. transformers are recommended.

CHAPTER XX

LOW FREQUENCY AMPLIFICATION

ONCE electrical impulses have been rectified and thus reduced to low frequency (i.e. audible frequency) impulses they can then be amplified at that frequency. On the low frequency side there are three methods of amplification, viz. by means of L.F. transformers, chokes and resistance capacity coupling.

Transformers ensure a good volume, but, if of indifferent design, will introduce distortion. Chokes and resistance capacity coupling tend to produce pure results, but a good deal depends on the value of the components chosen. A very good method is to use a first class L.F. transformer in the first stage, and to follow this up by one or two stages of resistance capacity coupling.

A few examples are given here, while the best methods of L.F. amplification will be found in Chapter XXIV, page 220, where the B.B.C. sets, "B" and "C" are illustrated. These two sets show how L.F. chokes* are used in the amplifier.

The action of the L.F. transformer is well known to us by now, and below you will find two methods of adding transformers to (i) a crystal receiver and (ii) a valve detector.

In Fig. 111 two transformer stages are added to a crystal detector. The primary of the first transformer goes across the telephone terminals of the crystal set, which also have a by-pass condenser across them. The secondary of the transformer is connected to the grid of the next valve and the negative side of the filament. One end of the primary of the second transformer is connected to the anode of the first amplifying valve, while its other end goes to the positive terminal of the H.T. battery so as to give the anode of that valve a positive potential. The secondary of the second

* An L.F. choke is a coil wound on an iron core.

It is a fallacy to seek too large a volume of sound. The best rule to observe is that the Loudspeaker should give just enough volume to produce an impression of the performer being in the same room. Thus good quality can be ensured. If a large volume is required, say for dancing, the last L.F. valve should be a power valve, which is somewhat larger than an ordinary valve, and is specially designed to deal with a large amount of energy. If a large number of valves is used in a set and the output is fairly high, it is best to use a low resistance Loudspeaker and connect it through a telephone transformer (i.e. a step-down transformer).

It is useful to know how a telephone transformer is connected in circuit, and the diagram below gives the method of doing so.

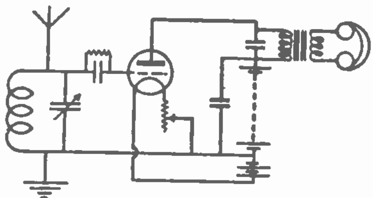


FIG. 114

CHAPTER XXI

REACTION AND OSCILLATION

THERE is another method of amplification called the *regenerative method*. This method consists of the use of a coil in the anode circuit of the detector valve which is coupled to the aerial circuit, or rather to the secondary coil of the loosely coupled aerial circuit. This method is illustrated below:

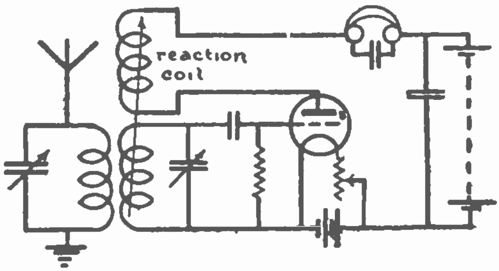


FIG. 115

You have noticed that in every circuit we have used a by-pass condenser across the telephones. This by-pass condenser is used to by-pass the so-called *high frequency component*. There is no rectifier that will work in such a way as to cut out completely one half of the wave. We said that the crystal offers a very high resistance in one direction and a much lower resistance in the other. However high this resistance may be, it is not infinite, and therefore a certain amount of current will pass in the opposite direction to the rectified current. Thus we are always left with a small high frequency current flowing in our receiving circuit, or the high frequency component trying to pass through our telephones; hence by-pass condensers.

In the case of the valve, we shall have a precisely similar effect, since a valve is not an ideal rectifier that will completely wipe out one half of the wave, but we can make use of this high frequency current for amplifying purposes.

Now let us consider the two coils: the secondary coil and the reaction coil in the above diagram. A high frequency current is flowing in the secondary coil. There is a high frequency component in existence in the reaction coil. If the reaction coil is brought near the secondary coil, and the reaction coil is wound in the right direction, there will be a transfer of energy from the reaction coil to the secondary coil, strengthening the currents flowing in the secondary coil, and thus impressing a larger variation of potential difference across the grid and the filament of the valve. The result will be much louder signals as compared with an identical circuit but without the reaction coil.

The reaction coil should not, however, be too tightly coupled to the secondary coil, since in such a case the regenerative effect will become too strong and will energise your aerial and convert your receiving station into a transmitting station which will be sending out a wave of its own. This wave, in passing the aerials of your fellow listeners, will induce in them currents of its own that will become apparent as a piercing whistle in their telephones and Loudspeakers.

Your set is said to be oscillating, and you become one of those scourges of the listening community whom they call "oscillators," and whom experts do their best to track to their lair.

If your set is provided with measuring instruments you can see at a glance whether your set is oscillating or not. Without the instruments it is sometimes difficult to realise that oscillations are taking place.

The B.B.C have published an excellent booklet on oscillation and its prevention. The book is supplied free on request and can also be obtained from your local wireless shop. Being illustrated by Bateman it makes interesting reading, and helps a good deal to avoid becoming a nuisance to everybody in the neighbourhood.

There is a much safer method of using reaction, and that is to couple the reaction coil to the anode coil in the H.F. stage. (Fig. 116.)

With such an arrangement there is little danger of your set oscillating. The values of reaction coils are given by the makers in their tables of coils.

When your set is oscillating, distortion immediately sets in, and your reception may be ruined. Should this occur, when your reaction coil is coupled to the aerial, move the reaction coil away from the secondary coil as far as it will go, and then gradually bring it near again till maximum signals are reached without any trace of distortion. When tuning in, start with the coils far apart, and, having tuned

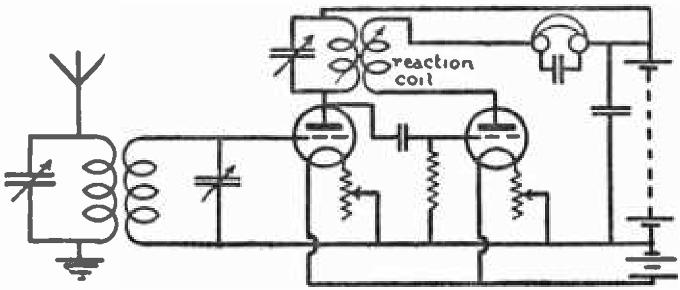


Fig. 116

in, bring them slowly together till the best signals are obtained.

In the case of the arrangement of your circuit as in Fig. 115, when you have to use three coils, a three-way coilholder will enable you to move the aerial coil in respect to the secondary, and also to move the reaction coil in respect of the secondary. Thus you can vary the coupling between all the three coils. When the reaction coil is coupled to the tuned anode, you will want two two-way coilholders, one for the aerial Primary and Secondary, and one for the tuned anode and reaction coils.

CHAPTER XXII

MEASURING INSTRUMENTS

THE man who operates his "wireless" set without measuring instruments is working in the dark.

He can do a good deal by guesswork if he has considerable experience, but guessing is not of much use if the best results are to be obtained from the set. We are all familiar with the clock and the watch. These are measuring instruments measuring time. How many go about without a watch? And yet, when it comes to voltmeters and ammeters, which, by the way, are much more simple than the watch, we feel that there is a good deal of mystery attached to them.

In electrical work there are two important problems: one is to measure voltages and the other is to measure currents. Once we know the voltage applied to the circuit and we know the current flowing through it, we can determine the resistance of the circuit by simple calculation.

From Ohm's law you no doubt remember that the voltage is directly proportional to the current. Thus, if we measure the current we can always deduce the voltage. In using a voltmeter or an ammeter we measure in each case the strength of the current. The dial of our ammeter is calibrated in amperes or milli-amperes, while the voltmeter is calibrated in volts. Once the resistance of the voltmeter is constant to each current flowing through it there must be a definite voltage. In other words, while in the ammeter we measure the current direct, in the voltmeter we measure the voltage indirectly by measuring the current and translating it on the dial into volts.

Now let us see how such measuring instruments are constructed.

The general principle is this: If near a coil of wire a piece of soft iron is placed on a pivot, the coil being fixed, the pivoted piece of iron will move under the influence of attractive magnetic forces due to the magnetic field around the coil when a current is flowing in it. The stronger the current flowing through the coil the stronger the force of attraction and the larger the movement of the pivoted piece of iron.

Therefore the displacement of the iron will be proportional to the strength of the current. If a light pointer is fixed to the iron it will indicate the degree of deflection on a dial placed under it. By using standards we can find the degree of deflection for every ampere of current, and obtain a direct reading in amperes, or in volts, it all depends how we have calibrated it.

Such instruments are known as *Moving Iron Instruments.*

We can achieve the same thing by other means. If instead of a fixed coil and a pivoted piece of iron we take a permanent magnet which is fixed, and place near it a movable coil, we shall find that, each time a current flows through, the coil will be attracted to the magnet and will move.

The pointer is now fixed to the coil, and the calibration is done in the same way. Such a measuring instrument is called a *moving coil instrument.* Measuring instruments usually have to be "damped." When the current is switched on or is changed rapidly, the pointer tends to overshoot the mark, and to vibrate for some time before coming to rest. This would make the reading of a measuring instrument a slow affair. For this reason a device is used that serves to reduce the vibrations of the pointer to something like two vibrations. Such instruments are known as "dead beat" instruments. The damping is effected by liquid friction, glycerine and oil being used for this purpose. There are other methods of damping. Still, the above-named method will give us an idea of how the damping is carried out.

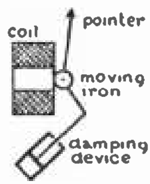


FIG. 117

From Fig. 117 we see at a glance that if the pointer tries to overshoot the mark the damping piston will come up against the damping liquid and cause the pointer to slow down.

From Ohm's law we know that the volts are the product of amperes and ohms (E=IR). Thus if the resistance is known the voltage can be determined for each strength

The Use of Ammeters and Milliammeters.

The difference between an ammeter and a milliammeter is that an ammeter reads the current in amperes while the milliammeter reads it in milli-amperes or in thousandths of an ampere.

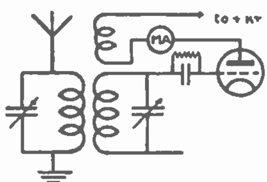
The milliammeter is very useful when incorporated in the anode circuit of the detector valve. One of the greatest dangers in any set employing reaction is to have the set oscillating without one knowing it.

There are various ways of guessing when a set is oscillating, but guessing does not take us far enough. We can find out definitely whether a set is oscillating.

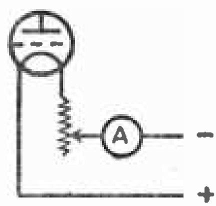
The effect of oscillation is distortion of signals. Unfortunately many people are unable to appreciate the fact that distortion is present. The milliammeter is usually connected in the anode circuit of the detector valve. If the pointer is moving during reception it means that the signals are being distorted, and that oscillation is taking place.

The stronger the oscillation the greater is the movement of the pointer. This means that the strength of current is constantly changing. If the pointer remains at rest—the signals are pure and there is no oscillation. Distortion may be present without the set oscillating, and may be due to the L.F. transformer stages, especially if cheap transformers are used.

If you find that the pointer of the milliammeter is moving, move the reaction coil away from the coil to which it is coupled and you will find that the pointer will remain steady. Now adjust the reaction coil without the pointer moving and your reaction is correct.

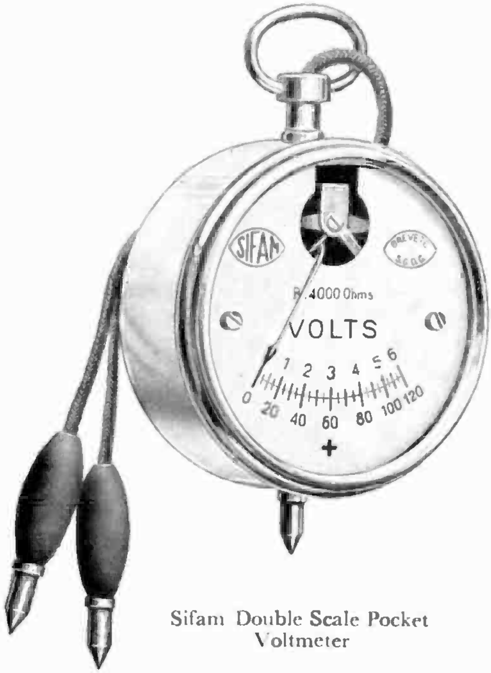


A MILLIAMMETER IN THE ANODE CIRCUIT



AN AMMETER IN THE VALVE FILAMENT CIRCUIT

FIG. 122



Sifam Double Scale Pocket
Voltmeter

Sifam E-70 A Milliammeter
(Moving Coil)

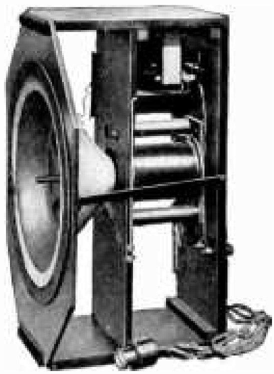
Sifam E.A. 66 No. 1
Ammeter (Moving Iron)

LOUDSPEAKERS

A Veteran
Speaker
The Original
S. G. Brown
H1 Model

S. G. Brown
Q Horn Type Speaker

Celestion Cone Speaker



Marconiphone Moving
Coil System

CHAPTER XXIII

LOUDSPEAKERS

THE quality of reproduction depends a good deal on the Loudspeaker. It is rather fortunate for us that the days of nasty tinny sounds have gone, and that present-day Loudspeakers, although not ideal, are really good.

There are three main types we have to consider: the horn type, the cone type, at the moment universally adopted, and the moving coil speaker, which has been developed recently.

If you remember, when we discussed head-telephones we found that they consist of a permanent magnet to which

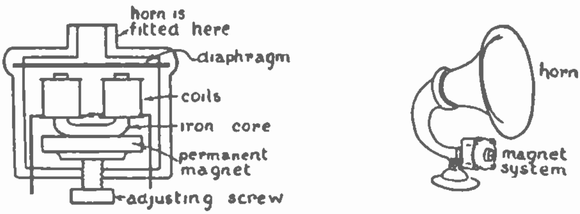


FIG. 123

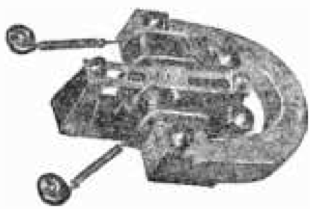
is clamped a horseshoe-shaped electro-magnet and a soft iron diaphragm placed near so that any change in the magnetic field around the magnet will act on the diaphragm. The permanent magnet holds the diaphragm in tension, and this tension is strengthened or relaxed as the magnetic field varies. The horn type Loudspeakers are built roughly on the same principle, and depend on the horn for increasing the volume of sound.

In the cone type an iron reed is introduced near the permanent magnet in such a manner that it tends to bridge the poles of this magnet and thus close the magnetic circuit. The pull of the permanent magnet is balanced by the stiffness of the reed, so that an equilibrium is maintained. An increase in the magnetic field strength causes the reed to approach the poles, while the weakening of the field enables the reed to recede.

Thus we can see at a glance that the action on the reed is the same as the action on the diaphragm in the telephones. When currents flow in the electro-magnet windings they affect the magnetic field and the reed begins to vibrate. Now, in the case of the diaphragm vibrating we produced sound waves by the diaphragm itself.

The reed is actually vibrating in air, it is producing sound waves to some extent, but owing to its small area it affects the air only very slightly. In order to produce a larger vibrating area, a large disc or a large diaphragm is attached in its centre to the reed. It is essential that such a diaphragm should be light, and also as rigid as possible for its size. The form which best fulfils such conditions is a shallow cone. The angle of the cone is a compromise between a flat disc which can be light but is not sufficiently rigid, and a long small-angled cone, which though rigid is unduly heavy.

The essentials, then, of a cone type Loudspeaker are a magnet, a winding, a reed and a diaphragm.



THE CELESTION MAGNET SYSTEM
FIG. 124

The cone Loudspeaker seems to be very simple at the first glance, but in designing it the application of general principles to a practical instrument involves attention to many details and dimensions if an efficient and evenly responsive instrument is to be obtained.

The dimensions of the reed, the pole pieces, the resistance and inductance of the windings, the magnet material, all have to be taken into consideration. Thus, for instance, the success of one of the well-known cone speakers, the Celestion, is due to a large extent to a great degree of precision in the adjustment of the reed mechanism and also to the employment of a reinforced diaphragm which gives great rigidity combined with extreme lightness. The large vibrating area of the diaphragm eliminates the tendency of the reed to resonate at its natural frequency. (The size of the diaphragm is 24 inches in diameter.)

The action of the diaphragm at all frequencies is not the same. At low frequencies the diaphragm may move as a whole, like a piston, but at higher frequencies the outer edge cannot follow the movements of the centre rapidly enough, so that only a portion of the diaphragm around the centre is effective. The higher the frequency, or in other words the more rapid the vibrations, the smaller is the area which acts effectively. By reinforcing the diaphragm this effective area is increased for all frequencies within the range of the diaphragm, and obviously this results in a greater volume of sound being obtained for a given input than would otherwise be the case.

There is one point in connection with Loudspeakers that is not sufficiently realised, viz. to reproduce the lowest notes effectively, either a baffle or a fairly large cabinet is required. Consequently it cannot be expected that a Loudspeaker, say 12 inches square, will give the same low-note output as an instrument having a baffle board which is perhaps four feet across.

Another point which should be carefully noted is the relative balance of the frequencies that are within the range of the Loudspeaker. The ideal, of course, is an instrument which reproduces the complete range of audible frequencies at their correct relative strength. Such an instrument has not yet been produced, although great strides have certainly been made towards it.

Moving Coil Loudspeakers.

The diagram in Fig. 125 gives a fairly good idea of how moving coil Loudspeakers are constructed.

The permanent magnet is of the shape as shown, and carries a winding which is energised from an outside supply, so that a strong magnetic field is produced. In this magnetic field a coil of wire, attached to a large cone diaphragm, is floating freely. This coil is wound with fine wire and is connected through an amplifier to the receiver. Currents will flow in the floating coil and will cause it to vibrate longitudinally in the gap between the pole pieces. The coil drives the cone diaphragm and causes it to vibrate as well. The moving coil speaker thus uses as driving mechanism a freely floating coil instead of the reed of the cone speaker.

The rigidity of the diaphragm is such that it does not introduce any distorting effects. The flexible suspension of the diaphragm enables it to have a very low natural frequency, well below the audible range. The results thus obtained

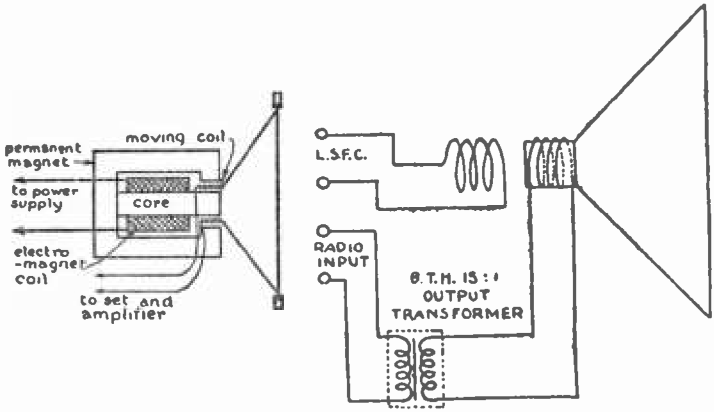


FIG. 125 (*By courtesy of B.T.H.*)

are no doubt excellent, but there is a definite drawback. The moving coil speaker requires a great deal of electrical energy in the magnet windings and also a comparatively high output of the receiver. So much so that with an average receiver a special amplifier is required.

Although the moving coil speaker is an excellent thing it would be a sheer waste of money to use it with an indifferent receiver, which introduces enough distortion to disable any speaker.

It is not within the province of the author to recommend any special make. It is up to the reader to compare the various types and decide for himself what is the best for him. But there is one point to consider: The Loudspeaker must suit the set. Any reliable wireless manufacturer will be pleased to recommend you the right model for your particular receiver, once you let him have the details.

It is essential, when connecting a Loudspeaker or head-telephones to a set, to connect them the right way round. If you inspect the Loudspeaker or telephone terminals you will notice that one terminal is marked +. This is done so that the current flows in the right direction and does not demagnetise the magnets.

To find out which of your receiver telephone (or Loudspeaker) terminals is positive and which is negative attach two wires to the set terminals and use the so-called "pole finding paper" (makers: Messrs. Armstrong & Co., Twickenham, London).

Tear off a section of the paper and moisten it slightly with water. Press the two wires in question upon the paper for a few seconds, keeping the wires about $\frac{1}{8}$ of an inch apart (for high voltages $\frac{1}{4}$in. to $\frac{1}{2}$in. apart).

The wire that leaves a red mark on the paper is the negative wire.

Clean the ends of the wire before making the test. This test is especially important when Loudspeaker extension wires are used in another room.

are placed as they are, in order to enable the grid charges to leak away slowly at the right moment. The inductance L_3 is the reaction coil coupled to the secondary coil L_2. One end of the reaction coil is connected to the anode of the detector valve and the other end to the IP terminal of the L.F. transformer. Across the primary of the transformer a by-pass condenser C_{10} is connected to deal with the H.F. component. The secondary of the transformer is connected with its IS terminal to the grid of the valve V_4, while the OS end of the secondary is connected to a separate grid bias battery. The OP side of the primary goes to the H.T. positive terminal. The anode of the valve V_4 has a resistance in its circuit and is coupled to the last valve through a condenser and a grid leak. The grid leak of the last valve has a separate grid bias. There are by-pass condensers across the Loudspeaker and the H.T. battery, (C_8 and C_9 respectively).

You will notice that the anode of each valve is getting its positive potential from the H.T. battery: V_1 and V_2 through inductances L_4 and L_5, the detector valve through the reaction coil and the primary of the transformer, the valve V_4 through the resistance R, and the last valve through the Loudspeaker winding. Now let us consider what happens in the set when signals are being received. We first tune the circuit C_1L_1 with the reaction coil thrown as far apart as possible. As soon as weak signals are heard we tune the condenser C_2 and approach the coils L_1 and L_2. The next step is to tune the two ganged condensers C_3 and C_4. As a final adjustment the reaction coil is manipulated till the maximum signal strength is reached.

Once we are in tune we get the maximum possible voltage across the circuit C_1 and L_1. This voltage is varying all the time, and produces varying voltages across the grid and the filament of the first valve. A varying current is now flowing in the tuned anode of the first valve, producing a larger voltage variation across the grid and the filament of the second valve, and thus causing a still larger current variation in the second tuned anode. A still larger voltage variation is introduced across the grid and the filament of the detector valve. Now we have finished with the high frequency stages and a rectified current is flowing in the anode of the detector valve and through the coil L_3 accompanied by the high frequency component that is always present. This high frequency component through the mutual induction of L_3 and L_2 causes stronger variations in potential across the grid and the filament of the first valve, and thus we get extra amplification. Now, the large voltage variations are passed across the primary of the L.F. transformer (the high frequency component passing via condenser C_{10}), and the secondary delivers magnified voltage variations which are applied between the grid and the filament of the valve V_4 the grid of which has an initial potential due to a separate grid bias battery. A greatly magnified varying current passes through the resistance R_1, and causes large varying potentials across the grid and the filament of the last valve; thus we get a resultant large current in the anode of our last valve, which passes through the Loudspeaker windings and causes the diaphragm to vibrate in the same way as the microphone diaphragm is vibrating in the studio.

The diagram on page 217 is theoretical only, and in practice many refinements will have to be made, and the values of various component parts carefully chosen. Valve and transformer manufacturers are usually willing to advise on this point, as there is a definite relation between valve and transformer values.

As an example of well-designed receiving circuits that will give excellent quality of reception the three diagrams, on page 220, representing receivers recommended by the B.B.C. engineers for school use will prove interesting.

Now that we know more or less what is happening inside our receiver, the next point to consider is whether our present receiver really meets our requirements. A great deal depends on the position of the residence.

If you expect Loudspeaker results you must have an adequate set.

The following are the recommendations of the B.B.C.:

Loudspeaker Ranges.

DAVENTRY 5XX.

Over 150 miles, a minimum of 5 valves (two H.F. stages, one detector valve and 2 L.F. stages).

The next most popular type of set is a four valve set consisting of one stage H.F., a detector valve and two L.F. stages transformer or R.C. coupled. Such a set, if well designed, will bring in all the British stations, given a favourable position, and a number of foreign stations.

Please remember that the performance of any set depends greatly on the locality.

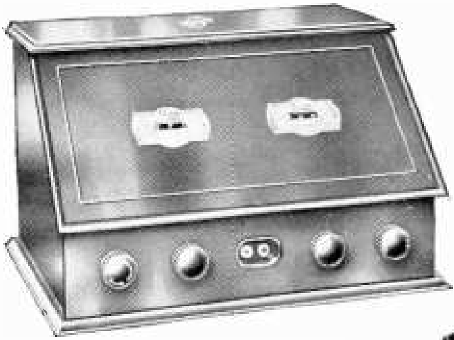
There are also on the market five and seven valve sets which are highly selective, and have large Loudspeaker ranges. Such sets are necessarily expensive from the point of view of initial outlay.

When deciding on a set ask the advice of your friends, consult your local wireless dealer and, if necessary, write to the manufacturers explaining your requirements.

In conclusion there is one point to be noticed. Do not judge wireless reproduction by the demonstrations given by some wireless dealers, who place a Loudspeaker over their doorway and let it compete with the local traffic. You cannot obtain even a semblance of good reproduction unless the acoustic conditions are reasonably good. You may imagine what the acoustic conditions are when a Loudspeaker is placed in the open air in a main street. The wireless dealer who resorts to such demonstrations does himself more harm than good, as people go away under an impression that wireless means a terrible noise from an overloaded Loudspeaker competing with every passing lorry.

If you want to know what real wireless reproduction means, visit one of the numerous B.B.C. demonstrations of their recommended sets, usually run at local wireless exhibitions, and hear for yourselves. It will be a revelation to you how good wireless reproduction can be. There are many people trying to listen with poorly designed home-made sets turned out by some schoolboy for a birthday present. The author once came across such a set, which would not have been out of place in any of Heath Robinson's drawings. The old lady who received the set as a present from her young nephew was extremely proud of it. Every time you tried to tune, the tuning coils fell out of their holders, and the old lady peeevishly insisted that the set

RECEIVERS



Marconiphone
Model "34"
Short Wave
Receiver

Marconiphone "Super Eight"
Super-Heterodyne Receiver

Marconiphone
"61"
Six Valve Receiver

PORTABLE RECEIVERS

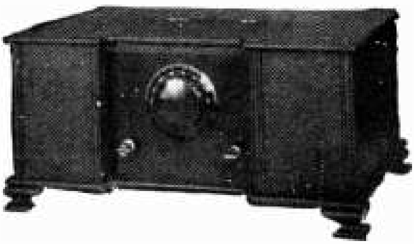
Marconiphone

BATTERY CHARGERS AND ELIMINATORS

Met-Vick Eliminator

Ferranti Permanent Trickle Charger

MAINS RECEIVERS



The Gambrell Table Model Two Mains Receiver should be left alone . . . the coils were all right if you did not touch them. The set was supposed to be working a Loudspeaker; you could hear a noise of sorts if you were quite close to the speaker . . . still, isn't he a clever boy? It is lucky for the boy that he did not meet the author that day, there would have been murder done.

CHAPTER XXV

FAULT FINDING

ONE cannot lay down hard and fast rules for finding a fault in a receiver, but it is possible to indicate the general procedure in fault finding.

The whole secret of success and quickness is a methodical search in which one part after another is investigated. Always start with the aerial system. See if the aerial *is* connected to the set by the aerial-earth switch. Also see if the wire on the aerial terminal is gripped tight.

Sometimes, especially in wet weather, intermittent signals are observed; they come on and off with a series of cracklings and rustlings—your aerial wire is touching the roof or a bough of a tree.

If the aerial connections are in order, inspect the earth connections.

The earth wire may be broken at the soldered point. If clamped to a waterpipe the clamping may not be tight enough, or the joint dirty.

If this is all right, see that the earth wire is tightly gripped by the earth terminal of the set.

As *a copper wire will often break inside insulation*, feel all the way through a suspected wire or give it a continuity test as explained below.

In cold weather the earth may become frozen and signals will become faint. A kettleful of hot water poured over the earth will remedy that.

The next suspicious points are the L.T. and the H.T. battery.

Measure the voltages of the accumulator and the battery. Inspect the connections. Sometimes a purring noise is heard during reception. This is often due to the L.T. leads (i.e.

leads to your accumulator) wearing out at the spade tags or breaking completely, but still hanging on by the insulation.

The gap may be very small, and an arc will take place across the break, resulting in purring noises.

If the supply is in order test the valves. Take all the valves out and measure the voltage across the filament sockets of each valve holder.

If there is no voltage it means that a connection is broken inside the set. A very hard fault to locate is a broken connection inside an "antiphonic" valve-holder. If the voltages across the filament are O.K., measure the voltages across one filament socket and the anode socket (take care to use the right range of your voltmeter).

If the voltages are all right, put the valves in (first disconnecting the H.T. battery, in case of accidents) and try for signals. If no signals, replace each valve in turn by a spare valve, or interchange valves; this sometimes does the trick.

If spare valves make no difference there is a fault somewhere inside the set. Disconnect the set completely and inspect the wiring. If the wiring does not show any faults, i.e. there are no broken wires or unsoldered joints, and there are no wires touching, turn your attention to your transformers. The primary coil or the secondary coil may be broken. Carry out a continuity test.

Put a potentiometer across your accumulator and, with the help of the voltmeter, adjust your voltage to one volt between one terminal of the potentiometer and the slider. Connect one end of the potentiometer to one terminal of the suspected coil and one of your telephone tags to the other terminal of the transformer coil. Touch with the other tag of your telephones the slider of the potentiometer, and if the suspected coil is O.K. you should hear a click. If there is no click, move the slider a little forward, and if there is still no click the coil is "dis."

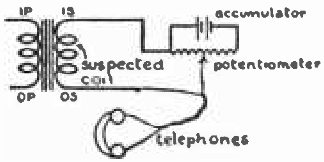


FIG. 128

Replace your transformer.

If resistance capacity coupling units are used suspect the clipped resistances and all the connections.

Sometimes you hear a noise like a machine gun fire; this means that your detector valve grid leak is out or is making bad contact.

If you proceed in this manner you are sure to find the fault sooner or later, but whatever you do, do not take your set to pieces till you are sure that your aerial and earth systems are O.K., that your H.T. and L.T. supplies are in working order and that your valves are not burnt out.

Loud crackling noises in your Loudspeaker mean that the H.T. battery has developed a fault. Test the voltage of each tapping and you are sure to find a "dud" cell. Loud crashes mean atmospherics.

As you realise, a thousand and one faults may occur in your sets, but as you acquire practice you will soon find your way about.

In conclusion, it is necessary to mention a source of trouble that may occur with "plug-in" components such as coils, H.T. transformers, etc. The plugging-in is done by means of inserting split legs into sockets. Very often the split leg does not make proper contact with the socket. Introduce the edge of your pocket knife into the split and *gently* force the halves apart. This will ensure good contact.

If you keep all your terminals and components clean, and often use measuring instruments, you will find that you are able to prevent many a fault, and prevention is better than cure.

Books to Read :

Talks about Wireless, Sir Oliver Lodge.

A First Course in Wireless, by R. W. Hutchinson, M.Sc., A.M.I.E.E.

Wireless Valve Receivers and Circuits in Principle and Practice, by R. D. Bangay and N. Ashbridge, B.Sc., A.M.I.C.E.

Wireless step by step, Dictron.

CHAPTER XXVI

HIGH TENSION SUPPLY AND BATTERY ELIMINATORS

A "WIRELESS" receiver is a piece of apparatus which will multiply minute variations of voltage, and therefore any departure from absolute voltage constancy in the source of high tension supply will be multiplied and come through in the form of noises. If the variations are of regular frequency emanating from the electric mains they will come through as a steady note or hum. The better the Loudspeaker and the lower the frequencies to which it will respond, the more serious does this become.

Voltage constancy is, therefore, the very first essential in a source of H.T. supply.

A *small internal resistance is the second desirable attribute.* The third consideration is *the ability to supply comparatively heavy currents on demand, unaccompanied by any appreciable fall in voltage* or other restriction.

As regards internal resistance, any ohmic resistance in the source of H.T. supply will produce serious trouble under two distinct heads:

(i) Being common to various valve circuits, it gives rise to a phenomenon called "back coupling" or "motor boating," which impairs the purity of reception. This cannot always be overcome by the usual expedients of blocking condensers* (with risk of insulation leakage or breakdown), or separate resistance feed to the anode of each valve. The latter also inevitably reduces seriously the voltage actually reaching the anodes.

* A blocking condenser is a condenser which isolates one part of the circuit from another, as for instance the grid condenser.

out any irregularities that may be present. Although this sounds fairly simple in practice it is quite a problem to obtain satisfactory results, and that is where the manufacturer comes in. There is a number of battery eliminators on the market that can be relied on to give satisfactory results.

The eliminator, if it is to be a success, has to smooth out an unsteady voltage sufficiently to get rid of any hum or noises that may be present. This can only be achieved by the inclusion of chokes in series with the circuit, and the anode current must pass through these chokes.

The greater number of turns on the choke the higher is the inductance, and the better the choke will fulfil its duty in our circuit, but the greater is also the ohmic resistance.

It is, therefore, obvious that the more nearly the eliminator approaches perfection in smoothing the voltage, the more seriously it must fail on the count of ohmic resistance in the H.T. circuit unless the chokes are wound with very thick wire, involving a rise in size and therefore in cost.

It is important that a D.C. eliminator should be very well designed, as the whole mains system back to the generator at the Power station is included in the H.T. supply circuit, providing numerous sources of disturbance.

A.C. Supply.

If your supply is an alternating one, the problem of mains supply is somewhat more difficult, for not only has the voltage to be stepped down by means of a transformer but the current also has to be rectified.

In "wireless" reception we know two rectifiers: the crystal and the valve. But in the case of low frequency rectification (standard industrial frequencies between 25 and 100 cycles per second) there are numerous rectifiers, as you can see from Chapter XXVII.

A good deal depends on the nature of the rectifier employed.

In the case of an A.C. eliminator the resistance of the circuit is increased by the resistance offered by the rectifier.

These resistances cannot be avoided, and give rise not only to back coupling, but also to a fall of voltage supplied to the anode in proportion to the current passing.

An eliminator will fail progressively as more and more current is being taken from it, since not only is the voltage drop greater, but also its smoothing is impaired, due to a reduction in the impedance of the chokes as saturation of the cores is approached, that is to say, hum increases. An eliminator is very convenient to use, but its performance, as you can see, depends on sound design and the employment of first class components in its manufacture.

One has to be very careful, when buying battery eliminators, to buy a reliable product, for with a cheap article there is always an element of danger to one's property and life. The main's voltage is always considerable, and if inferior components are used a breakdown is sure to occur at some time or other. Such a breakdown may result in a fire, or an electric shock to the operator or a member of the household. Whatever you do, do not use "home made eliminators," as more than often a "little knowledge is a very dangerous thing." The danger arises from high potential surges set up in the chokes and condensers which form the smoothing system.

You no doubt appreciate that a battery eliminator is a different thing from an accumulator charger. The former dispenses altogether with accumulators and batteries, while the latter is simply used for charging accumulators, and therefore does not require any smoothing system. (See Chapter XXVII.)

There are sets on the market incorporating battery eliminators, so that the set becomes a "main's receiver," and can be run directly from a lampholder.

A man being what he is, "a lazy animal," will naturally welcome a main's receiver, as there is nothing to do to it . . . just attach it to a convenient lampholder and press the switch whenever you wish to listen. One does not have to worry about charging accumulators or buying H.T. batteries, but . . . (there is always a "but") it is not an absolutely ideal method of obtaining H.T. and L.T. supply. The method has drawbacks, but then there are drawbacks to everything, and therefore the way in which you obtain your supply is largely a question of convenience.

There are many things to consider: Presence of an electrical supply in one's house (you cannot do as an old lady did at the exhibition, purchase a main's set and then ask which end is connected to the gas pipe), charging facilities, and last but not least the capacity of one's pocket (this capacity is the capacity for losing or gaining not electrons but the coins of the realm).

Whatever method you choose, make sure that you are buying a reliable product.

CHAPTER XXVII

CHARGING ACCUMULATORS FROM THE MAINS

Communicated by the Engineering Staff of the Chloride Electrical Storage Company (makers of "Exide" Batteries).

THE charging of accumulators from the mains falls into two quite distinct categories:

(1) Charging from D.C. (Direct Current) Mains.
(2) „ „ A.C. (Alternating Current), Mains.

Battery Charging from D.C. Mains.

The current is, as the term implies, uni-directional, and therefore accumulators can be charged off D.C. mains direct, without the interposition of any apparatus other than a simple resistance. The dwellers in districts fed with D.C. or those possessing their own private house lighting plants (which are invariably D.C. also) may for this reason conceive themselves as more fortunate, from the point of view of battery charging, than their brethren with A.C., since the latter needs the assistance of transformers and rectifiers before it can be used for this purpose.

Actually, as will be seen, this is not the case, for charging from D.C. is associated with very strict limitations—and while, within them, the problem is to some extent simpler, it is much harder to give the layman simple rules which will apply universally.

Fig. 129 sets out the simple, and universal, circuit for battery charging from D.C. mains.

A battery, and a resistance, are connected in series across the mains.

Suppose the mains voltage is 200 volts. Then if a "wireless" low tension accumulator of, say, 6 volts only was connected straight across them there would obviously be a short circuit, for there would be an unbalanced voltage of 200−6=194 volts. This would entail an enormous rush of current, and the house fuses, if in order, would blow, with considerable risk of fire, especially if the battery was a celluloid one. This unbalanced voltage must be absorbed, and that is the function of the resistance, which may be thought of as a kind of throttle.

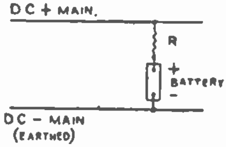


FIG. 129

Ohm's Law: Current $=\dfrac{\text{Voltage}}{\text{Resistance}}$, makes its evaluation a simple matter.

Suppose we want to charge at 2 amperes.
Voltage to be absorbed is 194 volts.

$$\text{Then } 2=\frac{194}{R}, \text{ or } R=97 \text{ ohms.}$$

Actually, when an accumulator is being charged, its voltage rises above 2 volts per cell, and lies between that and about 2·6 volts per cell, the exact value of its back E.M.F.* depending upon its state of charge and the magnitude of the charge current passing. In the case of low tension accumulators, however, where the voltage is only a small percentage of the main's voltage, this makes so little difference that it can be neglected, and the accumulator voltage may be regarded as equal to its nominal voltage, 2, 4, or 6, volts, as the case may be.

If, then, we make the resistance equal to 97 ohms, we shall attain a voltage balance with 2 amperes passing approximately. The conception of a "voltage balance" should be grasped if possible, as it is the essence of the problem and makes everything clear.

2 amperes passing through 97 ohms involve a voltage drop of 194 volts, with the odd 6 volts dropped in the battery—thus making up our 200 volts to balance the mains.

If we wanted to charge at 1 ampere only, the resistance,

* The E.M.F. due to the accumulator itself.

to effect a balance, would have to be doubled, viz: 194 ohms, while, if the charge rate was to be 4 amperes, the resistance would be halved, viz: 48 ohms. The product of Resistance ×Current must always be equal to Mains Voltage—Battery Voltage.

Now for the high tension accumulator; suppose the nominal voltage of this is 120 volts (60 cells). Here we cannot neglect the voltage rise on charge. As already mentioned this varies according to the current and state of charge, but we can approximately average it sufficiently closely for most purposes at 2·35 volts per cell. The back E.M.F. will therefore be 141 volts. Thus the unbalanced voltage to be absorbed in resistance=59 volts.

Let us charge at 100 milli-amperes=·1 amp:

Then resistance must be $\frac{59}{\cdot 1}=590$ ohms.

But if we want only to trickle charge at say 20 milli-amps., the resistance must be 2,950 ohms.

It should be noted in passing that an accumulator of 100 cells, nominally 200 volts, floated straight across 200 volt mains, *could never be fully charged*, and an accumulator of higher voltage than the mains would *discharge itself back into the mains*. If, therefore, the mains are only 100 volts, an H.T. accumulator voltage of 86 is the maximum that could be kept charged. Those with private plants of low voltage, say 50, are even worse off. Such a man, wanting to charge his 120 volt H.T. accumulator, could, however, do so by dividing it into 3 banks of 40 volts each, and charging these in parallel. Suppose it was required to pass 50 milli-amps. through all the cells, i.e. ·05 amp. Back E.M.F. on charge would be approximately 47 volts. Voltage to be absorbed in resistance is therefore 3 volts.

Since ·05 amp. has to go through *each* bank, and there are three of them, total current to pass through resistance=·15 ampere.

Therefore, resistance=$\frac{3}{\cdot 15}$=20 ohms. The situation is then as shown in Fig. 130.

This is the obvious way. But there is a better way. The common resistance provides that a common voltage of 47 is impressed on all three batteries.* But if one bank is a little more discharged than the others, or if it contains one or two weak cells, with a consequently lower back E.M.F., that bank will take more current than the others, perhaps a good deal more, thus starving the others of their share. It is better, therefore, to arrange matters as in Fig. 131 with a separate resistance for each bank—each resistance, by the same law, now being 60 ohms. This will ensure the desired charge current passing through every cell.

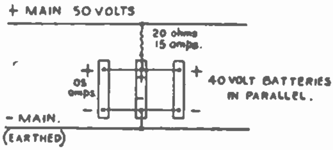


Fig. 130

Let us again glance at the theoretical case.

Let the Mains Voltage be V_M, Battery Voltage V_B, and V_R the voltage dropped in resistance $R = RI$ where I is the current passing.

$$V_M = V_B + V_R$$

Now the power taken from the mains is measured in Watts=Volts×Current (amperes), and they are the basis of our quarterly electricity bill.

Multiplying through by I, we get:—

IV_M = Watts from Mains = IV_B (Watts expended usefully in charging the battery) + IV_R (Watts wasted in resistance).

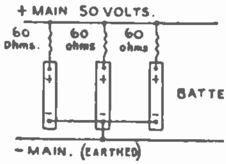


Fig. 131

If Mains Voltage, $V_M = 200$, $V_B = 6$ and $V_R = 194$ and Current = 1 ampere.

We have, Watts from Mains = 200

and on the other side, Watts expended usefully in

charging	6
Watts wasted in resistance	194
	200

* Let us call a bank of accumulators a battery

So that only $\frac{1}{33}$ of the energy we pay for does any good.

One unit, which costs in many districts 6d.=1,000 watt hours.

Suppose we want to put 50 amp. hrs. into a 6 volt low tension accumulator.

We have to take 33 times that energy from the mains to do it, viz:—1,650 watt hours, costing nearly 10d. whereas the value of the energy actually put into the battery is only ⅓d.

In all cases, ratio of useful to wasted energy $= \frac{V_B}{V_R}$

$$= \frac{\text{Battery Voltage}}{\text{Difference between Mains and Battery Voltage}}$$

With a high tension battery, we get much more favourable results.

Say Mains=200 volts. Battery voltage 120. Back E.M.F. 141 volts.

$$\text{Then } \frac{\text{Useful}}{\text{Wasted}} \text{ energy} = \frac{141}{60} = \frac{7}{3} \text{ roughly.}$$

Suppose, to recharge, 6,000 milli-ampere hours are required.

6,000 milli-amp. hrs.	= 6 amp. hrs.
	= 846 watt hrs.
Watts wasted	= 234 ,, ,,
Total from Mains	=1,080 watt hrs.

Cost, about 6½d., of which only about 1½d. is wasted.

There only remains to be considered the type of resistance to use. The most usual and convenient is an ordinary lamp bulb, suitable for the Mains voltage. There can then be no fear of a dangerous short circuit, for the lamp itself can stand the full voltage of the mains.

Lamp bulbs are usually marked in watts, this indicating the rate at which they absorb energy.

Take the case of a 200 volt. 60 watt bulb.

$$200 \times \text{current} = 60 \text{ watts.}$$

$$\text{Therefore, the current taken} = \frac{60}{200} = \cdot 33 \text{ amp.}$$

and its resistance = 666 ohms.

$$\text{In general, Resistance of a lamp} = \frac{(\text{Voltage})^2}{\text{Watts}} \text{ ohms.}$$

$$\text{Current passed by a lamp} = \frac{\text{Watts}}{\text{Volts}} \text{ amperes.}$$

A lamp of suitable wattage for the purpose in view can thus be selected, and 2 or more can be connected in series or parallel, or any combination of both, to fulfil any given circuit conditions.

N.B. The resistance of a lamp so arrived at is its resistance at full load only, i.e. filament bright. As the current through the lamp, and with it the filament brightness, falls, the resistance of metal filament lamps falls, while that of carbon filament lamps rises. These effects must be watched for when laying out a charging circuit. Resistance curves against current for both types of lamps are obtainable. For battery charging the metal filament lamp has the better resistance characteristic of the two.

When connecting lamps in parallel, in order to pass a larger current, it is simpler to regard each as a channel for the passage of so much current. When connecting them in series, in order to increase the total resistance, it is simpler to think of the resistance of each. Each case has to be worked out on its merits; it is not possible to give a simple formula to cover every set of conditions. This has to be borne in mind in the installation of D.C. charging apparatus. Some battery makers give useful tables of recommended lamp wattages for recharging in their battery instructions.

Except where convenience is deemed worth a high price the home charging of single low tension accumulators from high voltage D.C. mains has to be regarded as uneconomical, but this does not, of course, apply to charging stations where several accumulators may be connected in series, so making the battery and mains voltages less disproportionate.

But there is a method whereby the home charging of L.T. accumulators may be less uneconomically carried out. This consists of passing the current from one or more of the house lights through the accumulator when these lights would be on in any case, thus reducing the cost of recharging to nil, Fig. 132.

The circuit from a group of lights may be intercepted at some suitable point, often the fuse box, though in that case care should be taken to include a suitable fuse in the battery circuit.

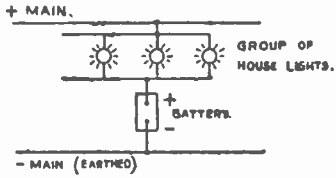


FIG. 132

Special plugs for the purpose are however obtainable, which can be permanently wired into the house circuits by any electrician, and special plug adaptors are also supplied for plugging into any lighting point and utilising the current passing through that lamp, the lamp furnishing the necessary resistance.

In such a case the brightness of the lamps would be slightly reduced, due to the voltage reaching them being reduced by the amount of the battery voltage. But this is so small a percentage of the Mains Voltage where a low tension accumulator is concerned that the dimming is usually unnoticeable.

This method is, however, open to several objections, and should not be attempted except by those with some battery and considerable electrical experience. It is, in any case, obviously impracticable with high tension accumulators.

When charging, the positive of the battery must go to Mains positive, and negative to negative, which involves a knowledge of the polarity of the mains. This can be ascertained by means of pole-finding paper or by dipping wires from the mains, with a lamp in circuit as a resistance, into a weak solution of salt and water. Bubbles will be given off from both wires, but much more rapidly from one than from the other. The wire from which bubbles come the more rapidly is the negative.

A wireless battery should never be connected to the mains for "charging" while actually operating a wireless receiver. In a D.C. system, either the positive or the negative may be the earthed main. If it is the positive, and the battery negative is earthed through the receiver, a serious short circuit will result. Even if the earthed main is the negative the station earth and the set earth may nevertheless not be at quite the same potential, and in any case it is against the regulations to earth either main. The batteries should always be completely disconnected from the receiver for charging from D.C.

It is recommended that it be ascertained which main is earthed, and that, when charging, the battery be always connected to the earthed main, the resistance, lamp or otherwise, being interposed between the battery and the unearthed main. This keeps the battery at low (earth) potential.

Which main is earthed is easily ascertainable by connecting one pole of a lamp bulb to earth, and connecting the other to the two mains in turn. The main which causes the lamp to glow brightly is the *unearthed* main.

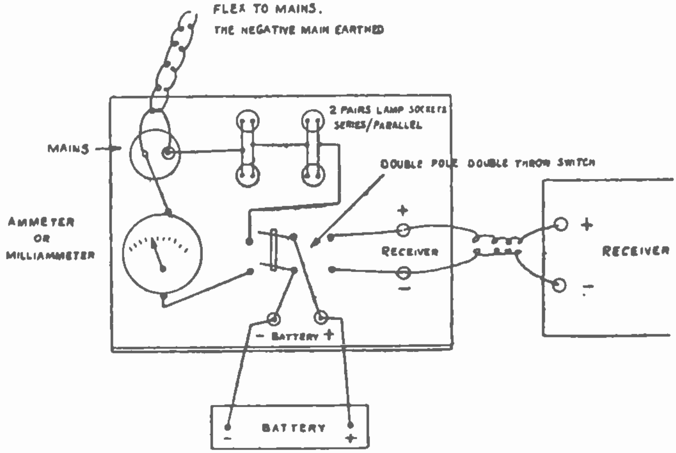


FIG. 133

A simple and satisfactory charging layout for D.C. mains is shown diagrammatically, Fig. 133.

Two pairs of lamp sockets for lamp resistances are shown, connected series/parallel, so that a very large range of resistances would be obtainable with standard lamps, and a short circuiting plug.

A simple Double Pole Double Throw switch alternatively puts the battery on to the receiver, isolating the mains, or puts the battery on charge but isolated from the receiver. The same layout could be used for either H.T. or L.T. battery charging, or a combined arrangement for both could be made by duplicating the switch, resistances, etc. A Grid Bias

Battery charging circuit could be added in the same manner. The Negative main being the earthed main, the resistance lamps are inserted between Battery+ and Mains+. This layout is well adapted to the system of permanent trickle charging which is the basis of the Exide Trickle Charge for A.C. mains, described below.

Such an apparatus can be made up for a few shillings; exclusive of the meter, which is desirable but not strictly essential once the correct resistance lamps have been found.

Battery Charging from A.C. Mains.

In the case of A.C. Mains, both current and voltage alternate rapidly in direction. Starting from zero, the current and voltage rise to a maximum in one direction, then fall to zero, reach an equal maximum but in the opposite direction, and again return to zero. That is known as one complete cycle or period, and the number of such complete cycles that occur per second is known as the frequency or periodicity of the mains. In England the frequency of different mains systems varies from 25 to 100 cycles per sec.

The voltage or extent or amplitude of each swing is also different on different systems, and any apparatus to be installed must be made suitable for both the voltage and periodicity of the particular mains system on which it is to work. Consequently, when ordering any A.C. apparatus, the voltage and periodicity of the mains should always be stated. These are almost always given on the supply meter.

If raw A.C. current was passed through a battery, one half swing would tend to charge it, but the following half swing would discharge it, if not accompanied by a dangerous short circuit. Means must, therefore, be found to cut out all the half swings or waves in the unwanted direction, the others being passed through with as little loss as possible.

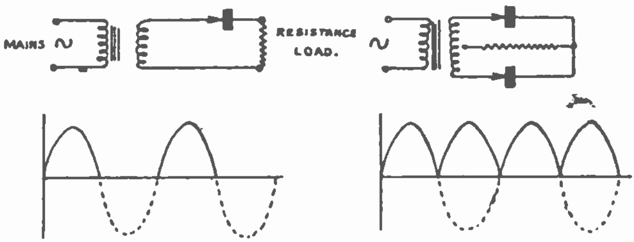
This is done by a Rectifier. A rectifier is a device which presents a low resistance to current passing in one direction, and a very high resistance to current passing in the reverse direction. The lower the former, and the higher the latter, the better the rectifier. In any case the resistance to current in the unwanted direction should be so high that the reverse current is made so small as to be negligible.

It is usual to interpose a transformer between the mains and the rectifier charging circuit, the latter being connected to the secondary. This has three big advantages.

(*a*) It ensures complete metallic separation of the mains from the battery rectifier circuit, thus eliminating any complications or danger due to a common earth.

(*b*) It enables, by suitably proportioning the wire turns in primary and secondary, any desired secondary voltage to be exactly obtained.

(*c*) It enables full wave rectification to be obtained by providing the secondary with a central tapping.



(*a*) FIG. 134 (*b*)

Fig. 134 shows the arrangements of a simple rectifier circuit with a plain resistance load, and the nature of the rectified current obtained (*a*) with half wave rectification, (*b*) with full wave rectification with centre tapped secondary and two rectifiers.

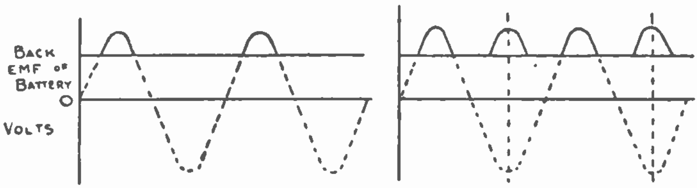


FIG. 135

If the load is a battery, or combination of a battery and resistance, the results are as in Fig. 135, this being a voltage curve. The current curve would be similar in shape and characteristics.

It is obvious that no current can pass through the battery until the rectified voltage exceeds the back E.M.F. of the battery. The full line pulses represent therefore the voltage available to drive current through the battery in a charging direction, and the current that actually passes will be similar. Charging current thus only passes at the peaks of the waves, and it will be seen that as long as the *peak* voltage exceeds the battery back E.M.F. some pulses of charging current will pass, though their magnitude and duration get smaller and smaller as the battery voltage approaches the peak voltage.

It will also be seen that the charging current is not steady, but is a series of pulses separated in time. The equivalent steady charging current is the average of these on a time basis. The reading given by a moving coil D.C. ammeter or milliammeter gives, sufficiently closely, this average.

Rectifiers for battery charging are of 5 main types, but there are several forms and makes of each:

(*a*) *Thermionic Valves*—similar to the ordinary wireless valve but with no grid.
(*b*) *Gas or Glow Discharge Valves.*
(*c*) *Mercury Arc Rectifying Valves.*
(*d*) *Electrolytic Rectifiers.*
(*e*) *Dry Metallic Rectifiers.*

Space does not permit a detailed discussion of their several features, but each type has its sphere of usefulness, and all are widely employed.

The dry metallic rectifier is the most recent development and one of considerable promise. It has considerable advantages over any of the valve types since, as far as can be seen, and if not overloaded, it is practically everlasting, which cannot yet be said of any valve. The best known type consists of alternate discs of lead and copper pressed together and held by an insulated longitudinal bolt, all the copper surfaces facing one way being oxidised by a secret process. Rectification is believed to take place at the copper-copper oxide contacting surfaces, though the nature of the effect is not yet fully understood.

Both dry and electrolytic rectifiers eliminate the provision of extra energy for filament heating as required by thermionic and gas valve rectifiers. This extra energy always necessitates a special low voltage winding on the transformer.

With both dry and electrolytic rectifiers full wave working can be provided by arranging an extra pair of rectifying elements in the form of a bridge, a centre tapped secondary winding then being unnecessary, Fig. 136. With valves, full wave rectification is usually provided by making up a valve with two separate anodes and a common kathode, the filament. The latter is fed from a separate low voltage secondary winding, the main secondary being centre tapped, Fig. 137.

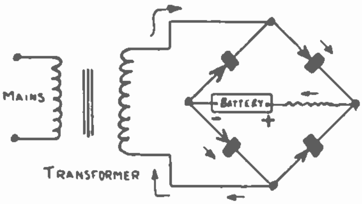


FIG. 136

Fig. 137 is the usual valve rectifier charging circuit, the resistance R being a stabilising resistance, the presence of which is essential not only to regulate the current, but also to protect the valve anodes from excessive current at each peak.

Valve rectifiers present certain problems of their own as regards charge current regulation, and the problem and limitations in either direction are different according to category of valve used. In general, charging apparatus making use of valve rectifiers does not lend itself to current regulation over such a wide range as electrolytic or dry rectifiers, in which these peculiar problems are wholly absent. With the dry or electrolytic rectifier, the charging current can be varied from zero to the full load rating of the rectifier by simply varying the resistance in series with the battery, as in the case of D.C. charging, and this gives them a considerable advantage over valves.

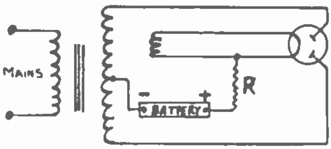


FIG. 137

As between dry and electrolytic types, the electrolytic rectifier consists of a cell containing an electrolyte, the nature of the electrolyte and electrodes varying in different types. Gassing takes place to an extent roughly proportional to the current passing. This means that they have to be topped up at intervals with distilled water. The operation of a dry rectifier is, however, associated with no internal action whatever. It requires absolutely no attention, it is absolutely noiseless, and it is moreover far less bulky than any electrolytic rectifier for the same output. There can be no doubt that for the home charging of wireless batteries the dry rectifier possesses enormous advantages over all other types, and as far as can be seen at present it is associated with no peculiar disadvantages of its own.

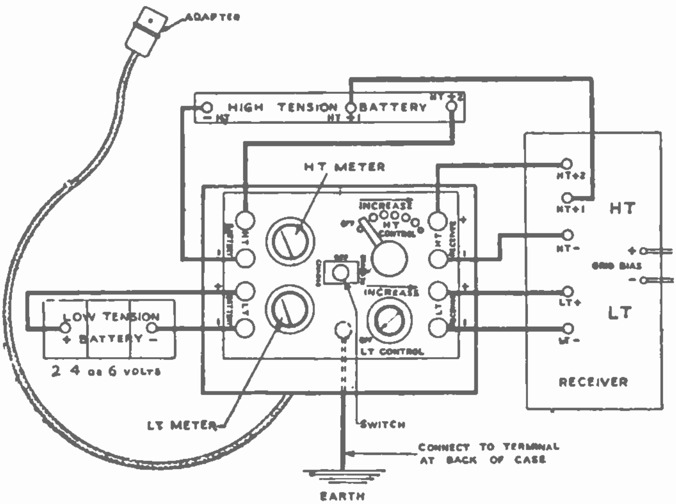


FIG. 138

Ready-made apparatus for the home charging of wireless batteries, both high and low tension, is on the market in a huge variety of forms, at all sorts of prices, and every type of rectifier is represented.

It would be quite impossible to review them all or even a representative number of types in the space of this chapter, but they all follow one or other of the basic principles and circuits already enunciated. It will suffice to describe briefly the Exide Combined High and Low Tension Trickle Charger, which has just appeared, as representative of latest and most advanced modern practice, and which is illustrated in Figs. 138 and 139.

This makes use of the Westinghouse dry metallic rectifier for both high and low tension charging circuits, the low tension circuit being arranged for full wave rectification by the bridge method, Fig. 136. High tension rectification is half wave only, the circuit being that of Fig. 134 (*a*), with the addition of the battery, of course.

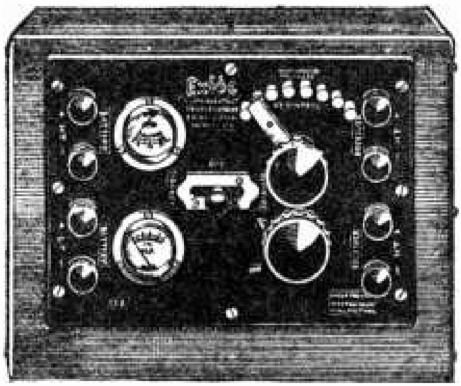
An adjustable variable resistance and a meter are connected in series with each charging circuit, the range of the low tension resistance being such that any desired value of charge current from zero to a maximum of ·5 amp. can be passed through low tension batteries of either 2, 4 or 6 volts, no other adjustment than that of the L.T. rheostat being required.

The H.T. rheostat permits of High Tension batteries of any voltage from 60 to 180 volts being catered for, at the same time providing for adjustment of the H.T. charge current to the desired value up to a maximum of 40 milliamperes.

Two sets of terminals are mounted, marked respectively "Batteries" and "Receiver," the charger being interposed between the batteries and receiver, and permanent connections made to both. Changing over from "Charge" to "Receive" and vice versa is effected by means of single multipole switch mounted in the centre of the panel.

This charger, as the schematic circuit diagram Fig. 138 will show, is intended to be an integral and permanent part of the receiver installation, so differing from the majority of chargers which require to be connected up to the batteries for charging, left on for a period, and then disconnected. Moreover the majority provide no current regulation, nor any meter to show whether current is passing, or its value. With these, charging has to be conducted at the set rate, which may or may not be convenient or suit the batteries, and the onus is also thrown on the operator to decide when and for how long charging should be conducted, which decision involves work with a voltmeter and hydrometer and some battery knowledge.

The Exide Trickle Charger operates on an entirely different and much more sensible principle. It is designed to keep the batteries charging permanently during the whole of the time that reception is not actually in progress, and at such a rate, having regard to the current consumption of the receiver in use, that the capacity taken out of the batteries during a day's average reception is restored, with a little



EXTERNAL VIEW OF THE EXIDE TRICKLE CHARGER
FIG. 139

extra to spare, during the ensuing night and day, the batteries being by then absolutely fully charged against the next day's reception. The layman's doubts as to when and for how long he should charge are thus answered by the simple injunction: "Charge all the time reception is not in progress at a predetermined rate adjusted to the consumption and average daily use of the receiver."

A further advantage of this system is that the charging, being spread over so long a time, is at a very low "trickle" rate, at which considerable overcharging can be indulged in without detriment to the batteries. The charge rate setting is therefore not critical and can be made liberal. Also at these low charge rates the batteries gas very little, and topping up with distilled water is exceedingly seldom required.

A single example will best illustrate the whole system. A receiver taking 1 amp. of L.T. current and used *on the average* 4 hours per day. 4 amp. hours are taken out of the battery per day, to be put back over the balance of 20 hours. The charge rate is, however, set at ·25 amp. so that actually

CHAPTER I

THE LEGAL ASPECT OF LISTENING

BROADCASTING, if it is to give the maximum benefit to listeners all over the country, has to be regulated by laws like everything else.

As yet the legal position is not very complicated, but as time goes on new laws come into force, and it is quite likely that a few years hence matters will be as complicated as they are, for instance, in the case of patents.

The Licence.

Every listener in possession of receiving apparatus is required by the Postmaster-General to take out a licence for reception. This licence costs 10*s*. a year, and can be obtained at any Post Office. The following are the conditions upon which such a licence is issued:

1. The Licensee shall not allow the Station to be used for any purpose other than *receiving* messages in the premises occupied by the Licensee.

2. The Station shall not be used in such a manner as to cause interference with the working of other Stations. In particular, reaction must not be used to such an extent as to energise any neighbouring aerial.

3. The combined height and length of the external aerial (where one is employed) shall not exceed 100 feet. An aerial which crosses above or is liable to fall upon or to be blown on to any overhead power line (including electric lighting and tramway wires) must be guarded to the reasonable satisfaction of the owner of the power line concerned.

4. The Licensee shall not divulge or allow to be divulged to any person (other than a duly authorised officer of His

£1 for each succeeding year). Higher fees will be charged for more powerful stations.

7. *Aerials.*—Dimensions allowed are as follows: Combined height and length not to exceed 100 feet.

8. *Portable Stations.*—General conditions same as for fixed stations.

Power of portable sending stations will usually be limited to 10 watts.

Use will ordinarily be authorised only within a radius of 10 miles of a fixed point.

The applicant for authority to use wireless sending and receiving apparatus should complete the form of application and return it to The Secretary, General Post Office, London, E.C.1, together with the required evidence of British nationality, etc.

The fee should not be forwarded until formal application is made for it.

As the result of the International Radio-telegraph Convention, 1927, transmission will normally be limited to the following bands:—

Frequencies (in kilocycles per second).	Approximate Equivalent Wavelengths (in metres).
1,740 to 1,970	172·3 to 152·2
7,050 to 7,250	42·53 to 41·35
14,060 to 14,340	21·32 to 20·91

Where, however, sufficient justification is shown transmission will also be allowed on one or both of the undermentioned bands of frequencies:—

Frequencies (in kilocycles per second).	Approximate Equivalent Wavelengths (in metres).
28,100 to 29,900	10·67 to 10·03
56,150 to 59,850	5·34 to 5·01

Licensees will be required to possess apparatus of the piezo-electric crystal, or other approved type, for accurately measuring the frequency of the emissions.

Needless to say that an attempt to receive or transmit without a licence will lead to serious complications at a court of law.

Having obtained a licence all one need do is to fix one's aerial in position in accordance with the conditions laid down by the Postmaster-General, although there may yet be difficulties if you are not the owner but the tenant of the house in which you live. There are always landlords who object to a wireless installation, and may forbid you to install an outside aerial. The landlord should be approached and his permission asked. If he objects, and insists on his rights, you can do nothing until your agreement expires and you are free to act. It is just as well, when assuming a tenancy, to make one of the clauses of your agreement to cover a wireless installation.

As regards the relations of Landlord and Tenant from the point of view of wireless, there is a booklet published by the B.B.C., *The Listener's Aerial*, written by the legal adviser to the B.B.C., which gives a good deal of clear information on the subject, and can be obtained on application to the publishers.

As a rule the local authorities forbid road crossings by a listener's aerial, and should there be no choice in your particular case you should approach these local authorities and put your case before them. You never know, the members of the local council may be listeners themselves and may treat your application sympathetically.

Mains Units and Electricity Supply Companies.

The following are the main points as regards the legal position at present. These points have been officially stated by the B.B.C. in *World Radio*, issue dated 31st August, 1928, and therefore can be fully relied on. The B.B.C. are informed by their legal advisers that the position is as set out in the five clauses below:—

1. An Authorised Electric Supply Undertaker cannot refuse to allow a consumer to connect wireless or any other form of electrical equipment to the Undertaker's system; provided that the consumer is in a position to demand a supply. But the consumer may not use any equipment

which is likely to interfere with the supply to other consumers, nor may he increase his maximum load without due notice.

2. Subject as stated in paragraph 1 it is not necessary for the consumer to obtain the consent of the Undertaker before installing any particular type of apparatus such as wireless apparatus.

3. When an authorised electricity Undertaker wishes to change the system of the supply, the Undertaker has to obtain the consent of the Electricity Commissioners or in certain cases of the local authority (as for instance the L.C.C. in the London area). The Commissioners and the local authority have power to attach conditions to the consent; the consent is usually given subject to the Undertaker replacing any of the consumer's apparatus, which would include wireless equipment, affected by the change.

It is, therefore, the Undertaker's responsibility to bear the cost of the necessary alterations to all household apparatus, including wireless equipment. If the Undertaker refuses to make good the change-over of the wireless equipment, or disputes the cost of it, the consumer (listener) can take the matter to arbitration in accordance with the conditions of the consent, which usually prescribe this course; and it is understood that it is within the power of the arbitrator to award that the cost of the arbitration shall be borne by the party against whom the award is given. It is further understood that under the form of consent now issued by the Electricity Commissioners the Undertaker is relieved of the responsibility for replacing consumer's apparatus, of whatever kind, installed after notice (six months) of the change-over has been given to the consumer. But it is believed that the responsibility for making good wireless equipment installed, *bona fide*, before notification of the change-over of a supply is given, rests upon the Undertaker.

4. The Electricity Commissioners (or the consenting local authority) have power to vary the conditions governing the consent for the change in supply. It is not thought, however, that the Electricity Commissioners will exclude wireless equipment from the household apparatus which requires to be replaced because of the change in the supply, except as stated in Paragraph 3.

5. It should be noted that the foregoing paragraphs state the legal position regarding authorised Electric Supply Undertakers only—that is to say, those Undertakers who have undertaken to supply electric current under the provisions of the Electricity Supply Acts 1882 to 1926, and to them only. There are a few comparatively unimportant undertakings which have been set up independently of those Acts, and over whom the Electricity Commissioners have no control. It must therefore be clearly understood that the above-mentioned Acts in no way apply to them, and the rights of the consumers in such cases will have to be a matter of bargain between them and the Undertaking concerned.

If a listener requires any enlargement on the above clauses we would refer him to the Electric Lighting (Clauses) Act of 1899. Section 27 of this Act deals with the necessity for the consumer to install suitably protected wiring, as is used in ordinary house lighting installations.

Insurance Policies.

It would possibly be advisable for listeners, when contemplating the installation of a mains unit, to inform their fire insurance companies of the fact and give them facilities for examining the equipment which has been installed. It is not thought that any difficulty or objection will be raised if the apparatus is built according to the I.E.E. Regulations, as these have already been approved by the fire insurance companies.

In the event of any difficulty arising it would be well for any listener, who may consider taking a dispute to arbitration, first to communicate with the B.B.C., giving full details of his case, as it may be possible to assist him. It will, of course, be realised that the B.B.C. is extremely anxious to establish their listeners' rights in matters such as this.

Royalties.

The most important wireless patents are held by a number of Companies who pooled their resources and are granting licences to other Companies to manufacture sets at so much per valve-holder. The terms of licence naturally alter from time to time, and the latest information can always be obtained from the Marconi's Wireless Telegraph Company, Ltd. Every amateur constructor having built a set under certain patents becomes legally liable for payment of Royalties under those patents. Before building your set you should therefore apply to the Marconi Co., and submit your circuit, so that the amount of royalty due can be assessed.

The *bona fide* experimenter can have the free use of patents owned by the Marconi Company, but all who desire to be secure in this privilege must submit their names to the Company with a statement of the grounds upon which their claim is based. In approved cases a free personal licence will then be issued.

Subject to this single exception, no person who assembles a broadcast receiver from components (whether made by himself or others or partly by himself and partly by others), either for his own use or for disposal by way of sale, exchange, or gift, is entitled to use the patents owned by the Company except upon payment of the appropriate royalty. Upon payment of the royalty a specially numbered plate will be supplied by the Marconi Company to be affixed to the receiver. In cases of doubt whether or not a particular apparatus employs any of the patents owned by the Company, inquiry should be made.

Any person making use or disposing of an unlicensed receiver employing any of the patents owned by the Marconi Company is liable to legal proceedings for infringement.

CHAPTER II

PROTECTION OF INVENTIONS

IF you happen to be of an inventive mind you should know something of the means by which you can protect an invention and obtain a patent.

What constitutes an invention?

It is well to know first of all that one cannot patent a mere idea. The invention must be of a concrete form, perfectly practicable and useful. After you have actually taken steps to protect your invention you must make sure that your invention is *new* and is not already protected by someone else.

You doubtless realise that many people may have had the same idea before you and have patented an article or a piece of apparatus working on the same principle. Should your invention infringe the patent granted to another person, you may not be able to obtain financial benefit from it.

The best way to avoid difficulties and waste of money is to engage the services of a good Patent Agent, who will do the whole thing for you quickly and at a minimum of expense.

But it is just as well to know the usual routine for obtaining a patent. In the first place you have to prepare, in duplicate, a clear and concise description of your invention with all the necessary drawings and sketches. You then obtain from the Patent Office at 25, Southampton Buildings, Chancery Lane, W.C.2., an application form for a patent known as form No. 1. This form should be stamped with a £1 stamp at the Patent Office and handed in, after completion, together with the duplicate description of your invention, drawings, etc.

It is not an easy thing for a layman to draw up a patent specification, i.e. description of an invention, as there are many pitfalls that must not be overlooked, especially as regards the extent of the field covered by the invention which

CHAPTER III

HOW TO EXPERIMENT IN THE RIGHT WAY

MANY important discoveries have been made by amateurs or experimenters. As a matter of fact the possibilities of short wave transmission were discovered by amateurs. Thus the wireless enthusiast plays an important rôle in the progress of science and should be encouraged in every possible way.

Yet there are few "wireless" experimenters so far who are really doing useful work. The general tendency is to follow in the other man's track and try to do something that has already been done by someone else. No doubt it is necessary for everybody to cover the old ground, since it is in covering this ground that one begins to get new and fresh ideas. Generally speaking, comparatively few amateur experimenters know their subject well. One must first of all obtain the necessary knowledge of the whole field covered by one's subject. Periodicals are all right up to a point, but they cannot possibly give one much elementary knowledge.

Thus, before you start experimenting, study your subject thoroughly and exhaustively. Do not let any difficulties stop you. The usual stumbling-block is lack of knowledge of mathematics. You cannot hope to go far with your studies of Radio engineering unless you know a good deal of algebra, trigonometry and calculus, not to speak of arithmetic and geometry.

These subjects can be learnt either at home or at many evening schools throughout the country. It is a good thing to join the evening classes either of a recognised University college or of one of the many Polytechnic Institutes. Many evening Institutes of the L.C.C. also offer good facilities in this respect. Even should an evening class of a certain nature not exist at a particular Institute, if you can find a number of friends who are interested in your subject, a class will be opened for you.

The Headmaster of the evening Institute you have in view will tell you the minimum number of students required for a class.

If one is to experiment one must have the necessary instruments, which as a rule are expensive, especially the precision measuring instruments. Many of the University colleges, such as King's College in the Strand, The East London College in the Mile End Road (People's Palace), hold evening laboratory classes. Similar facilities are also offered by many Polytechnics. Such colleges and institutes have all the necessary instruments and equipment, and you can perform your experiments there much more successfully, as you have everything at your disposal and the best of expert advice. A couple of evenings a week will carry you a very long way, and will add enormously to your present knowledge.

And there are many things that want looking into. There is short wave work that is just beginning; little is known on the subject.

The oscillating properties of crystals require investigating. There is the question of high frequency amplification, offering a wide field of research. There are many problems to be solved on the question of selectivity, and screening your receiver from interference. There is the question of reproduction of wireless transmission by means of Loudspeakers, and the reproduction of gramophone records by electrical means.

There are many things that should be investigated, and who knows but that you may be the man to make a new and important discovery. Here is a straight tip: a cold valve is wanted, i.e. a valve that does not require a heated filament. Start straight away studying the electronic emission, study the present valves and see what you can do. If you discover a cold valve, you will make your fortune.

CHAPTER IV

RADIO ENGINEERING AS A CAREER

In order to become a fully fledged Radio engineer there is only one thing to do. Get your matriculation and join a college of the London University or some other University and take a three years' day course of electrical engineers.

There are no two ways about it. A Radio engineer must know a great many things, and he certainly cannot be a Radio engineer unless he is a qualified electrical engineer. An electrical engineer does not study electrical engineering only. He also studies a good deal of mechanical and civil engineering, as well as a good deal of physics and mathematics. A sound knowledge of chemistry is also indispensable. This is one thing overlooked by our colleges in training electrical engineers—chemistry is omitted. Yet in many cases it is indispensable, especially in the manufacture of accumulators and dry batteries. A chemist, as a rule, does not know much about electrical engineering, though he ought to nowadays.

Having taken a course of electrical engineering for three years, and having obtained your B.Sc., you should take a year's post-graduate course and specialise in wireless. After that you are ready to leave college, and your market price is about 25*s*. to 30*s*. a week as an apprentice to an engineering firm. The reason for this is that you have not yet had practical experience, and for the first year you are more or less useless to the manufacturer. He has to train you. Having had a good deal of laboratory experience you may be lucky enough to get into the research "lab.", but even then you will find yourself handicapped by lack of practical experience.

However, a time quickly comes when you become more and more valuable to your firm, and the salary begins improving by leaps and bounds.

If, in the meantime, you belong to the Institution of Electrical Engineers (you can become a student member in your first year at college) and go to the numerous meetings held there you will be sure to keep abreast with all new developments. When you have gained the necessary practical experience you can become an Associate Member of the Institution (A.M.I.E.E.) and later on a full member (M.I.E.E.). Full particulars of the B.Sc. course can be obtained from the Head Office of the University of London.

When you leave college your technical education is by no means finished, it is just beginning. New books appear on the subject, and you must make acquaintance with every important publication. These can be obtained at the library of the I.E.E. The I.E.E. also publishes for its members the proceedings of the institution and the so-called "Science Abstracts" which keep you posted on all advances made in your subject from month to month; this information being given in tabloid form is easily assimilated. For those who cannot devote three or four years of their time to study without earning their living, the road is by no means closed. They can do the same thing in the evenings, and take their degree externally. This naturally takes longer, but many people have done it. Evening study is a very good plan, especially if it is combined with practical radio work during the day.

Wireless Operators.

To become a "wireless" operator at sea is not a career in itself; it is only a means to a career. A "wireless" operator, if he is a young man, is fairly well off, but he cannot afford to marry even on the maximum operator's pay. Still, few young men have the opportunity to travel round the world and see foreign countries. Here is a means of doing so as a part of one's education, and, say, three years' travelling in the fresh sea breezes will do any man a great deal of good.

One also gets used to discipline and obedience, which is an asset in any walk of life.

Incidentally, during your training and subsequent work, you will learn much about "wireless" apparatus, transmitting and receiving, and, having finished your travels, there is every chance for you to take up a good position with a "wireless" firm. There are many managers and salesmen who had their apprenticeship at sea, and most of them are doing well.

How to become a "Wireless" Operator.

(By courtesy of the Marconi Co.)

It is probably no exaggeration to say that the Wireless Department of the Mercantile Marine has, more than any other, loomed large in the imagination of the general public during the last fifteen years. From the popular point of view this is mainly due to the many dramatic and thrilling incidents in which the personnel of the "Wireless" Telegraphy Service has figured, but it is also largely due to the fact that during recent years "Wireless" Telegraphy has passed from the state of being a scientific novelty, which might or might not do what was claimed for it, to a state of being a positive and valuable asset to navigation and safety. Such a service makes a definite appeal to a section of British youth.

Before entering upon a course of study or training, the prospective candidate should satisfy himself that he is prepared to spend many years of his life at sea, and that the conditions and remuneration offered are such as appeal to him. Details regarding the latter may be had from any of the wireless companies, all of whom have offices in London and the main seaport towns of the United Kingdom. The number of shore positions available is not large.

The conditions of entry into the "Wireless" Service (M.M.) are:

1. The applicant must be the holder of a certificate of proficiency in radio-telegraphy issued by the P.M.G.
2. Must be of British nationality.
3. Be in a sound state of health, and able to take service in any part of the world.

Before enrolling as a student, the prospective candidate is advised to obtain from his own doctor a certificate to the effect that he fulfils this condition, especial regard being paid to hearing and the absence of any deformity.

The most suitable age to commence studying for the service is from 16 to 20 years. There is no fixed standard of education, and although most companies employing operators usually prefer youths who have had a secondary school education, those possessing a good elementary education and of average intelligence will have no difficulty on educational grounds. Clear and distinct writing, however, is an essential qualification.

Training may be had at any of the centres in London and the provinces. The time taken to qualify for the first class certificate varies according to the aptitude of each individual, but the average time is twelve months. Owing to the increasing technicalities consequent upon the advance and extension of marine radio-telegraphy, the examinations tend to become more severe. It is, therefore, necessary that students should not only attend a good school, but that they should diligently apply themselves to their studies. It is most important to note that wireless telegraphy cannot be taught through the medium of a correspondence course.

Whilst a knowledge of electricity, magnetism, and telegraphy are advantageous to the intending student, such knowledge is not essential, as the course of training at any good centre commences from the most elementary stage. Candidates for examination for the first class certificate (which is the only one of any real practical value for the purpose of obtaining employment) are required to pass in:

1. The working and adjustment of the apparatus;
2. Transmission and sound reading at a speed of not less than 20 words a minute;
3. Knowledge of the regulations applicable to the exchange of radio-telegraphic traffic.

The written examination consists of two papers, one covering electricity and magnetism, and the other technical wireless telegraphy. Two hours are allowed for each of these papers. The examination in the working and adjusting of the apparatus is, of course, practical. Knowledge of the regulations governing the exchange of radio-telegrams is tested by means of oral examination. At the present time examination, either theoretical or practical, in radio direction finding is not essential, but owing to the rapid extension which is being made in the use of this instrument students will find it a distinct advantage if they have a good knowledge of this branch of radio-telegraphy, and it is therefore advisable to train at a centre where such tuition is given.

Once the first class certificate has been obtained the holder has then to decide upon the particular company he wishes to enter. There are three wireless companies employing operators—The Marconi International Marine Communication Co., Ltd., The Radio Communication Co., Ltd., and Siemens Brothers, Ltd. These companies together control approximately ninety per cent. of the "Wireless" Telegraphy installations in the British Mercantile Marine. Certain shipping companies employ their own operators, but these are comparatively few. The monthly rates of pay (payable as from August 1, 1926) are as follows:

	Class of Vessel.		
Grade of Operator.	Class 1	Class 2	Class 3
Grade 1 operators on vessels with a tonnage of:—	£ s.	£ s.	£ s.
Not exceeding 8,000 tons .	16 0	14 0	13 0
8,001 and not exceeding 12,000 tons	17 0	15 0	14 0
12,001 and not exceeding 16,000 tons	18 0	15 0	14 0
16,001 tons and over ..	19 0	15 0	14 0

(Note.—The operator in charge on a Class 1 vessel is paid £1 a month extra.)

Grade 2 operators with:—	£ s.	£ s.	£ s.
6 months' and less than 1 year's service	8 10	8 10	8 10
1 year's and less than 2 years' service	9 10	9 10	9 10
2 years' service and over ..	10 10	10 10	10 10
Grade 3 operators	7 0	7 0	7 0

On obtaining an appointment the student becomes a third grade operator, and as such is qualified to serve on a ship carrying over 200 persons as third operator, or as second operator on a ship carrying less than 200 persons. Promotion to higher grades is dependent upon length of sea service as an operator in the Mercantile Marine. Six months' sea service qualifies for second grade, and three years' sea service qualifies for first grade. It will be seen, therefore, that three years of sea service makes a man eligible for service on the largest ships, and the salary of the officer in charge on this class of ship is £20 per month plus board, everything (except uniform, etc.) being provided. It should not be thought that all study is ended with successfully passing the examination for the first class certificate. Present-day "Wireless" Telegraphy practice at sea is so complex that the new entrant, if he wishes to make good, will need to concentrate upon acquiring much knowledge entirely outside the scope of the examination, and, in addition, to keep up to date with the rapid extensions and innovations which have marked marine radiotelegraphy during the past five years.

CHAPTER V

USEFUL INFORMATION

ABBREVIATIONS

A.C. . . .	Alternating current.
A.H. . . .	Ampere hour.
A.T.C. . .	Aerial tuning condenser.
B.S.W.G. . .	Birmingham standard wire gauge.
C. . . .	Capacity.
C.G.S. . .	Centimetre, gramme, second.
C.W. . . .	Continuous wave.
D.C. . . .	Direct current.
D.C.C. . .	Double cotton covered.
D.F. . . .	Direction finder.
D.S.C. . .	Double silk covered.
E.M.F. . .	Electro-motive force.
F.P.S. . .	Foot pound seconds.
H.F. . . .	High frequency.
H.P. . . .	Horse power.
H.T. . . .	High tension.
I.C.W. .	Interrupted continuous waves.
I.E.E. . .	Institution of electrical engineers.
I.P. . . .	In primary.
I.S. . . .	In secondary.
I.R.E. . .	Institute of Radio Engineers (American).
L. . . .	Inductance.
λ . . .	Wavelength.
L.F. . . .	Low frequency.
L.T. . . .	Low tension.
M.A. . . .	Milli-ampere.
Mfd. . . .	Microfarad.
M.M.F. .	Magneto-motive force

O.P. . .	Out primary.
O.S. . . .	Out secondary.
P.D. . . .	Potential difference.
R. . . .	Electrical resistance.
R.C.C. . .	Resistance capacity coupling.
R.M.S. . .	Root mean square.
R.P.M. . .	Revolutions per minute.
R.P.S. . .	Revolutions per second.
S.C. . . .	Silk covered.
S.G. . . .	Specific gravity.
S.H.M. . .	Simple harmonic motion.
S.C.C. . .	Single silk covered.
S.W.G. . .	Standard wire gauge.

INTERNATIONAL MORSE CODE

LETTERS

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FIGURES

IN FULL		ABBREVIATED	
1	· — — — —	1	· —
2	· · — — —	2	· · —
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But the fate of this second volume depends on your reception of the first one.

Please write, therefore, to the author, care of the Publishers, and state: (1) If you like the first book or not; (2) If you would like to see a further book, more advanced, on the same subject and by the same author; (3) Any points which are not quite clear to you.

Do not expect a personal reply, as there are sure to be many letters, but just wait for the second book, which will start by settling your doubts, and will then take you a stage farther.

You see for yourself how much there is in "Wireless." A mere mention of the principles involved has run into a fair-sized book.

Every opinion, every constructive criticism, every suggestion will be considered by the author as a great favour. And many thanks for reading this volume.

RALPH STRANGER.

c/o George Newnes Ltd.
8–11, Southampton St.
London, W.C.2, England.

P.S. This is what the author wrote two years ago. The demand for the second book containing more advanced information proved to be overwhelming.

The second book is called "Ralph Stranger's Wireless Library for the man in the street". It is being published in 18 parts.

The following parts are now ready:

[By courtesy of the B.B.C

BREAKSEA LIGHTSHIP
A Concert at Sea

[By courtesy of the B.B.C.

"GOOD-NIGHT, EVERYBODY—GOOD-NIGHT"

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