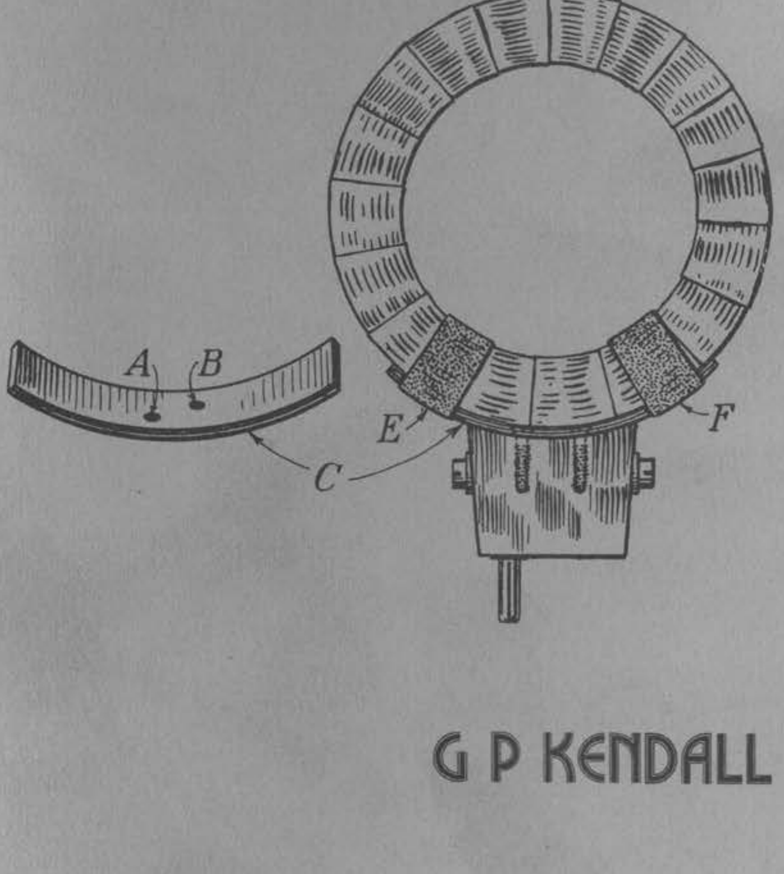
TUNING COILS
AND HOW TO WIND THEM



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TUNING COILS
AND
HOW TO WIND THEM

BY

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Joint Author of "500 Wireless Questions Answered,"

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PREFACE.

It is strange that so important a constituent of the receiving set as the tuning inductance should receive such scant consideration from the majority of experimenters. Possibly the cause is to be found in the fact that there are so many commercial coils of convenient form and reasonable price upon the market, but, be that as it may, the average user of a wireless set seems to assume that all coils are alike, and gives the matter no further thought. He will devote much care to the choice of a valve or a loudspeaker, and yet considers that a coil is a coil, and there's an end of it. This attitude is all the more regrettable in that the true facts of the matter are that efficient coils are the essential basis of an efficient set, and that many of the types used are directly responsible for the mediocre results obtained by some experimenters.

This little book has been written for the express purpose of showing that it is easy for the experimenter to wind really efficient coils for himself, and to urge all who desire the best results from the simplest apparatus to devote greater attention to their tuned circuits: time spent in winding good coils is never regretted.

G. P. KENDALL.

London, February, 1924.

WARNING

It should be remembered that the materials and practices described in this publication are from an earlier age when we were less safety conscious. Neither the methods nor materials have been tested to today's standard and are consequently not endorsed by the publishers. Safety is your responsibility and care must be exercised at all times.

CONTENTS.

TUNING COILS
AND HOW TO WIND THEM.

CHAPTER I.

GENERAL CONSIDERATIONS.

To design and wind one's own tuning coils successfully it is necessary to understand in a general way how they work and what features constitute a good coil or a bad one, and we must acquire this quite elementary knowledge before we can proceed to our study of the various types and the practical details of their winding. Moreover, every experimenter should know the characteristics and special advantages of each type in order that he may choose the one most suited to any particular purpose. It must be realised in this connection that the different varieties have certain definite suitabilities which the experienced constructor can turn to good account. Remember that success in making wireless apparatus depends to a considerable extent upon the choice of suitable components, and this is especially true of the tuning coils used with a receiving set; poor coils can completely spoil the performance of the best set.

Another point which deserves to be specially emphasized in these introductory pages concerns the relative efficiency of home-made and purchased coils. It is often thought that apparatus of amateur construction must necessarily be inferior to that of a professional maker, but nothing could be further from the truth in the case of coils. Given a little information and advice regarding the necessary numbers of turns, etc., it is *easy* to make coils at least equal to the best on the market, and superior to many. It is to be realised that it is not possible under commercial conditions to devote so much attention to the pursuit of ultra-efficiency as can be given to it by the amateur who is prepared to spend time upon slightly more efficient but slower methods of winding, to sacrifice compactness, and so on.

The purpose of a tuning coil (or " inductance," as it is often called) is to enable us to " tune " a circuit, as every experimenter knows, but what exactly do we mean by " tuning "? It is, of course, the process of adjusting the wave-length of a circuit to any desired value, but let us try to get a clearer idea of the operation by means of a simple analogy. If a weight is hung upon the end of a string it forms a pendulum, and will swing at a certain definite frequency (*i.e.,* number of times per minute) if struck, and this frequency can be adjusted to any desired number by varying the length of the string. The shorter the string, the more times per minute will the pendulum swing, that is, the higher the frequency, and *vice versa.*

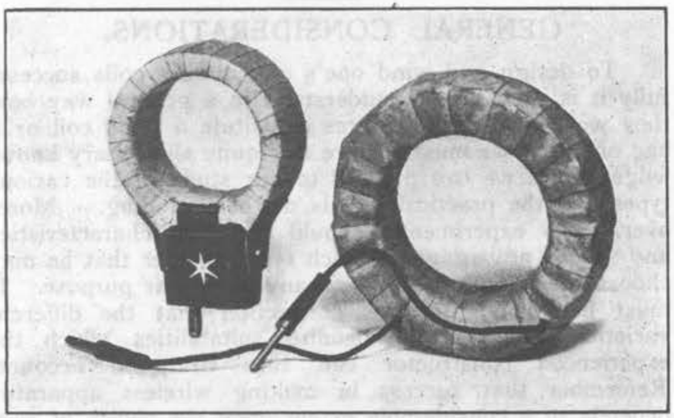


Fig. 1. An interesting comparison. These two coils have equal numbers of turns, one being wound with thick wire and the other with the finer gauge used in some commercial forms. Their relative efficiency may thus be compared by their bulk, the larger coil being greatly superior to the other. (Note.—The left-hand coil is *not* on the English market.)

Similarly, an electrical circuit can be made to oscillate (speaking more correctly, oscillations can be made to flow in it), and it will do so at a definite frequency which depends upon the electrical length of the circuit, this electrical length corresponding roughly to the length of the pendulum. The shorter the circuit, the more rapidly will it oscillate, or, in other words, the higher its " natural frequency." If this natural frequency is the same as that of the passing wireless waves, the circuit will be thrown into oscillation by them, and signals will be received. This, of course, is the condition which is described by saying that the receiver is tuned to the wave-length of the signals.

Now, the electrical length of a circuit depends partly upon the actual physical length of the wires composing it, and partly upon the capacity of any condensers which it may contain, and its adjustment to any desired value may be performed by varying either or both of these factors. The one with which we are concerned in this book is the length of the wire, and it must now be explained that it is not strictly accurate to refer to the physical length, since this is not quite the same thing as its electrical length. This latter is really dependent upon the intensity of the magnetic field around the wire, which will be greater if the wire is wound into a coil than if it is stretched out in a straight line.

We can, then, adjust our circuit by inserting in it varying lengths of wire, and these lengths of wire are coiled up in some suitable way, partly for convenience and partly because when a given length of wire is wound into a coil it becomes equal to a much greater length in a straight line. Thus, a shorter length can be used for any particular wave-length with a consequent reduction in the resistance of the circuit. (The resistance depends upon the actual number of feet of wire in circuit.)

The greater part of this book is devoted to the coiling-up process, and it is of the utmost importance as regards the efficiency of the circuit. The chief reason for its great importance lies in the fact that when we coil up the wire we produce not merely a magnetic field around it, but also an electro-static field between its turns. The turns, of course, are carrying currents, and are at differing potentials, and therefore act like the plates of a condenser. Hence the coil has capacity (usually referred to as self- or internal-capacity) as well as inductance, and its efficiency is reduced to a degree corresponding to the amount of this capacity.

Since internal capacity is exceedingly detrimental, the energies of the designer of coils must be largely devoted to keeping it as low as possible, and it will be found that this point is considered in greater detail in succeeding chapters. The principal methods of reducing it are manifestly to space the turns out from each other as much as possible, all the various systems of winding being devised for this express purpose, and to avoid the presence of dielectric material such as wax or shellac between them.

A final point concerning the efficiency of a tuning coil arises from a previous paragraph in which it was implied that resistance is detrimental in a tuned circuit. The effect may be mentally visualized by the aid of the pendulum analogy which we used at an earlier point. Suppose that, instead of hanging the pendulum in air, we had placed it under water: obviously the resistance of the water to its motion would have the effect of preventing it from swinging freely, and would have brought it to rest after perhaps two or three swings to and fro. Further, if we had suspended it in treacle the resistance would have been so great that it would not have been possible for it to swing at all.

These conditions are exactly matched in oscillatory circuits. Resistance in the wire has a damping-down effect upon the oscillations, and if it is greater than a certain value will prevent the circuit from oscillating at all. It is therefore important to use wire as thick as is practicable and to sacrifice a certain amount of compactness to the reduction of damping.

It will be found in later chapters that various methods can be adopted for bringing different amounts of inductance into circuit to tune to given wave-lengths, the common ones being to use either a large coil with a means of including any required portion of it in circuit by means of a switch and tappings or a sliding contact, or alternatively a series of coils of fixed, graduated values mounted on some sort of interchangeable arrangement so that they can be plugged into circuit as required. The second method is undoubtedly the most efficient, since it eliminates the "dead-end" effects mentioned in the chapter on taking tappings.

CHAPTER II.

TURN NUMBERS.

"How many turns shall I wind on a coil to tune to Paris?" "What size of coil should I use to receive the broadcasting?" These questions, and a host of similar ones, are inevitably asked by the beginner when he commences to make his own tuning coils, and their correct solution is essential before he can achieve success.

The whole question of turn numbers is one which at first sight appears exceedingly complex, but which is nevertheless capable of being made perfectly simple by the use of a few rules and an understanding of certain quite elementary principles.

It must be realised that so far as the majority of multi-layer coils, such as the duo-lateral, are concerned, mathematical methods are of little practical use to the ordinary experimenter, and rule-of-thumb methods must be adopted. For example, if it is desired to ascertain the wave-length range which will be covered by a coil of 250 turns with a condenser of 0.0003 μF capacity, it is not a practical proposition to try and calculate the inductance of the coil and then apply the wave-length formula. The process would be difficult and the errors large, and therefore it would seem that experiment and actual measurement were the only course. However, so much experimental work of this sort has been done, and so many tables published showing the wave-length ranges of various types of coils wound upon different sizes of formers that it is an easy matter to make a fairly accurate estimate by methods of comparison. How this is done will become apparent at a later point when we examine one of these tables and see how it may be applied.

The best way to use multi-layer coils, as is explained elsewhere, is in the form of interchangeable units, each coil being mounted on a plug so as to be capable of insertion in a standard coil holder, and this makes it necessary to design a complete set of coils of progressively increasing size, so that they will cover the desired range of wave-lengths.

The numbers of turns on the coils should be such that each covers, with a variable condenser of suitable size, a range of waves which overlaps that of the coil above and the coil below. Thus, the first three coils of a series might cover the following wave-length ranges: No. 1, 150-300 metres; No. 2, 250-450 metres; No. 3, 400-700 metres.

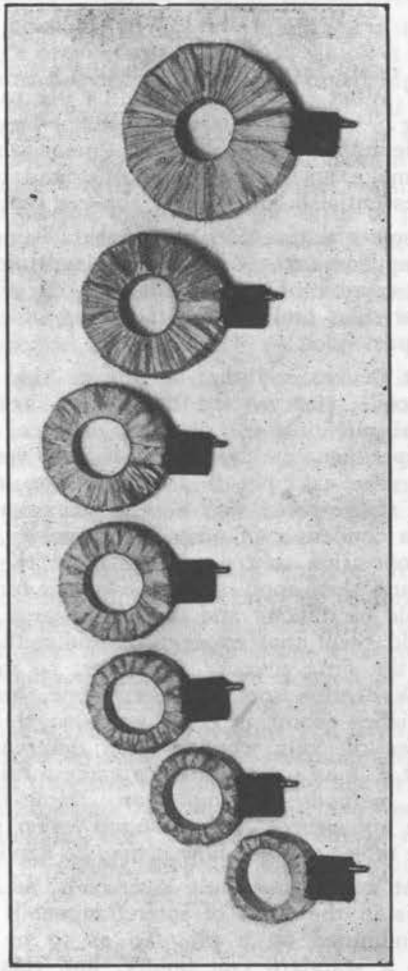


Fig. 2. Seven coils of the Burndept series. The coils are designed with a progressive increase in turn numbers, as may be seen from their size, so that they cover a wide range of wavelengths without gaps.

The reason why this arrangement is desirable may be found in the fact that better signals are usually obtained when one has a large coil in circuit and as little capacity as possible. Hence, the intervals between the numbers of turns on the coils should be fairly small, so that one shall always be able to use a coil with which only a small amount of capacity will be required to tune to a given wave-length. Thus, referring back to the three coils just mentioned, it would be better to tune to a wave-length of 420 metres by means of coil No. 3 and a little capacity in parallel than coil No. 2 and a good deal of capacity.

Another point which should be borne in mind is this: on the shorter wave-lengths a difference of a few turns between one coil and the next makes a much greater difference in the wave-length than it would upon a longer wave. To make such a proportionate change upon the longest waves as that between coil No. 1 and coil No. 2 above, it would be necessary to add or subtract hundreds of turns. Consequently, a properly designed set of coils to cover the whole band of waves now in use (150—25,000 metres) will have progressively increasing intervals between the turn numbers of each.

To design such a set of coils from first principles without any experimental data would be an exceedingly difficult task, and it is fortunate that we possess enough knowledge of suitable sizes obtained from experience to dispense with the process altogether. The table which follows gives the standard numbers of turns for a complete set of coils and indicates the wave-length range of each under certain definite conditions. These conditions are that the coils are all wound upon a former two inches in diameter (*i.e.*, that the interior diameter of each is two inches), and that they are shunted with a variable condenser having a maximum capacity of 0.0005 μF, no other apparatus which would affect the tuning being connected to them. In particular, no aerial or earth is allowed for. The wave ranges covered are therefore those which the coils would give when used in a tuned anode or as secondary circuit coils.

The wave-length ranges given are *approximate*, and must not be accepted without reserve. For example, no mention is made of the method of winding of the coils, the figures given being averaged from a number of tables of different types. Lattice, honeycomb, duo-lateral, and most other types of multi-layer coil will agree fairly closely, with slight differences only in the maximum and minimum wave-lengths. These, of course, result mainly from the variations of self-capacity which arise from the differences in the systems of winding.

COIL NUMBER	NUMBER OF TURNS	WAVE LENGTH RANGE (metres)
1	25	100—250
2	35	150—350
3	50	200—500
4	75	300—700
5	100	400—1,000
6	150	500—1,500
7	200	800—2,000
8	250	900—2.500
9	300	1,200—3,000
10	400	1,500—4,000
11	500	2,000—5,000
12	600	2,500—6,000
13	750	3,000—8,000
14	1,000	4,000—10,500
15	1,250	5,000—15,000
16	1,500	6,000—18,000

Basket coils will differ more seriously, since they give slightly less inductance per turn, and their self-capacity is much lower than that of the other types mentioned. The result will be that their minimum wave-length with a given condenser will be much lower, while their maximum will also be reduced, although to a lesser extent. Further, their inductance is affected to a much greater extent than is that of other types by the actual details of winding, number of pins, gauge of wire, and so forth, and therefore it is not possible to give definite figures for these coils. The table, however, will serve as a rough guide in their case.

Another stipulation is necessary regarding the type of variable condenser which is used with the coils. To obtain the wave-length ranges quoted the condenser must be one of the type having moving vanes separated by *air* dielectric, since other patterns have not a sufficiently low " minimum " value to give the specified wave-length ranges. Remember that when a condenser is set to its " zero " point there still remains a certain amount of capacity in circuit, whose magnitude depends upon the design of the condenser: a good condenser is one which has, among other things, a low minimum value, and this means that, when a maximum wave-length range with any given coil is desired mica dielectric is practically ruled out, and that ebonite top and bottom plates are preferable to metal ones. If a condenser of a different pattern is used it will often be necessary to use a coil of smaller size, say the next smaller in the list. For broadcasting, for example, with an efficient variable condenser the correct coil to use in a tuned anode circuit is one of 75 turns, but with an unsuitable condenser it will be necessary to employ a 50-turn coil.

The arrangement of the wiring in the set will also affect the size of the coil for a given wave-length to some extent. If the wires are all short and well separated from each other, they will not appreciably alter the figures given, but if long leads are taken off to coil holders, switches, and so on, the effect will be to add on the capacity of all this wiring to the minimum capacity of the condenser. Any given coil will not then tune down to the minimum wave-length given.

We have been considering so far coils used in tuned anode and secondary circuits, and the matter is rather less simple where the aerial circuit is concerned. In this latter case we have not only the inductance of the coil and the capacity of the condenser to take into account, but also the inductance and capacity of the aerial-earth system. Moreover, the latter factors are variable, since different aerials vary in their characteristics within quite wide limits.

It is not possible, therefore, to give definite wave-range figures for coils in aerial circuits, but it may be said in a general way that the effect is much as though a fixed condenser of about 0.0003 μF were permanently connected in parallel with the coil, its wave-length range being raised correspondingly. The matter is further complicated by the fact that the tuning condenser may be connected in series or parallel, and a different size of coil is required accordingly. (The series position usually necessitates a coil one size larger.)

The table below will be found valuable in choosing coils for both the tuned anode circuit and the aerial circuit, alternative coils being given for this last for the reasons mentioned above. It is assumed that a parallel condenser of 0.0005 μF capacity will be used in the aerial circuit, and one of 0.0003 μF in the anode, both to be of an efficient (*i.e.*, " low minimum ") pattern, these being good average values.

WAVE-LENGTH	STATIONS TO BE RECEIVED	AERIAL CIRCUIT	ANODE CIRCUIT	REACTION
300-500	British Broadcasting and Shipping	35, 50	50, 75	75
600	Shipping	50, 75	100, 150	100
800–1,000	Aircraft	75, 100	150, 200	150
1,050	Hague	75, 100	150, 200	150
1,600	B.B.C. High Power Station	100, 150	250, 300	200
1,780	Radio-Paris	150, 200	250, 300	200
2,600	Eiffel Tower ...	200, 250	300, 400	200

Alternative sizes are given for the anode coil to allow for variations in the wiring of different sets. If your wiring is short and well spaced, you will be able to use the larger size, but if you have a sort of miniature thicket of leads inside your cabinet you will only be able to use the smaller one, with correspondingly reduced signal strength.

Most of the manufacturers of coils now supply a special set of " short-wave " or " concert " coils for broadcast reception having distinguishing letters or numbers which do not indicate the number of turns. With these coils it is usually correct to use a No. 2 or 3 in the aerial, and No. 4 in the tuned anode for broadcast reception.

All the coils we have dealt with so far have been assumed to have an inner diameter of two inches; that is, to have been wound on a former two inches in diameter. It is well to adopt this size as a standard throughout, but there are occasions when it is inconvenient and some other size is preferable, and therefore it must be explained how the necessary correction is made. A rough rule is sufficient for the purpose, since large departures from the standard are unlikely. A sufficiently close approximation for practical purposes can be made by assuming that the wave-length range will be raised or lowered in direct proportion to the change in the diameter. For example, if a coil tunes to 400 metres with a certain capacity, increasing the diameter from two to two and a half inches, keeping the number of turns constant, will raise the wave-length in the proportion of $2 : 2\frac{1}{2}$, *i.e.*, the wave-length will become $\frac{400 \times 2.5}{2} = 500$ metres.

Single-layer coils are only in common use for the wave-lengths below about 1,000 metres, on account of their bulk, and for these shorter waves it is fairly safe to assume that the turn numbers given in the preceding tables will hold good for single-layer inductances if they are wound on $3\frac{1}{2}$ in. formers. This is a convenient size, and may be adopted as a good standard. Such coils, however, are usually provided with tappings, and reference should be made to the chapter on their actual construction for a fuller treatment.

CHAPTER III.

THE CHOICE OF WIRE.

An important factor in the design of an efficient coil is the selection of a suitable kind of wire, and it is proposed to give some hints upon the making of a correct choice in this chapter.

The decision has to be made upon two questions, the first concerning the thickness (or " gauge ") of the wire, and the second referring to its covering or insulation. Now, the choice of the gauge is always a matter of compromise, in the sense that efficiency demands that the wire shall be thick so that its resistance may be low, yet if thick wire is used for any except the smaller coils they become unwieldy in size. One must therefore endeavour to choose for any given coil such a size of wire as shall be the thickest permissible if the bulk of the coil is to be kept within reasonable limits, and this involves using different gauges for coils of different sizes. Coils having only a few turns (*i.e.*, short wave coils) should be wound with quite thick wire, say No. 20 or 22 S.W.G. (" standard wire gauge "), while long wave coils possessing hundreds of turns must be reduced in size by the use of wire of No. 32 or 34 S.W.G. Examples showing how the size of the wire is adjusted to coils of varying size are given in later sections of this book, where tables appear which show the numbers of turns, size and covering of the wire, etc., for winding sets of coils of the various types.

The preceding remarks apply, of course, to solid conductors, and do not refer to the type of wire known as Litzendraht, which consists of a large number of separately insulated strands of fine wire. It is exceedingly doubtful, in the opinion of the author, whether Litz gives any real increase in efficiency, in spite of the apparent advantage of the reduction in high-frequency resistance which results from breaking up the wire into a number of separately insulated strands. (Remember that H.F. currents travel on the *surface* of the wire, and therefore increasing the surface reduces the H.F. resistance.) Many authorities consider that the dielectric losses in the insulation between the strands, and other losses inherent in stranded wires partially or entirely counterbalance the above-mentioned advantage.

In any case, the practical difficulties in the way of the use of Litz by the amateur constructor are so great that it is not to be recommended. The principal objection is based upon the fact that if any one of the strands should chance to be disconnected or broken, very considerable losses result, and this is always liable to occur in amateur work, since it is decidedly difficult to ensure that every strand is properly soldered into circuit.

The type of covering to be selected depends chiefly upon the type of coil, and to some extent upon whether the coil is to be impregnated with wax or shellac or left without such protection against moisture. If the coil is not to be damp-proofed, cotton-covered wire should always be used, since cotton absorbs considerably less moisture from the air than silk (the proportion is, roughly silk 11 and cotton 8). Provided that the covering is to be impregnated, it may sometimes be permissible to use silk in cases where great compactness is essential. Silk, of course, is thinner than cotton, and therefore less desirable whenever it is possible to allow for the greater bulk of a coil wound with cotton-covered wire. The thicker the covering, obviously, the greater the spacing between turns and the lower the internal capacity of the coil, the effect being similar to that produced by increasing the distance separating the plates of a condenser. For this reason it should be made a rule to use *double* silk or cotton in all cases.

Enamelled wire is not very suitable for tuning coils, since it is so thinly covered that the spacing between adjacent turns in a winding is extremely small, and therefore the internal capacity of the coil is high. The only legitimate use of enamelled wire is undoubtedly for winding single-layer coils of the slider variety, where it is necessary to be able to bare a strip along the coil for the moving contact.

CHAPTER IV.

TAKING TAPPINGS.

The most efficient form of inductance is no doubt the interchangeable plug-in type without tappings, but it is often expedient to sacrifice a little efficiency to the great convenience of operation conferred by a coil with tappings taken out at intervals along its length to the studs of a switch. With such a coil quite a broad band of wave-lengths can be covered in a few seconds by the manipulation of the switch and with much greater facility than by plugging-in a series of coils.

The loss of efficiency which results may be slight, or it may be great, depending upon the method of switching and the extent of the tapping. The principal sources of loss are two: Firstly, if numerous tappings are taken at short intervals along the coil and led by wires of considerable length to the switch, a serious addition will be made to the internal capacity of the coil, since the bunch of wires is equivalent to a condenser of some size. The remedy is to keep the tapping wires short and few in number, say ten or a dozen at the outside, and use stiff wire so that they can be spaced out and separated from each other. Secondly, what are known as dead-end effects are liable to be present in the unused portion of the coil, and this is the more dangerous possibility. The "dead" section of the coil possesses both inductance and capacity and will therefore have a natural wave-length, and if this wave-length chances to be the same as that being received, serious trouble will be experienced with absorption effects, a complete wipe-out of signals being a possibility. It would seem at first sight that such an occurrence would be a somewhat improbable coincidence, but it must be remembered that similar effects will be produced if the natural wave-length of the "dead-end" is a harmonic or over-tone of that being received, and therefore the chances are much increased.

The chief precaution which may be taken to minimise the risk is to keep the dead section small, and this means in practice that the coil should be so designed that a considerable part of it shall always be in circuit. In other words, do not try to make a coil to cover a very wide range of waves. Thus, it is fairly safe to wind one to tune from 300 to 600 metres by means of tappings, but to attempt to cover 300 to 5,000 metres with one coil would almost certainly be to provide oneself with dead-end effects upon the shorter waves, since the amount of the coil left out of circuit on the short-wave adjustments would be large. Examples of fairly safe designs are given in the chapter on single-layer coils.

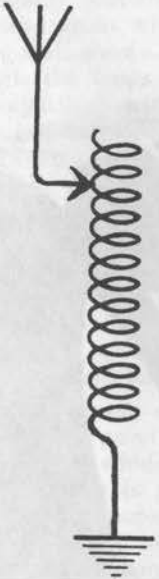


Fig. 3. The wrong way to connect a tapped or slider coil in circuit.

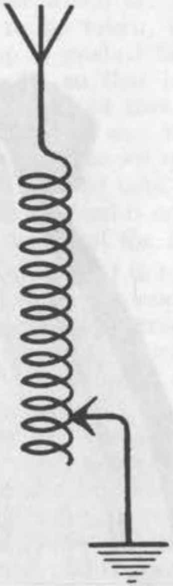


Fig. 4. How to arrange a coil to reduce dead-end effects.

It is sometimes recommended that elaborate switching devices should be used to cut the dead section of the coil completely out of circuit, but it is very doubtful if they are worth the additional complication involved. They certainly *reduce* dead-end troubles, but they most decidedly do not eliminate them entirely, and may prove exceedingly deceptive to the unwary. Whatever method of switching is adopted, the dead turns remain magnetically coupled to the live ones, and may produce absorption effects.

It should be noted that we have been considering so far tappings taken from single-layer coils, and it may be asked whether similar conditions obtain in multi-layer coils, such as lattice and honeycomb coils: most decidedly they do, and the risks of dead-end effects are very much intensified by the strong coupling between the used and the unused turns. In consequence it should be taken as a definite rule that tappings should never be taken from multi-layer coils under any circumstances.

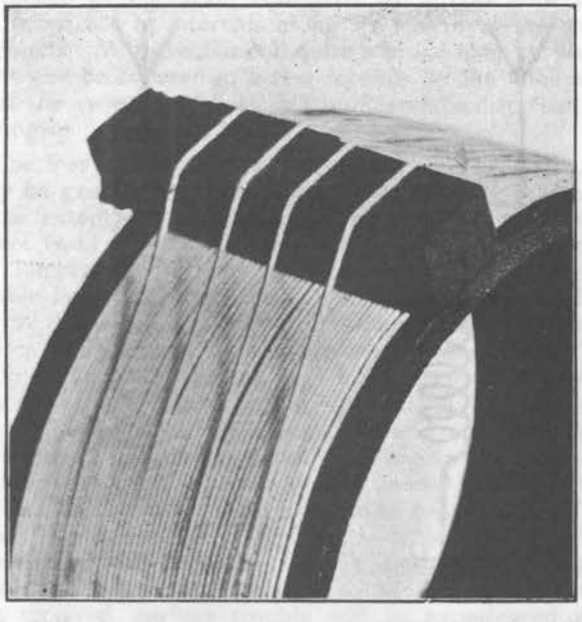


Fig. 5. A good method of preparing tapping points upon a single layer coil.

Another possible dead-end loss other than that due to resonance in the unused turns is that which will occur if the dead-end is left hanging upon the *aerial* end of the coil, as shown in Fig. 3. The useless capacity of the dead-end will absorb small amounts of energy, and this should be prevented by connecting the coil and its switch or slider as shown in Fig. 4.

To turn to the practical details of making tappings: Much the best plan is to make the tappings as winding proceeds, rather than to wind on all the wire and then try to make connection to it at the desired points. Various methods may be adopted for making the tappings, but the one advocated by the author as being the neatest and simplest is illustrated in Fig. 5. The method consists in placing upon the coil a strip of ebonite a quarter of an inch square (cut from $\frac{1}{4}$ in. sheet), over which are looped the turns from which tappings are to be taken, as the photograph shows. The ebonite strip is pushed forward through the loops as winding proceeds, so that its end is always flush with the edge of the turns, so that winding is not impeded, but yet the strip is ready and in position for each successive tapping point to be looped over it. When the coil is complete the wire is scraped bare where it passes over the strip, and to each point a lead is soldered whose other end will be connected to a stud of the switch.

Another easy but less workmanlike method is to twist a loop in the wire at each point, leaving all the loops projecting from the winding, and making loops every ten turns, or at whatever intervals are required. Each loop is then scraped bare and soldered upon as before.

Another way often employed is to drill a hole in the tube at each point from which a tapping is to be taken, and when the winding arrives at each hole it is doubled into a loop, which is pulled through into the interior of the tube. If the loops are made of sufficient length, they can be taken along inside the tube and out to the switch studs, to which they can be soldered directly. This method is attractive in its simplicity and neatness, but it is certainly inefficient in that it adds unnecessarily to the capacity of the coil, and its use is not advised.

The question of the intervals at which tappings should be taken in various different types of coils is considered in Chapter VI.

CHAPTER V.

DAMP-PROOFING.

We now come to one of the vexed questions of coil construction, namely, the problem which may be expressed as "to impregnate or not to impregnate." The whole question is one of considerable difficulty: many who are entitled to be regarded as authorities take diametrically opposite views, and the author considers that we lack sufficient experimental data to come to a definite decision.

The point, briefly, is this: if a coil is left without any form of damp-proofing impregnation, the cotton or silk covering of the wire is liable to absorb moisture in damp weather, whereupon the insulation between turns is impaired, and also *the capacity between them is increased.* This latter point is not sufficiently clearly realised, and it is well worth noting, since it is a powerful argument in favour of impregnation. It results, of course, from the fact that the "specific inductive capacity" of water is very high.

The alternative is to impregnate the covering of the wire with some damp-proofing compound, the usual ones being paraffin wax and shellac varnish, and it is strongly contended by many that so doing greatly impairs the efficiency of the coil, since the presence of the impregnating material between the turns increases the internal capacity of the winding. (The specific inductive capacities of both wax and shellac are fairly high.) Naturally, the loss of efficiency, which undoubtedly occurs, depends for its extent upon the method of carrying out the impregnation. If the process is carried out properly, so that the absolute minimum of wax or shellac remains between the turns, it is probable that the lesser evil has been chosen, and the coil will be more efficient than one which is unprotected against damp.

No doubt the ideal arrangement would be a coil in which every turn is separated by an air space from every other turn at all points, but this desirable state of affairs is exceedingly difficult to achieve in practice, and is well-nigh impossible in the case of a multi-layer coil such as the honeycomb. Something approaching it can be obtained in single-layer coils wound upon ebonite tubes, if a thread is cut in the tube and the winding done with bare or enamelled wire, but this method is expensive, and can only be adopted for coils of a relatively small number of turns. A simpler way of achieving the same end is to wind enamelled wire upon a plain tube, spacing each turn from the next with a turn of string, wire and string being wound on simultaneously. When the coil is completed, secure the end of the wire firmly and unwind the string, thus leaving the turns of wire separated from each other by spaces.

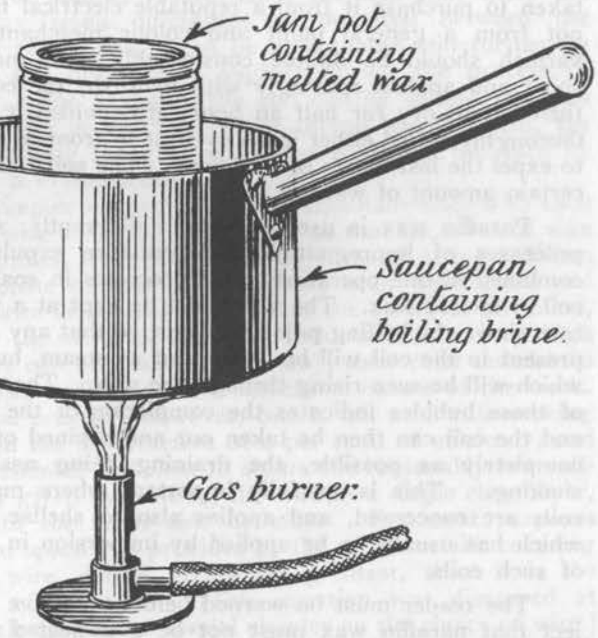


Fig. 6. This sketch shows the safest way to heat paraffin wax.

To sum up: Except in the case of small single-layer coils which can be wound with spaced turns upon a tube, it would seem to be the lesser of two evils to impregnate the coil against damp with the least possible quantity of wax or shellac. In cases where it is decided *not* to impregnate, it should be noted that cotton-covered wire is to be preferred, since cotton absorbs less moisture than silk.

It is obvious that to minimise the ill-effects of impregnation it is important to insure that the least possible quantity of shellac or wax remains in the cotton or silk when the process is finished, and a few notes upon the operation itself must be given. The first essential to the successful use of shellac is the employment of suitable varnish of good insulating properties, and care should be taken to purchase it from a reputable electrical firm, and not from a general paint and colour merchant. The varnish should be diluted considerably with methylated spirit and applied sparingly with a brush, the coil being then left to dry for half an hour, after which it is to be thoroughly baked either in an oven or in front of a hot fire to expel the last traces of moisture. (The spirit contains a certain amount of water.)

Paraffin wax is used somewhat differently, since the processes of impregnation and moisture expulsion are combined in one operation, which consists in soaking the coil in melted wax. The wax must be kept at a temperature above the boiling point of water, so that any moisture present in the coil will be driven out as steam, bubbles of which will be seen rising through the wax. The cessation of these bubbles indicates the completion of the process, and the coil can then be taken out and drained of wax as completely as possible, the draining being assisted by shaking. This is specially important where multi-layer coils are concerned, and applies also to shellac varnish, which has usually to be applied by immersion in the case of such coils.

The reader must be warned before we leave the subject that paraffin wax must not be over-heated: if it is allowed to boil, it gives off quantities of inflammable vapour, and is likely to catch fire, probably with a small explosion.

As regards the relative advantages of the wax and shellac methods, there is little to choose between them. Wax is possibly easier and certainly quicker to use, while shellac can be more readily limited as to quantity by using it in a much-diluted state. As a matter of personal preference, the author always uses shellac.

CHAPTER VI

SINGLE LAYER COILS.

It was explained in a preceding chapter that the single-layer coil is most suited to short-wave reception, its special advantage being its low internal capacity. This characteristic, of course, results from the fact that there are only very small differences of potential between the adjacent turns, and it can be accentuated still further by spacing the turns apart slightly during the process of winding. For example, the coil can be wound upon an ebonite tube in which a coarse thread has been cut, the wire following the groove and being spaced out turn by turn as a consequence.

A simpler method is to wind simultaneously with each turn of wire a turn of thin string, so that the turns of wire are separated from each other by turns of string. When the requisite number of turns have been wound, the end of the wire is secured tightly and the string is unwound, leaving the wire air-spaced. Inductances of very high efficiency can be wound in this way, their chief drawbacks being their bulk and the troublesome nature of the work. In actual practice, however, one is not as a rule seeking to obtain the last fraction of a per cent. of efficiency, and it is considered sufficient to secure the reasonably low self-capacity given by winding the wire in a single close layer, *i.e.*, with the turns side by side. For most purposes sufficient spacing is provided by the cotton or silk covering of the wire, cotton giving the greatest, since it is the thicker of the two. (This question was discussed at greater length in the special chapter on the choice of wire.) Enamel covering is less desirable than either cotton or silk on account of its extreme thinness, and its use for slider coils is to be regarded as an unavoidable evil. Cotton or silk covered wire would be used for such coils, but for the difficulty of baring a track for the slider.

Single-layer coils are made in two principal forms, one being the familiar slider coil, of which a typical specimen is illustrated in Fig. 7. Such a coil is extremely useful for experimental work, since it enables one to vary the inductance turn by turn, and therefore to dispense with a variable condenser in the majority of circuits. The construction of a slider coil is a simple matter, and little more information is needed than that which is conveyed by Fig. 8. A cardboard tube of suitable size is wound with the desired number of turns of enamelled wire, two wooden end pieces are fitted, and a slider rod is fixed to these so that the plunger of the slider presses upon the wire as it is moved along. The wire is then carefully bared along the track of the slider by rubbing with emery paper, and it only remains to provide two terminals. One of these is mounted direct upon one end of the slider bar, and the other is placed upon one of the wooden cheek-pieces and connected to one end of the coil. (The *other* end of the coil is simply fastened off to holes in the tube, and is not connected to a terminal.) The slider bar and slider can be purchased very cheaply, and it scarcely seems worth while to make them for oneself.

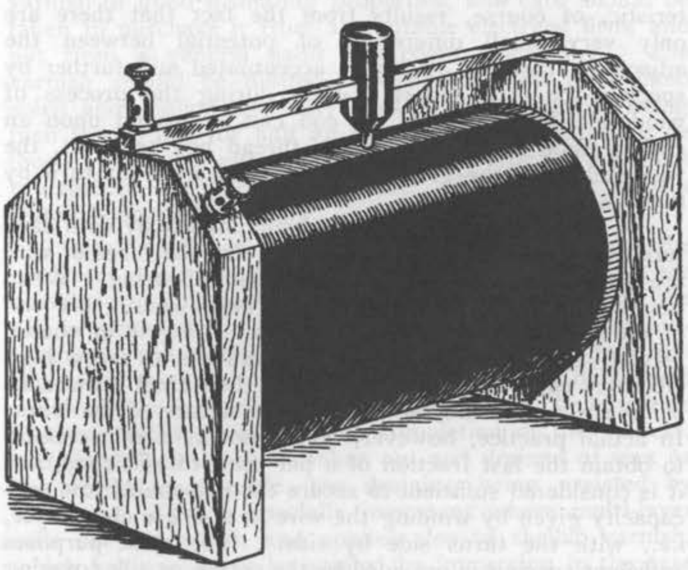


Fig. 7. A simple form of slider coil.

It is most important that the winding of a slider coil should be kept perfectly tight and be securely fastened in place when finished. It is therefore necessary to adopt some effective method of fixing the two ends of the coil, the device recommended being that shown in Fig. 9. As will be seen, the method is simplicity itself, consisting as it does merely in passing the wire through four small holes drilled in the tube, leaving a free end of sufficient length for connections. On the completion of the winding the finishing end is secured in a similar manner, but no free end need be left for the connection. Cut the wire about half an inch from the last hole through which it has passed, and press this half-inch end down flat upon the tube. If the ends have been pulled tight, the winding will now be quite secure.

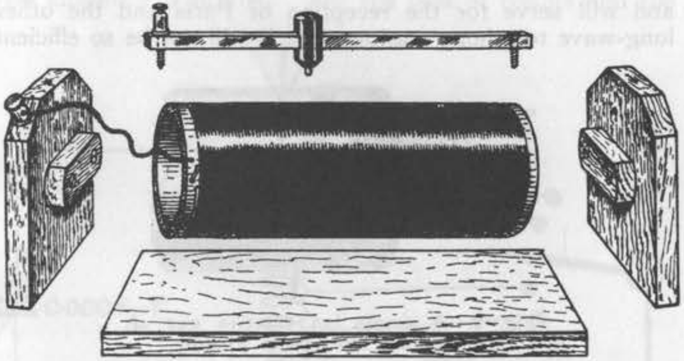


Fig. 8. Showing the constructional details of an easily made slider coil.

The choice of suitable dimensions for a slider coil depends, obviously, upon the wave-lengths to be received, and some specimen designs will now be given, from which the reader can select one to suit his requirements. Coil number one is intended to cover the broadcasting wave-lengths when used in the aerial circuit, and consists of a tube 3 inches in diameter and 5 inches long, wound for 4 inches of its length with a single layer of No. 22 enamelled wire.

Coil number two will cover the same wave-lengths, and in addition will tune to 600 metres to enable the user to pick up the signals of ships and the coast stations which work with them. Its tube is 7 inches long, 3 inches in diameter, and is wound for 6 inches with the same wire as that used for coil number one. It will actually tune to rather over 700 metres on the average aerial, but it is necessary to specify the dimensions just given in order to cover the possibility of the coil being used with abnormally small aerials. (A similar comment may be made regarding all the other designs given in this chapter.)

It is useful to possess also a slider coil of considerable size to permit of tuning to the longer waves between 2,000 and 3,000 metres, and coil number three is designed to meet this need. Its tube is 5 inches in diameter and 12 inches long, wound for 11 inches with No. 26 enamelled wire. This coil will tune from about 300 to 3,000 metres, and will serve for the reception of Paris and the other long-wave telephony stations, but it will not be so efficient upon the shorter waves as either of the two previous coils, on account of the large " dead-end " remaining connected to the circuit when the slider is near the minimum adjustment.

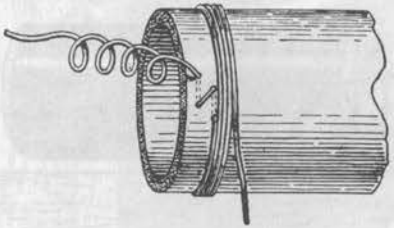


Fig. 9. A simple but effective way of securing the end of the winding.

Now, slider coils are very convenient to use and are easy to construct, but they have certain serious drawbacks, the chief one being the unsatisfactory nature of the contact which is made with the turns of wire by the slider. Unless great care is taken to keep the plunger of the slider, the underside of the slider bar, and the bared track along the winding perfectly bright and clean, trouble is certain to result from the imperfection of the contact. The usual symptoms of such trouble are weakness of signals and much noise when the slider is moved. The sparing use of vaseline along the slider bar and the bared strip is helpful in preventing the development of a bad contact, since it preserves the metal from tarnishing under atmospheric influences.

The frequent movement of the slider, moreover, has a perceptible wearing effect upon the wire, and may ultimately have a noticeable influence upon the efficiency of the coil. Further, the copper dust which results from the wearing process is apt to collect between the turns, and is liable to short-circuit some of them. The remedy, of course, is to be found in the use of a stiff brush for dusting.

Taking these various points into consideration, it will be seen that the slider coil cannot be recommended where real efficiency is desired. For the best of results and the greatest freedom from trouble it is advisable to use a coil wound with cotton or silk covered wire, with tappings taken to the studs of a good rotary switch at suitable intervals. The questions of the sort of wire to use and the most suitable method of taking tappings have both been dealt with in previous chapters, and it remains to give data for a few useful sizes of coils for various purposes.

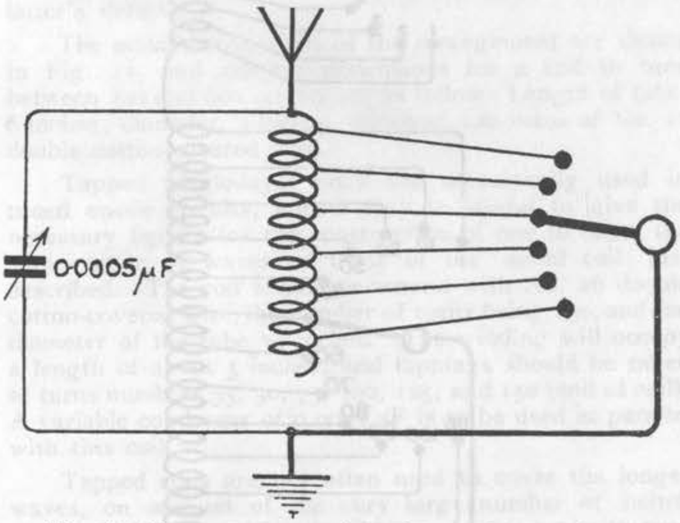


Fig. 10. The correct connections of a tapping switch and the associated variable condenser.

For tuning the aerial circuit to wave-lengths between 200 and 600 metres, a coil may be made by winding 100 turns (*i.e.*, about 4 inches) of No. 22 double cotton-covered wire upon a 3½in. tube, taking tappings to switch studs at the following numbers of turns: 25, 30, 35, 40, 50, 60, 75, 100 (end of coil). This coil should be used with a condenser of 0.0005 μF in either series or parallel, and should be connected in the aerial circuit as shown in Fig. 10, which indicates that the switch arm should be connected to earth and the other end of the coil to the aerial. This

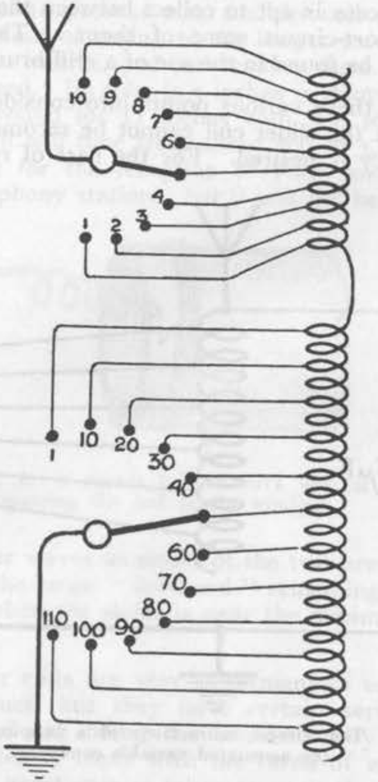


Fig. 11. The connections of the "units and tens" system of tapping a coil. The numbers indicate the number of turns brought into circuit on any given switch stud.

arrangement is desirable, in that it reduces the losses in the "dead" part of the coil.

Such a coil as that just described, of course, necessitates a variable condenser for the exact adjustment of the circuit to a given wave-length, and in that respect it is at a disadvantage as compared with a slider coil. The drawback can be removed, however, by the use of a slightly more complicated method of switching known as the "tens and units" system. In this, two switches are used, one of which varies the turns in circuit in steps of ten at a time, and the other switches them in or out one at a time. Hence, the number of turns in circuit can be varied between one and the total number upon the coil one by one, just as in the case of a slider, but without the latter's defects.

The actual connections of the arrangement are shown in Fig. 11, and suitable dimensions for a coil to tune between 200 and 600 metres are as follow: Length of tube, 6 inches; diameter, 3 inches; winding, 120 turns of No. 22 double cotton-covered wire.

Tapped single-layer coils are occasionally used in tuned anode circuits, and it may be useful to give the necessary figures for the construction of one to cover the same range of waves as those of the aerial coil just described. The coil should be wound with No. 26 double cotton-covered wire, the number of turns being 150, and the diameter of the tube 3½ inches. The winding will occupy a length of about 5 inches, and tappings should be taken at turns numbers 35, 50, 75, 100, 125, and 150 (end of coil). A variable condenser of 0.0003 μF is to be used in parallel with this coil.

Tapped coils are not often used to cover the longer waves, on account of the very large number of switch studs required, but it is possible to construct one to tune between about 300 and 3,000 metres if used with a variable condenser of 0.001 μF and a series-parallel switch. The coil consists of a tube 5 inches in diameter and 12 inches long wound for eleven inches with No. 28 double cotton-covered wire, tappings being taken as follows: Six at intervals of half an inch, then tappings every inch along the remainder of the coil.

CHAPTER VII.

BASKET COILS.

A coil which, in general character, lies between the single-layer type and the commoner forms of multi-layer coil is that known as the basket. It is somewhat more "concentrated" than the single-layer coil, that is, a coil of given inductance occupies a smaller space, yet its turns are well spaced and the differences of potential between them are small. Hence, the basket coil has a very low internal capacity, and its efficiency is high, considerably higher, in fact, than that of the true multi-layer types, and quite comparable with that of the best single-layer coils.

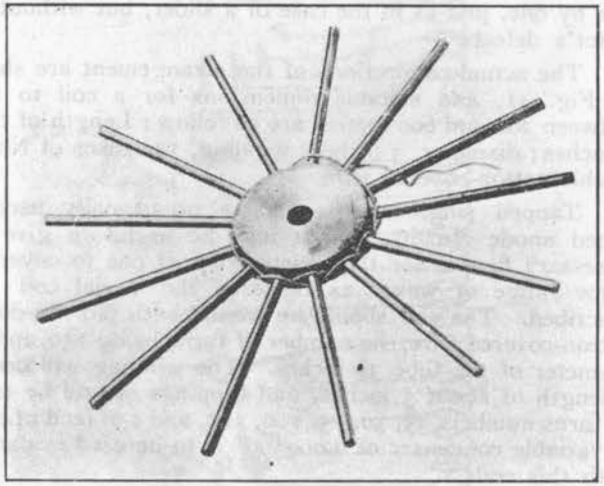


Fig. 12.—A "spider" for the winding of basket coils. Two complete turns are shown in position.

The only serious drawback of this coil is its somewhat fragile nature, since to render it sufficiently strong and self-supporting to enable it to be taken off the former on which it was wound it is necessary to impregnate the coil with either wax or shellac varnish, thereby raising its self-capacity somewhat. In this respect it falls short of the single-layer coil, which can be left "dry," as it is called.

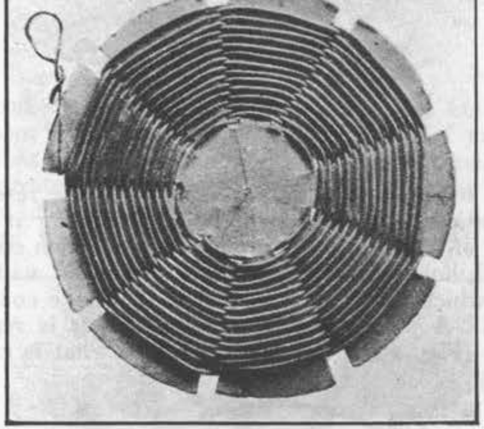
Fig. 13.—Illustrating the winding of a single basket coil.

The basket coil takes its name from the resemblance which exists between the method of winding it and the weaving of a basket. A former is used which consists of a central hub of metal or wood furnished with radial spokes, which must be *odd* in number for the coil to wind properly. A photograph of such a former is reproduced herewith (Fig. 12). Winding a coil of what is called the single-basket type is simple, and consists in passing the wire alternately over and under the spokes until the required number of complete turns round the former have been wound on. The wire is then cut and the end of the winding is secured by tying it with thread to the turn beneath in two or three places, after which the coil is to be impregnated with wax or varnish according to the instructions given in the chapter on damp-proofing. The spokes can then be pulled out carefully with a pair of pliers and the coil taken off the former.

Fig. 14.—Plan showing how a double basket coil is wound.

Fig. 15.—Plan view of the first four turns of a double basket coil.

The mechanical strength of basket coils can be much improved by judiciously tying the turns together at a few points with thread. This is especially desirable with the first three or four turns, since it is usually the inside of the



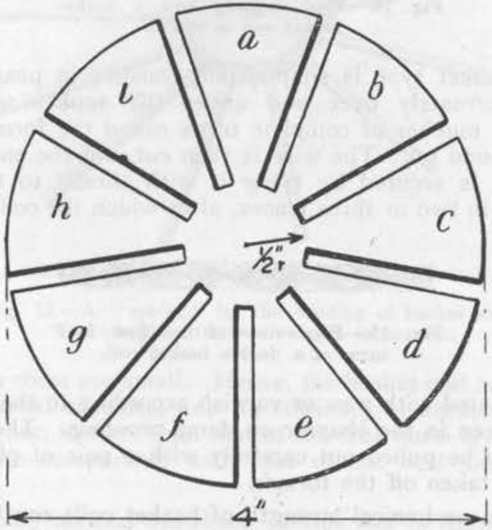


Fig. 16.—How a basket coil is wound on a slotted cardboard disc.

coil which breaks down under rough treatment. The tying, by the way, should be done as winding proceeds, and not when the coil is finished; it is much more difficult to pass the thread through the required points in the winding if one waits until the coil is complete.

The simple basket coil which has been described, and whose method of winding is illustrated in Fig. 12, is capable of modification in a variety of ways. For example, there is the double-basket method of winding: in this form the wire is taken over and under *two* spokes at a time instead of one, the result being a coil of greater strength and compactness, and very slightly higher internal capacity. In the author's opinion the double-basket coil is a distinct improvement on the single, and is to be preferred for all normal uses.

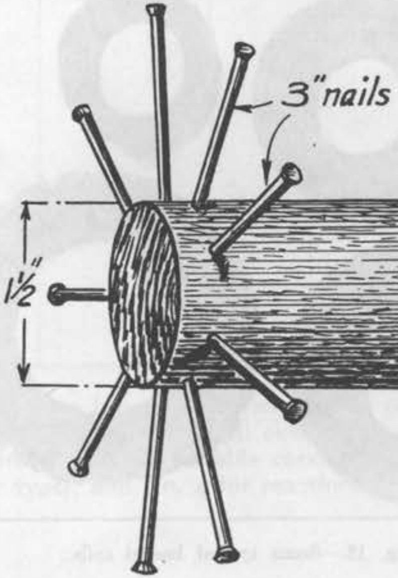


Fig. 17.—An improvised spider.

Instead of using a former (or "spider") having radial spokes, basket coils can be wound upon formers made of cardboard or thin sheet fibre or ebonite. A circle of cardboard is cut out and slit as shown in Fig. 16, and the coil is wound as before, the spokes of the former having been replaced by the radial strips a, b, c, etc., of the card disc. Here, again, the coil can be wound as a single or double basket, the latter being recommended.

If cardboard is used for the former it should be shellac varnished and well baked, and it will not then be necessary to impregnate the coil itself. Its self-capacity may therefore be kept a little lower than that of a coil wound upon a spider, since the latter must be waxed or varnished, but against this must be set the di-electric losses in the former.

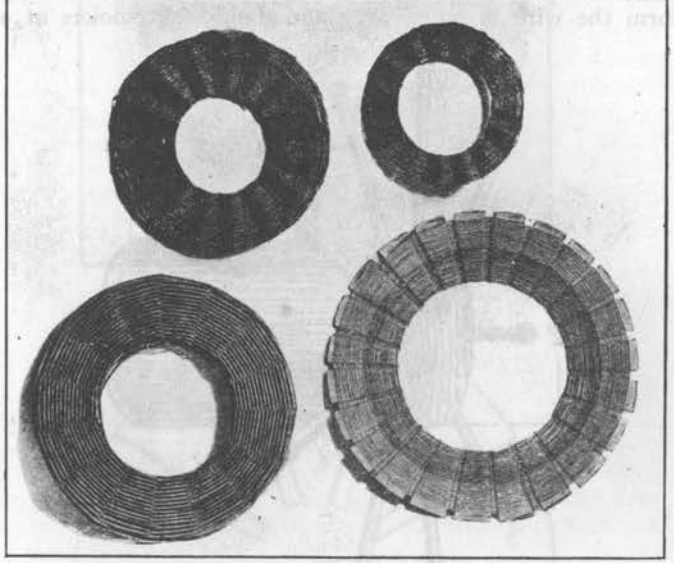


Fig. 18.—Some typical basket coils.

The spider used for winding basket coils should preferably be purchased, since they are difficult to make, but reasonably cheap to buy. At a pinch a make-shift one can be made by driving three-inch nails into a cylindrical piece of wood, as illustrated in Fig. 17.

The basket coil is not sufficiently compact for use upon the longer waves, but for wave-lengths up to about 2,500 metres it is extremely good, and a table is given opposite providing data for an efficient set of coils to tune from 200 to 2,500 metres when used in the aerial circuit with a variable condenser of 0.0005 μF capacity.

The hub of the spider should be from ¾in. to 1½in. in diameter.

COIL NUMBER	NUMBER OF TURNS	GAUGE OF WIRE
1	25	
2	35	22 d. c. c.
3	45	
4	60	
5	80	
6	100	30 d. c. c.
7	150	
8	200	34 d. c. c.
9	250	

To receive broadcasting with these coils, No. 2 or 3 will be required for the aerial circuit, No. 5 for the tuned anode circuit (with a variable condenser of .0003 μF, air dielectric type), and No. 4 for reaction.

CHAPTER VIII.

SLAB COILS.

At this point we commence the consideration of the various forms of multi-layer coil, and it will perhaps be well to preface our study of the first of these types by an explanation of certain points concerning the general principles of such windings.

At the outset it must be realised that each type is of necessity a compromise between two opposing factors. The effieciency or otherwise of any particular type depends very largely upon a satisfactory balance having been achieved between those factors, and if the reader will realise clearly what the balance should be he will waste no more of his hard-earned cash upon inefficient coils in which it scarcely exists. (It should, perhaps, be explained at this point that the author considers that almost the only way to obtain coils of really high efficiency is to wind them oneself. A very large number of the types upon the market sacrifice efficiency to various commercial considerations, chiefly in the matter of the use of too fine a gauge of wire).

Let us consider, then, what are the two opposing factors between which a satisfactory compromise must be achieved to produce a good multi-layer coil. They are briefly, efficiency and compactness, and they are opposed in this sense : the whole object of the multi-layer coil is to obtain compactness—that is, we wish to coil up a large quantity of wire in a small space—yet we know that the efficiency of a tuning inductance depends, among other things, upon keeping its internal capacity as low as possible, which can only be achieved by keeping well separated from each other all turns between which there is much difference of potential. Thus, turn No. 20 must not lie side by side with turn No. 1, though turn No. 5 and turn No. 1 may do so without much harm resulting. The worst possible arrangement would be to wind a layer of, say, 100 turns upon a tube, then over this another layer, and so on until the required number of turns had been wound on. A moment's thought will show why this arrangement of turns is bad, and will enable the reader to appreciate the statement that the best possible system of winding, judged from the internal-capacity point of view, is the simple single-layer type, in which there is very little difference of potential between adjacent turns. From the foregoing it will be grasped that the difference of potential between any two turns depends upon the number of turns separating them electrically in the winding. Thus, there will be a comparatively small difference of potential between, say, the first and third turns, and a comparatively large one between the first and fiftieth.

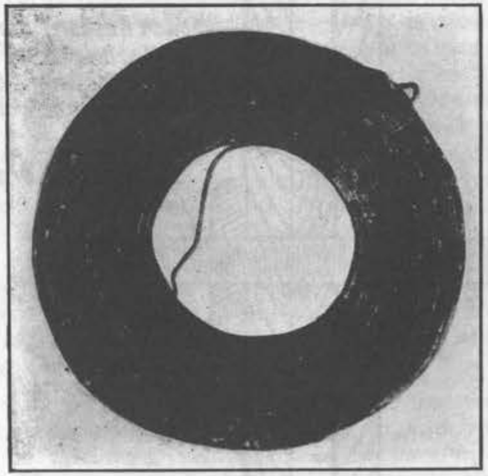


Fig. 19.—A small slab coil after removal from the former in which it was wound.

It follows, then, that a good system of multi-layer winding is one in which turns with a considerable difference of potential between them are kept well apart in the coil, and in which all turns are spaced out from their neighbours as much as is possible without making the coil too bulky.

The essential point to grasp is that there must be *spacing* between the turns : no coil which appears to be a solid mass of wire, with considerable depth and breadth, can possibly be really efficient, no matter how it is wound. Since in most systems of multi-layer winding the spacing

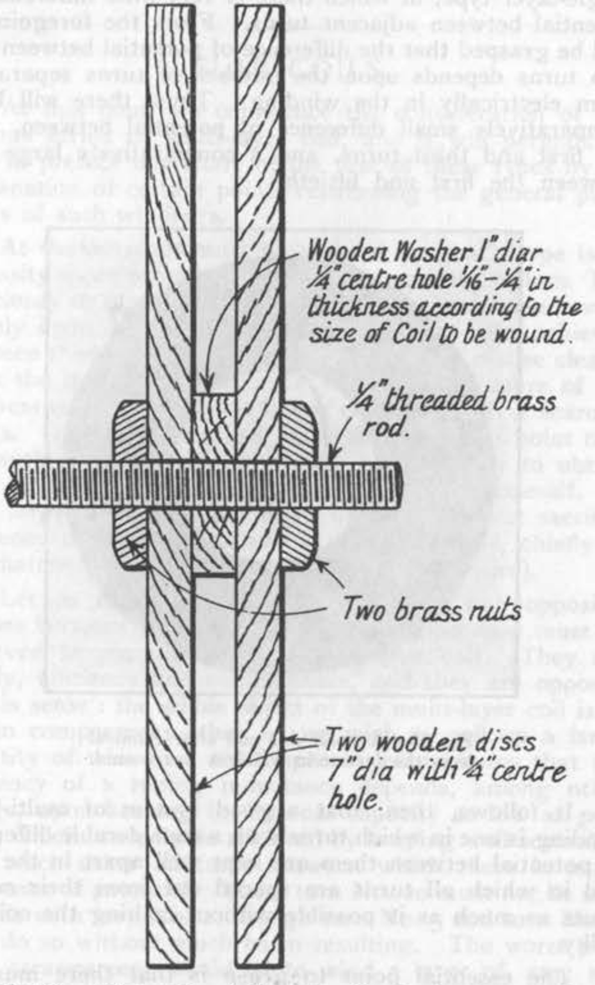


Fig. 20.—A former for winding slab coils. In the absence of a lathe the parts can be cut out with a fret saw.

is produced by some arrangement of crossing turns the actual amount of spacing-out depends in part on the thickness of wire used, and therefore use as thick a gauge as reasonable limits of size will allow. This is important, not merely because it reduces the internal capacity of the coil, but because it helps to keep down its resistance, and hence the damping of any circuit in which it is connected. This matter of the gauge of wire to use is one to which the amateur would do well to pay greater heed, and reference should be made to the chapter upon the subject for a more detailed explanation.

It is not, apparently, generally realised that the basic principles of the " slab " and the " pile " systems of coil-winding are essentially the same : in each we find that although turns between which there is much difference of potential are fairly well separated, there is no spacing between adjacent turns other than that provided by the insulation of the wire. Hence, while fair efficiency can be obtained in properly wound examples, these systems do not give the best possible results. Of the two, pile-winding usually produces a coil of least internal capacity, but it is not a sufficiently compact system for coils of very high inductance, and for these the slab coil is generally preferred. The latter type is extremely compact, very easy to wind (or cheap to buy, as the case may be), and, in spite of its only tolerable efficiency, it may be recommended for long-wave tuning to the beginner who wishes to put together as cheaply and easily as possible a set which will work, and which can be improved upon later.

The slab coil consists of a flat disc of wire, varying in size from perhaps 2 in. to 5 in. in diameter, and from $\frac{1}{16}$ in. to $\frac{3}{16}$ in. in thickness, held together by paraffin wax or varnish. The process of winding is extremely simple : a wooden former or bobbin is used which is very similar to those employed for winding the sections of spark coils, and the wire is run in quite irregularly until a coil of the required size has been produced. The former is then soaked in a bath of melted wax, taken out and cooled, and the coil taken out by separating the two halves of the wooden bobbin. The necessary details for the construction of a simple former are given in Fig. 20.

To wind slab coils with the maximum of ease some means of rapidly revolving the former is required ; the one illustrated is intended to be held by its central spindle in the chuck of either a lathe or a breast-drill held in a vice. By either of these methods the wire can be run in at quite a high speed, and large coils wound in a few minutes.

When the required amount of wire has been wound in, secure the end and soak the former in melted wax until bubbles cease to rise; then take it out, drain out the superfluous wax, and allow to cool until it is only slightly warm. Next slacken off the clamping nuts of the former, and separate the coil from the wooden discs by running a hot table-knife round between them. The coil can then be easily removed when the former is taken apart. (Do not heat the knife in the fire; dip it in boiling water.)

A series of slab coils suitable for long-wave tuning may be wound with No. 30 double cotton-covered wire with the following numbers of turns: 500, 750, 1,000, 1,250, 1,500.

CHAPTER IX.

PILE WINDING.

The very useful system of multi-layer winding known as pile-winding differs from the slab method mainly in that it produces a cylindrical coil, and that the turns are arranged in a definite order. It bears a considerable superficial resemblance to ordinary layer-by-layer winding, the distinction being that in pile-winding the turns are wound on so as to bring together only those between which there is a small difference of potential, and to keep others separated. This is actually done by winding on all the layers at once, instead of one by one; one turn is wound upon each layer in rotation until the coil has grown to the necessary size. Thus, if a three-layer pile-wound coil is being made, the wire will be wound on in this order: first, a turn on the bottom layer, then one on the second layer, and then one on the third, after which the wire returns to the bottom layer and the process is repeated. Fig. 21 (*a*) and (*b*) will probably convey a clearer conception of the method than any verbal description. Fig. 21 (*a*) is a section of a "three-pile" winding, and Fig. 21 (*b*) is a section of a three-layer winding in which the layers have been wound on separately. The numbers within the circles representing the turns of wire indicate the order in which the turns were wound on.

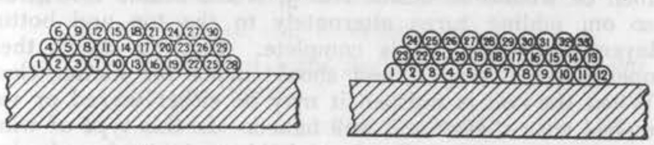


Fig. 21. A comparison of pile winding (a) and layer winding (b).

Pile-winding is naturally somewhat more difficult than the previous method, and a certain amount of skill has to be acquired before it can be done easily and quickly. The process is rendered considerably easier by the use of a suitable gauge of wire, since the thicker wires are too stiff for convenience and the thinner ones not stiff enough for the turns to remain where they are placed. Nos. 24 to 28 will be found to be the easiest for pile-winding.

For the first attempt a two-pile winding should be tried, since this is the easiest for a novice to tackle. The method of procedure follows: First secure the end of the wire to the tube upon which the coil is to be wound (by passing it through two holes), and then wind on two turns side by side. Next, keeping the wire tight, hitch it back and wind the third turn on top of the first two, in the groove which is formed between them. On the completion of this turn take the wire down on to the former again and wind turn No. 4 beside turn No. 2. Turn No. 5 will then be wound on beside No. 3, No. 6 beside No. 4, and so on, adding turns alternately to the top and bottom layers until the coil is complete. Fig. 22 shows these operations in stages, and should make the matter clear. When the coil is finished it may be either waxed or varnished with shellac and well baked. In this type of winding, by the way, shellac is probably to be preferred, since it is extremely difficult to drain out the superfluous wax if this agent is used for impregnation. The shellac, if used (see the chapter on damp-proofing), should be exceedingly dilute, and the baking should be particularly thorough.

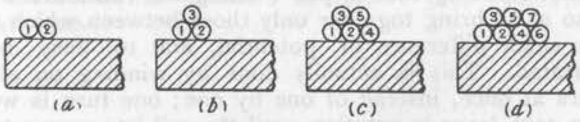


Fig. 22. Stages in two-pile winding.

To wind a three-pile coil the procedure is as indicated in Fig. 23; while the beginning of a four-pile winding is shown in Fig. 24. A greater number of layers than four, or perhaps five, is not advisable, partly on account of practical difficulties in winding, and partly because the self-capacity of the coil becomes excessive if a greater depth of winding is used.

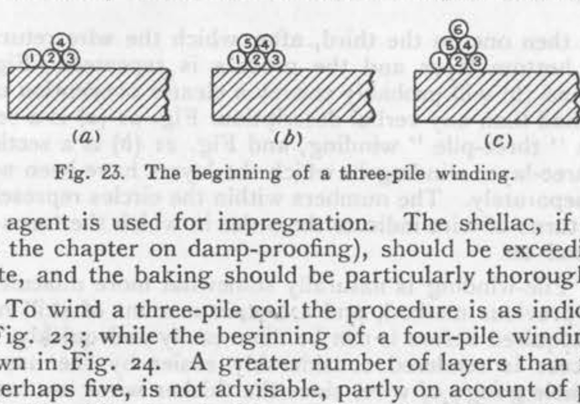


Fig. 23. The beginning of a three-pile winding.

It should be pointed out that the pile-wound coil has one point of superiority over all other multi-layer types: it is quite easy to calculate its inductance with an accuracy sufficient for rough purposes. The following formula will be found to give quite a good approximation:

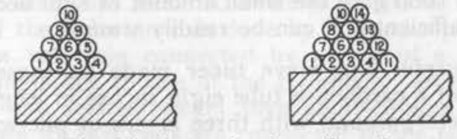


Fig. 24. Start of a four-pile coil.

$$\underset{\text{(microhenries)}}{L} = \frac{\pi^2 D^2 N^2 P^2 \, l \, k}{1{,}000}$$

Where D = diameter of coil in centimetres.
l = length of coil in centimetres.
N = number of turns per centimetre in any *one* of the layers.
P = number of layers or "piles" in the coil.
k = a constant whose value depends upon the ratio of the length of the coil to its diameter. Various values of k are given in the table below.

$\frac{l}{D}$	k
0.50	0.51
0.75	0.62
1.00	0.67
1.50	0.76
2.00	0.81
2.50	0.84
3.00	0.86
3·50	0.88
4.00	0.90
5	0.91
6	0.92

A very successful tuner for the longer waves, between, say, 2,000 and 20,000 metres, can be made by the use of pile-winding upon a fair-sized cardboard tube, tappings being taken at appropriate points to switch studs. Pile-winding is certainly a little difficult to do at first, but practice will soon give the small amount of skill necessary, and a very efficient coil can be readily wound.

A useful long-wave tuner made on these lines may consist of a cardboard tube eight inches in length and four in diameter, wound with three layers of pile-winding with No. 32 double cotton-covered wire, giving rather over 1,000 turns. Tappings should be taken at equal intervals along the winding from ten points, and the required wave-length range will be easily covered with the aid of a variable condenser of 0.001 μF capacity.

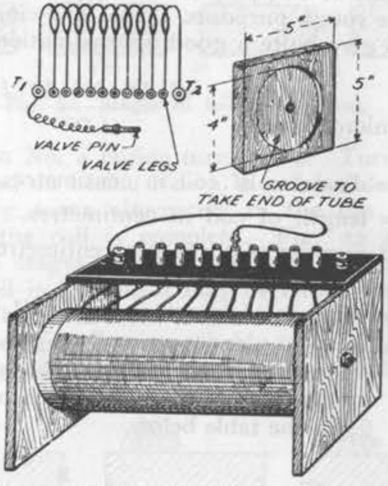


Fig. 25. The construction of a pile-wound long-wave tuner.

The tube is to be mounted between wooden end-pieces, such as that whose details are given in Fig. 25, and the whole firmly clamped together by means of a threaded brass rod passing through the centre of the tube and out through the end-pieces. A length of about a quarter of an inch projects at each end, and upon these are screwed a pair of nuts to hold the assembly together.

A strip of ebonite 8 in. long, 1 in. wide, and $\frac{3}{8}$ in. thick is attached to the wooden ends by means of two round-headed brass wood-screws, and carries two terminals and ten valve socket legs. Wires connecting the valve legs to the tapping points on the coil should be soldered in after the ebonite strip has been screwed in position, and the variation of the inductance is done by a wander-plug consisting of a valve-pin connected by means of a six-inch length of single flex to one of the terminals. Insertion of this pin in any desired socket then short-circuits part of the coil, since its two ends are connected to the terminals.

The ebonite strip shown is to be screwed on *at one side* of the coil, and not exactly over its centre, in order to make room for the projecting shanks of the valve legs beneath, and to facilitate the soldering of the tappings.

The method of making tappings calls for some explanation, since it is not very easy to make them in a pile-wound coil; as a rule, it is not worth while to attempt to make them as winding proceeds, but to wait until the coil is finished. On completion of the winding, soak the coil in *dilute* shellac varnish (thinned down with methylated spirit) and bake it in an oven of moderate warmth until thoroughly dry. Then take a pair of sharp-pointed scissors and cut one of the turns at each of the tapping points, turn back the two cut ends of each severed turn and scrape them bare with a knife. Solder these ends in pairs to their respective tapping wires.

This tuner is intended as a loading coil pure and simple, reaction requiring to be otherwise provided for, but it could easily be modified to include a reaction coil. For example, one end could be left open like a loose-coupler and a coil consisting of a tube 3 in. in diameter and 5 in. long wound full with No. 36 enamelled wire arranged to slide inside.

CHAPTER X.

LATTICE COILS.

Taking into account its efficiency and its ease of winding, the " lattice " or Burndept coil is perhaps the most suitable multi-layer for general amateur use. Its construction is very simple, for it is merely a layer-by-layer winding, the layers of which contain a small number of turns, and are separated by a special zigzag spacing turn, the coil being in the form of a disc of diameter up to 5 in., and thickness up to 1 in. (Fig. 26). A section of a portion of a lattice winding is given in Fig. 27.

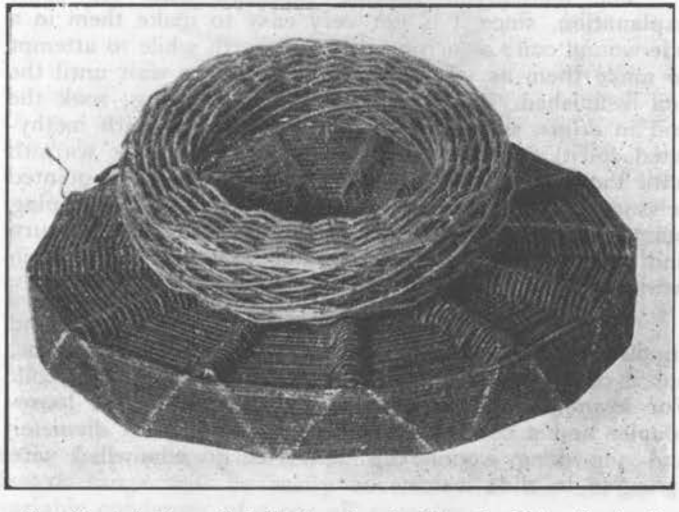


Fig. 26. A lattice coil (below), and a duo.lateral. Note: the track of the zig-zag spacing turn in the lattice coil has been marked with chalk.

The method of winding by hand is simple: A former is used, which consists of a wooden cylinder, say $1\frac{1}{2}$ in. in diameter and 2 in. long, in which are driven two radial rows of pins, say twelve in a row, the pins being " staggered " in the rows, and the rows separated by a distance depending upon the thickness of the coil to be wound (Fig. 28). Suitable pins for the purpose may be made by cutting No. 16 or 18 galvanised iron wire into lengths, or one can use slender wire nails, or the pins which joiners call " panel pins." The method of winding is to commence by putting on a zigzag turn round the outside of the pins, as shown in plan in Fig. 29 (*a*). On the completion of this turn the wire is wound on in a single layer across the former (Fig. 29 (*b*)), then another zigzag turn is put on, to be followed by another layer, and so on alternately until the required number of turns has been wound on. The coil is then well soaked in melted paraffin wax, taken out and drained as completely as possible, allowed to cool, and removed from the former by extracting the pins (with a pair of pliers) and pulling out the first zigzag turn, after which it will come away easily.

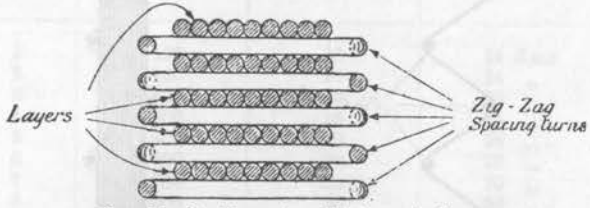


Fig. 27. Section of a lattice winding.

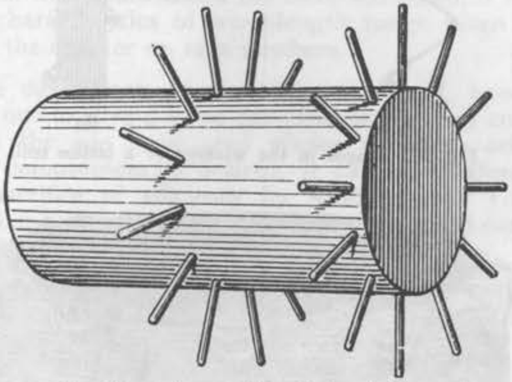


Fig. 28. A former for winding lattice coils.

It will be found quite a simple matter to wind a set of lattice coils, especially if the former can be mounted on some sort of spindle (or chucked in a lathe, of course), so as to be easily revolved, and they will be found very satisfactory for medium- and long-wave tuning. Data for a set to cover approximately 1,000 to 20,000 metres are given below.

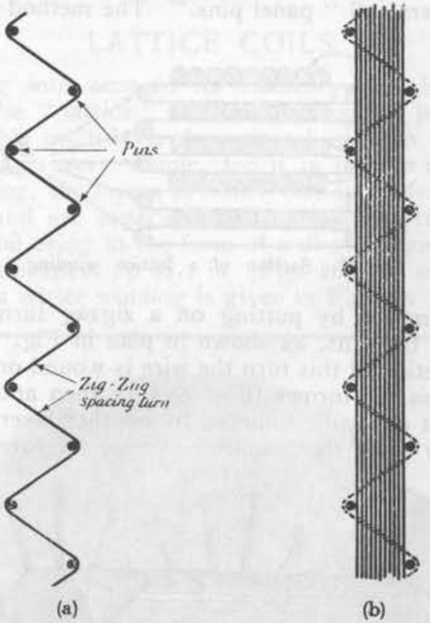


Fig. 29. Stages in the winding of a lattice coil.

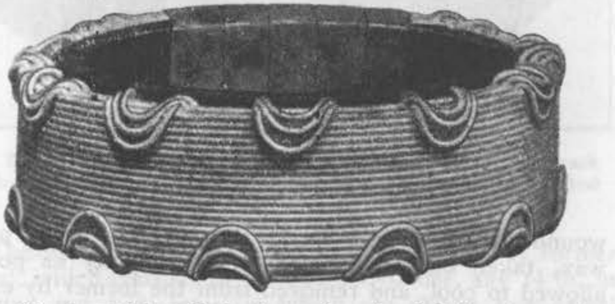


Fig. 30. A useful method of securing the finishing turns of a lattice coil. The projecting loops of the zig-zag turns are bent back over the top layer, which is thus firmly held.

COIL	TURNS	TURNS PER LAYER	WIRE
1	100	10	24 d.c.c
2	150	10	24 ,,
3	200	10	24 ,,
4	300	15	24 ,,
5	400	20	26 ,,
6	500	20	26 ,,
7	750	20	30 ,,
8	1,000	30	30 ,,
9	1,250	30	30 ,,
10	1,500	40	30 ,,

Diameter of former, 2 in.; number of pins per row, 12; distance between rows of pins (*i.e.*, thickness of coil): coils, 1-3, $\frac{3}{8}$ in.; coils 4-7, $\frac{5}{8}$ in.; coils 8 and 9, $\frac{7}{8}$ in.; coil 10, 1 in.

With these dimensions the coils will conform roughly to the characteristics of wave-length range given in the table in the chapter on turn numbers.

The data given, it should be explained, have been worked out to give a good compromise between compactness on the one hand, and efficiency on the other; if greater compactness is desired, it can be obtained at a slight sacrifice of efficiency by winding coils 1-4 with No. 28 d.c.c. wire, and coils 5-10 with No. 32 d.c.c. wire.

The writer has found that the lattice coil is exceedingly useful as a starting-point for the origination of new systems of coil-winding, a little ingenuity sufficing to produce quite a variety of such modifications.

The two examples which follow are the most useful of the various types which have been obtained in this way. The first coil is of the flat disc or pancake type, which is convenient for some coupling purposes, and is intended to replace the basket coil, over which it has considerable advantages in mechanical strength, compactness, and quickness of winding. It is simply a lattice coil of only two turns per layer, those two being spaced apart, as shown in section in Fig. 31. It is wound upon a former which differs from the one already described in that its two rows of pins are only about ¼in. apart, and the method of winding is as follows: First the zigzag turn with which every lattice coil begins, then a turn straight

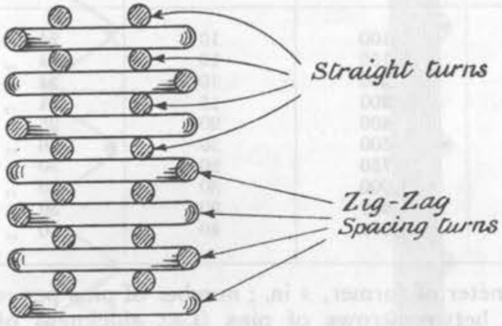


Fig. 31. Section of a disc-type lattice winding.

round close against the pins on one side of the former, across on a slant to the other side, and then one turn round against the other pins. Fig. 32 shows these first three turns, and should make the matter plain. After this, zigzag spacing turns alternate with layers composed of two straight turns until the coil is finished. On the completion of the coil tie the last turn tightly to the zigzag one beneath it with thread at two points, wax the coil and

Fig. 32. Plan of part of a disc-type lattice coil.

remove it from the former as before. It should perhaps be mentioned at this point that with all multi-layer coils it is generally worth while to tie the first turn to the one above it, and the last turn to the one beneath it, to eliminate any tendency to unwind. (*Note.*—In the case of lattice coils " first turn " does *not* mean the zigzag turn

which is put on at the commencement of winding, since this is always intended to be pulled out after the coil has been waxed or shellacked, to enable one to remove it from the former.)

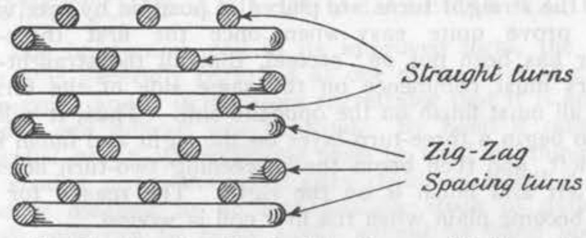


Fig. 33. A section of a duo-laterally spaced lattice coil.

The second type is one whose use for all short-wave purposes is strongly advocated, since it is distinctly the best multi-layer coil which the author has yet tested. The system of winding is such that the super-imposed turns

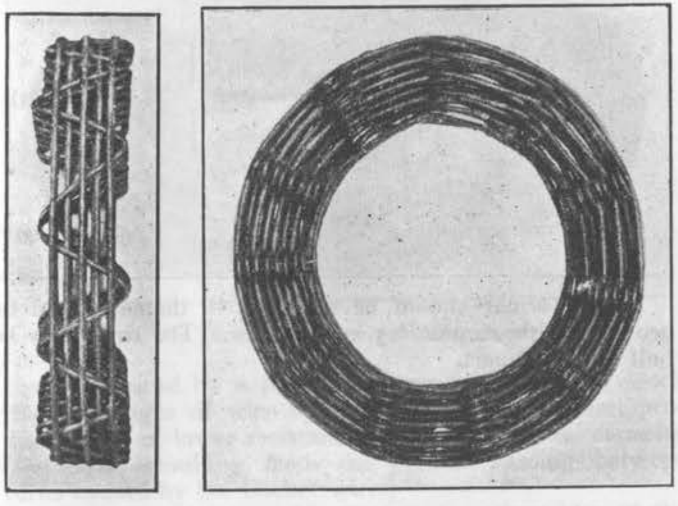


Fig. 34. A duo-laterally spaced (' staggered ") lattice coil.

are separated by quite as great a space as in the popular duo-lateral coil, and they are separated electrically by smaller differences of potential. This system was originated very simply from the preceding one by applying the duo-lateral principle and "staggering" the turns which come vertically above each other, as shown in section in Fig. 33. Instructions for winding this coil are scarcely necessary, the only points requiring mention being, first, that the straight turns are placed in position by eye, which will prove quite easy when once the first three-turn layer has been put on; second, that all the straight-turn layers must commence on the same side of the former, and all must finish on the opposite side. Thus, it will not do to begin a three-turn layer on the right and finish it on the left, and then begin the succeeding two-turn layer on the left and finish it on the right. The reason for this will become plain when the first coil is wound.

A set of coils of this type for tuning between 200 and 600 metres may be wound from the data given in the table below.

COIL	NUMBER OF TURNS	WIRE	TURNS PER LAYER
1	25	22 s.w.g. double cotton covered	2 and 3 (alternating)
2	35		
3	45		
4	65		
5	75	24	4 and 5 (alternating)
6	100		

The former should be 2 inches in diameter and be provided with 26 pins, 13 in each row. The rows may be half an inch apart.

CHAPTER XI.

HONEYCOMB AND DUO-LATERAL COILS.

The honeycomb coil in its improved form, the duo-lateral, is generally regarded as one of the best of multi-layer coils, and it is therefore regrettable that it is such a tedious and difficult one to wind. By hand it must be regarded as an impracticable task to wind anything but the smaller sizes, the large ones requiring either a coil-winding machine or an inexhaustible stock of patience. Small coils can be fairly easily wound by hand upon a former resembling that used for lattice coils, the only difference being that many more pins are required for the duo-lateral. Such coils are usually somewhat superior to those produced by a machine, since one can wind much thicker gauges of wire by hand and can, therefore, produce a coil of lower resistance and lower internal capacity (the latter resulting from the greater spacing between turns caused by the thicker wire.)

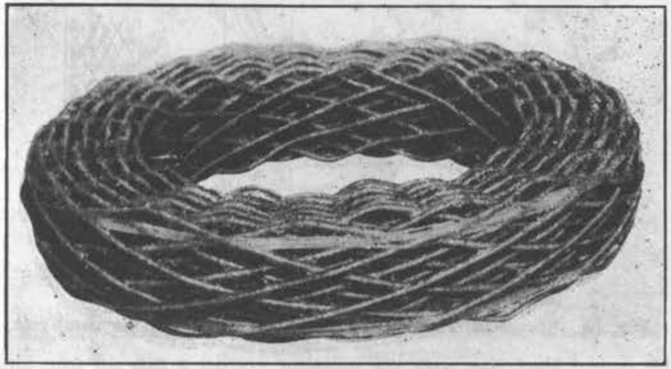
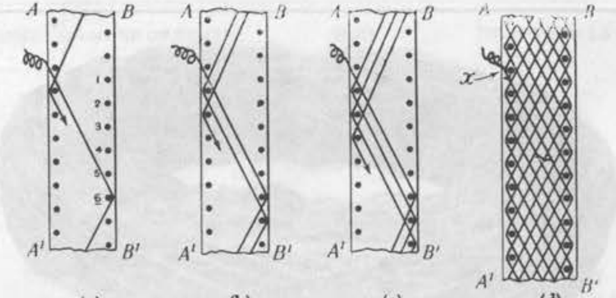


Fig. 35. A home-made duo-lateral coil.

It is almost impossible to convey a clear idea of the nature of the honeycomb and duo-lateral systems by verbal description, and we must invoke the aid of some diagrams. The essential characteristic of both systems is that the wire in passing round the former travels slantingly from side to side of the coil. On the completion of each revolution a fresh turn is begun at a point a few degrees ahead of, or behind, the spot at which the previous one started. An attempt is made to show this in Fig. 36 (*a*), which is a plan of the surface of the former, with the pins represented by dots, upon which one turn of wire has been wound. It must be emphasised that the figure is a plan of the *whole* surface of the former, not half of it. Thus, to accurately represent the original, the paper would have to be bent round so that the lines AB, A_1B_1, met to make the diagram circular. Figs 36 (*b*) and 36 (*c*) show the effect of adding turns one at a time, while Fig. 36 (*d*) shows the first layer completed. The second layer would begin at the point X, and would follow exactly the turns of the layer beneath (from which it is separated by the turns running crosswise), thus preserving the cellular structure seen in Fig. 36 (*d*) which gives the coil its name. It will



(a) (b) (c) (d)

Fig. 36. Stages in winding the first " layer " of a honeycomb coil.

be noted that the wire on passing round a pin on one side of the former slants across to the other side and passes round the *sixth* pin, counting six in this way every time it crosses over. This is indicated by the numbers in Fig. 36. In the case of the honeycomb any convenient number may be used, according to the closeness of winding desired (the larger the number the closer the winding). It is worth noting that the number of turns per layer is fixed by the number of pins " counted " in crossing over; in the example figured it can be ascertained by actual enumeration that each layer consists of eleven turns, which is twice the number of pins " counted," minus one. This rule holds good for all honeycomb and duo-lateral coils,

irrespective of the number of pins on the former, and is very useful when one is designing, say, a series of coils to have specified numbers of turns. If greater openness of winding is required, to give a coil of greater bulk and extra low self-capacity, one can put the same number of turns into a greater number of layers, each containing fewer turns.

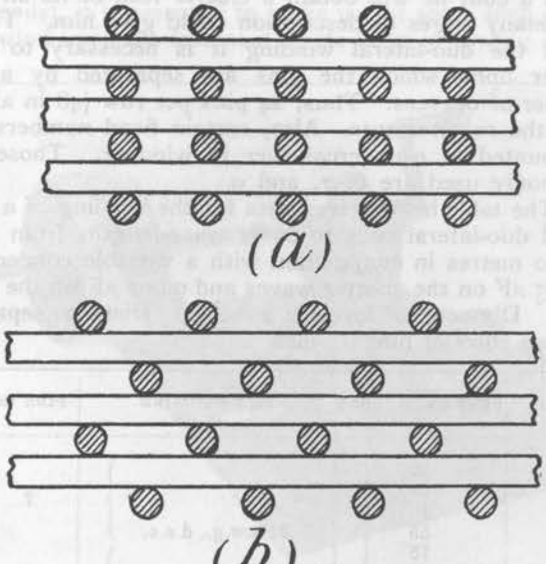


Fig. 37. Sections of honeycomb and duo-lateral coils, showing the difference in their structure.

The number of pins on the former may be any convenient figure, from 10 to 20 in each row, in the case of the honeycomb, but has to be one of certain definite numbers in the case of the duo-lateral. This latter coil is of a very similar cellular structure to the honeycomb, the difference being that in the duo-lateral the turns in one layer do not lie exactly above those in the one beneath, but come over the spaces between them. Fig. 37 shows this difference by means of sections through (*a*) a honeycomb, and (*b*) a duo-lateral winding. It is evident that the latter has nearly three times the space separating the turns in a vertical direction, and its capacity is, therefore, lower. The reduction is sufficiently considerable to make the duo-lateral almost universally used, the simple honeycomb now being rarely met with.

The actual difference in winding which produces the duo-lateral formation is difficult to describe, and, besides taking much space, would be of little interest or assistance. If the experimenter employs the following data and winds a coil, he will obtain a clearer idea of its structure than many pages of description could give him. To construct the duo-lateral winding it is necessary to use a former upon which the pins are separated by an *odd* number of degrees. Thus, 24 pins per row (48 in all) will fulfil the requirements. Also, certain fixed numbers must be counted at each cross-over in winding. Those most commonly used are 6, 7, and 9.

The table below gives data for the winding of a useful set of duo-lateral coils to cover wave-lengths from 200 to 20,000 metres in conjunction with a variable condenser of 0.0005 μF on the shorter waves and 0.001 μF on the longer ones. Diameter of former: 2 inches. Distance separating the two rows of pins: 1 inch.

COIL	NUMBER OF TURNS	SIZE OF WIRE	PINS COUNTED
1	25	22 s.w.g., d.c.c.	7
2	35		
3	45		
4	55		
5	75		9
6	100		
7	125	28 " "	
8	150		
9	200		
10	300		
11	400	34 " "	
12	500		
13	750		
14	1,000	36 " "	
15	1,250		
16	1,500		

The fact that some of the coils have an odd number of turns need not cause difficulty, since the necessary additional number of turns required over and above those provided by some definite number of layers can easily be counted individually as they are wound.

One or two points deserve mention concerning the practical details of winding. It is desirable to tie the first and last turns to those above and below respectively at two or three points with thread, to prevent any unwinding of the coil during the operation of mounting on a plug when finished. In order to be able to remove the coil from the former easily after it has been soaked in wax and cooled (wax impregnation is to be preferred in the case of these coils), it is essential to make use of some such device as to wind upon the former a single layer of sewing cotton before starting the coil. Fasten the two ends of the layer of cotton where they will be easily got at, then, after waxing the coil and extracting the pins, you can pull out the cotton and the coil will slip off quite freely.

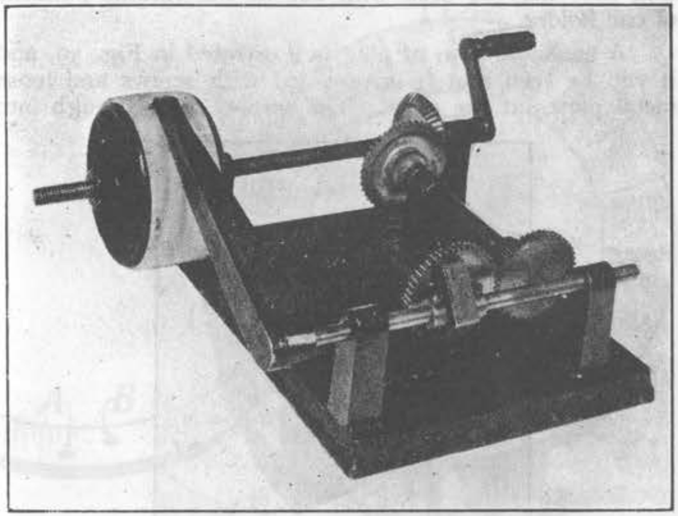


Fig. 38. The " Zodel " coil-winding machine.

The larger coils of the series given above would be exceedingly laborious to wind by hand, of course, and it is almost essential to use a coil-winding machine for the purpose. These machines, of which one type is illustrated in Fig. 38, are somewhat expensive, but enable quite big coils to be wound very quickly and easily. The makers usually supply full instructions for use with each machine.

CHAPTER XII.

MOUNTING COILS.

To make proper use of a set of coils of the basket or multi-layer type it is necessary that they should be interchangeable in circuit, and the best way of achieving this end is to mount them all upon the standard coil plugs so that they may be used with one of the various patterns of coil holder.

A common form of plug is illustrated in Fig. 39, and it will be seen that it is provided with screws and loose metal plates at the sides. The screws pass through into the metal parts within the plug, so that the two ends of the coil are to be connected to these screws. In many makes of plug there is an alternative method of making this connection, however, which is preferable. In these plugs the metal of the actual plug and socket contacts projects a little above the top of the plug, and the wires can be soldered directly to these, thereby ensuring a permanently good connection.

Fig. 39. A common type of plug upon which coils may be mounted

The screws serve also the useful purpose of providing a point of attachment for the coil, the two metal plates being also intended to assist in that operation. There are a variety of ways of fixing the coil to the plug, the one in common commercial use consisting of a fibre band whose ends are gripped under the metal plates on the plug, and which passes round the coil, securing it firmly. This method is that which the novice usually attempts first, having examined the commercial product, but by the time he has fully realised what a difficult business it is to tighten up those screws without letting the band slip a little and become slack, his enthusiasm for home-made coils has usually evaporated.

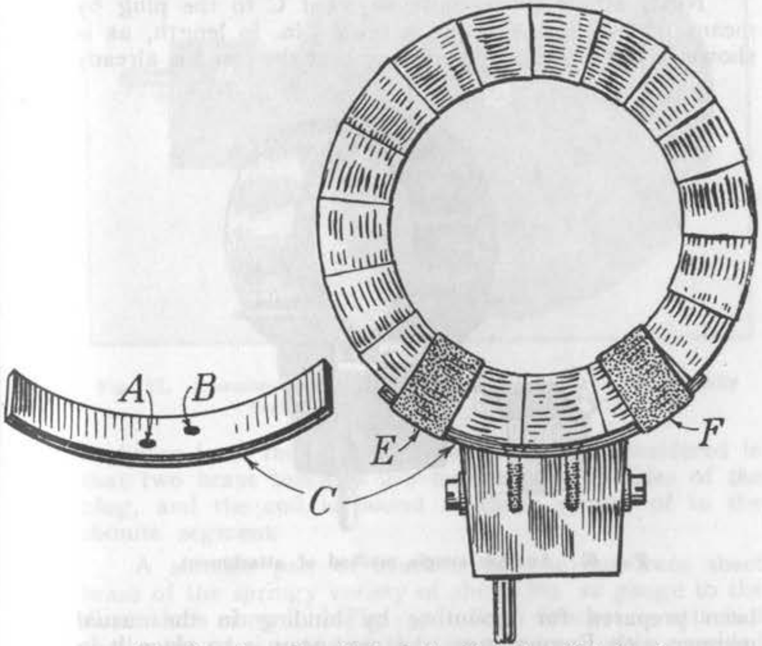


Fig. 40. A good method of attaching the coil to its plug.

Moreover, the method is not very satisfactory from the point of view of electrical efficiency, since fibre is *not* a really good insulator. It is always liable to absorb moisture, and, as the ends of the band are connected to the ends of the coil, quite serious leakage may occur.

The method of attachment illustrated in the accompanying figure will be found a satisfactory solution of the difficulty, which can be employed by anyone possessing quite simple tools.

The curved ebonite strip C is cut from a piece of tube having very roughly the same diameter as the coil to be mounted, and should be about 2½ inches long by ¾ inch wide. Two holes (A and B) are drilled in the positions shown with a 3 B.A. drill, and *slightly* countersunk, so that the heads of the screws which will pass through them may not project. Two corresponding holes are now drilled and tapped with a 4 B.A. thread in the plug.

Next, attach the ebonite segment C to the plug by means of two 4 B.A. brass screws ½ in. in length, as is shown in the diagram. Assuming that the coil has already been prepared for mounting by binding in the usual manner with Empire tape, the next step is to place it in position upon the plug and attach it firmly thereto by binding tightly round both coil and ebonite segment with sticky black insulating tape at the points E and F.

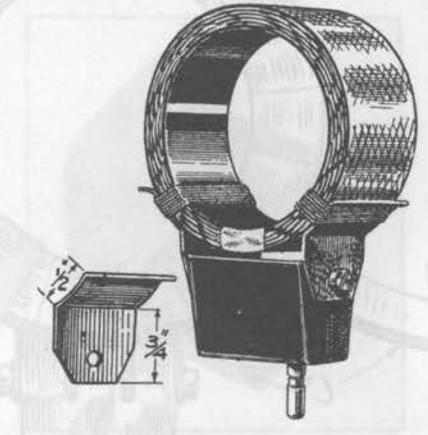


Fig. 41. Another simple method of attachment.

If the appearance of the two black bindings is disliked, they may be covered with a turn or two of Empire tape, secured in position by means of Chatterton's compound at start and finish.

Another good method is that introduced by the Giblin-Remler coil manufacturers for attaching their products to the standard plugs. Its essential features are shown in the accompanying sketch (Fig. 41), and it will be seen that it differs from the one which we have just considered in that two brass brackets are screwed to the sides of the plug, and the coil is bound to these instead of to the ebonite segment.

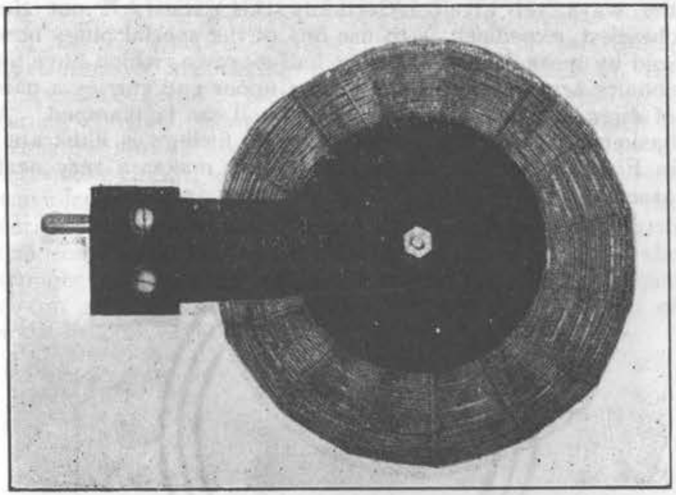


Fig. 42. A commercial basket coil mounted upon a plug specially designed to carry this type of coil.

A suitable pair of brackets can be cut from sheet brass of the springy variety of about No. 22 gauge to the dimensions shown in Fig. 41. Each bracket is attached to the plug by means of the two screws always provided upon such plugs for the purpose of connecting the two ends of the coil to the contacts, and the binding indicated in Fig. 41 should be done with strong waxed thread. The result is an exceedingly robust job of good appearance and greater efficiency than that possessed by the fibre band method.

It should perhaps be mentioned that both these methods of attaching coils to plugs are fully covered by patents, and therefore they are not available for commercial use, although the private experimenter may employ them for his own purposes with little fear of interference.

Basket coils call for somewhat different treatment, in that they are flat discs, and cannot be attached in any of the ways yet given. Certainly the easiest, if not the cheapest, expedient, is to use one of the special plugs now sold by most dealers at about half-a-crown, which have an ebonite arm fitted to them whose upper end carries a pair of discs between which the basket coil can be clamped. A basket coil mounted on one of these fittings is illustrated in Fig. 42, and it will be seen that it makes a very neat assembly.

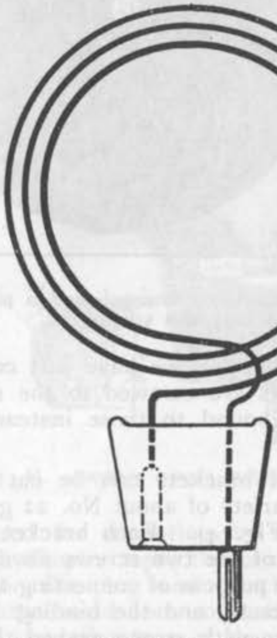


Fig. 4 a. The standard connections to a coil plug.

All coils should be connected to their plugs in the standard fashion, which is illustrated in the diagram on this page. They will then all function alike in regard to reaction, coupling of primary and secondary, and so on.

CHAPTER XIII.

"APERIODIC AERIAL" COILS.

At the time of writing, a number of interesting developments are taking place along the lines of the "aperiodic aerial" method of tuning. This system of tuning consists, essentially, of an aerial circuit which is probably almost aperiodic, and which is coupled to a secondary circuit, which is tuned accurately to the received wave-length. The aerial circuit usually consists of the aerial itself, a few turns of wire on a coil, and the earth connection, as shown in Fig. 43. Provided that the number of turns is small and the resistance low, this circuit responds fairly uniformly over the entire band of wave-lengths covered by the secondary.

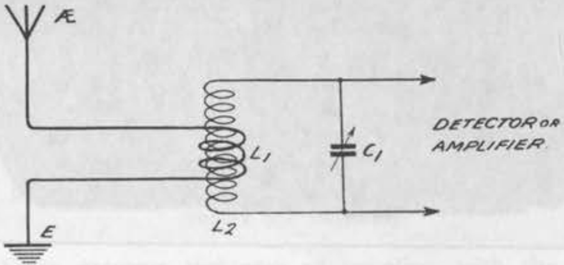


Fig. 43. A typical circuit employing the aperiodic aerial system.

Since the aerial circuit is required to function aperiodically, it might be expected that resistance in series would be beneficial rather than harmful, but the reverse is found in practice, and it is essential that the aerial coil be wound with quite thick wire. It is necessary, also, to keep down the resistance of the secondary circuit, and here, also thick wire must be used if really good results are to be obtained. The essential features of this system of tuning, then, are these:—Low resistance in both primary and secondary circuits, a relatively small number of turns in the aerial circuit, and extremely "tight" coupling between the circuits.

Granted these conditions, the method possesses several great virtues. First, its sharpness of tuning is very much superior to that of the ordinary single-circuit tuner, and practically equals that of a good loose-coupler, so that it is exceedingly helpful in reducing interference. Nevertheless, it is no more difficult to operate than a single-circuit tuner, and has none of the complication of the loose-coupled type. Further, if the coil is properly designed, there is little or no loss of signal strength, and the calibration of the circuit remains constant whatever the size of aerial with which it is used. This latter point is particularly advantageous where portable sets are concerned.

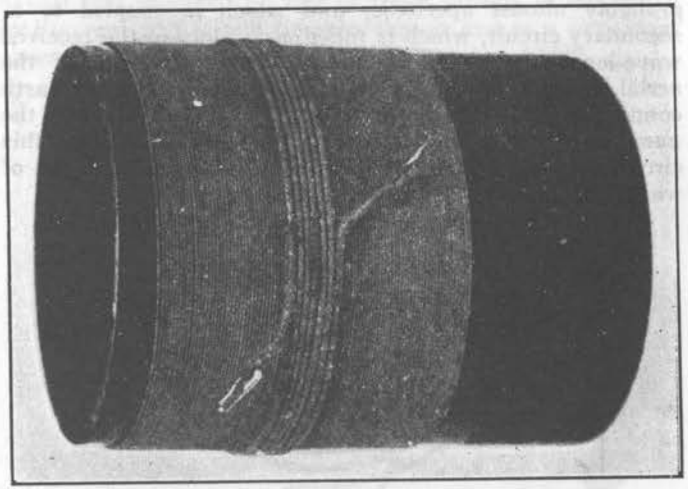


Fig. 44. A simple type of coil for aperiodic aerial tuning.

Since the tuning is independent of the size of the aerial, coils of the type which we are considering are especially useful upon the shorter waves (600 metres and below), as they remove any limitation upon the dimensions of the aerial which would otherwise be imposed by the exigencies of tuning. When a "Ducon" is employed, for example, it is often necessary to use a very small series condenser to bring the system down to the shorter waves, with consequent loss of efficiency in the case of an ordinary tuner. If the "aperiodic aerial" method is substituted, no series condenser is required, and signals are therefore much improved.

The original type of coil consisted of a single-layer secondary winding upon a tube, the aerial coil comprising about ten turns wound directly on top of the secondary at a point near its centre. (Several experimenters confirm that it is best to place the primary fairly accurately in the centre.) The larger the number of turns in the aerial coil, the less sharp the tuning, while if their number is reduced beyond a certain point, signal strength suffers.

A coil suitable for broadcast reception consists of a secondary winding of 70 turns upon a 3½ in. tube, and an aerial coil of 8 turns, No. 22 double cotton-covered wire being used for the secondary, and No. 20 double cotton-covered for the primary. This coil will cover a range of about 200 to 500 metres with a variable condenser of 0.0003 μF.

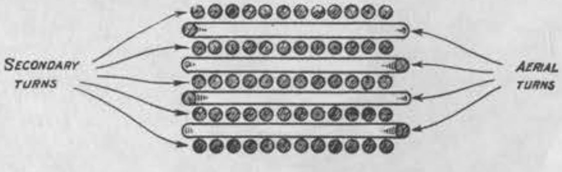


Fig. 45. A section of a lattice winding containing both primary and secondary.

Since extreme tightness of coupling with the minimum number of aerial turns is required, it is obvious that some form of multi-layer coil should give better results than the type which has just been described, and this expectation is borne out in practice. A number of experimenters, the author among them, have obtained remarkably good signals and selectivity by the use of a variety of multi-layer coils in which the aerial turns are interwoven with the secondary. The first successful coil made by the author was a duo-lateral having 80 turns of No. 20 d.c.c. constituting the secondary winding and 10 turns of No. 18 d.c.c. the primary. The latter took the form of a single layer wound upon the wooden former before commencing to wind the 80-turn coil. After putting on the secondary winding, the whole was impregnated with thin shellac, baked, and removed from the former as one coil. Better coupling would probably have resulted if the aerial coil had been inserted in the middle of the secondary by winding on 40 turns of the latter, then the ten primary turns, and over these the remaining 40 of the secondary.

A particularly effective coil recently wound by the author consists of what is really a modification of the lattice ("Burndept") coil. It will be remembered that the lattice coil is composed of alternate layers of wire and zigzag spacing turns, and it is a simple matter to adapt it to the requirements of the "aperiodic aerial" tuning system by winding the layers from one bobbin of wire and the zigzag turns from another. The result is two separate windings, of which the zigzag turns form the aerial coil, extremely tightly coupled to the other winding, which constitutes the secondary. A good coil for broadcast reception has ten layers of seven turns each, wound with No. 22 d.c.c., the nine spacing turns of No. 20 d.c.c. being connected in the aerial circuit. A section of part of such a coil is shown in Fig. 45, its inner diameter being 2 in.

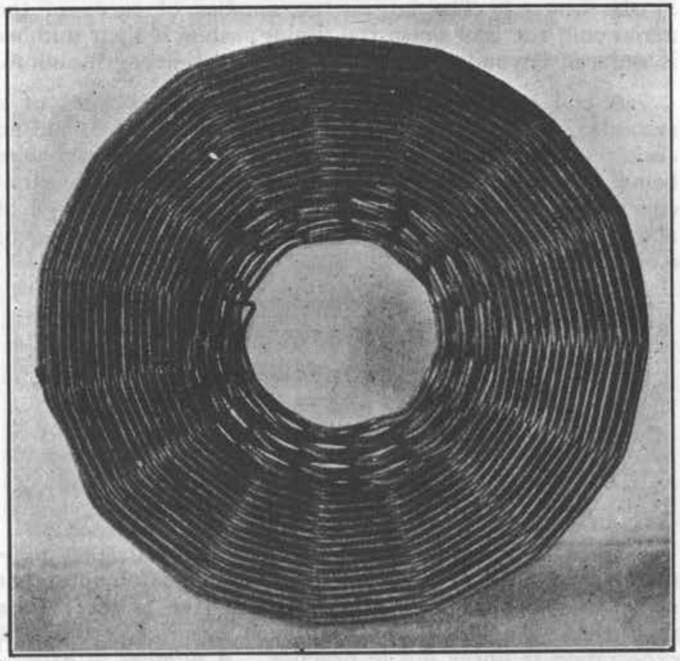


Fig. 46. A basket coil with an interwoven primary.

Since the spacing turns in this type of coil cross those composing the secondary winding at angles, it would seem that the magnetic coupling between primary and secondary must be poor. However, the coil gives excellent results, and it is suggested that the effective coupling is to some extent electrostatic.

A great variety of possible windings are provided by the basket coil, and some form of simultaneous winding such as that devised by Dr. Chapman for the Reinartz circuit, may be used. For example, the first eight or ten turns may consist of a double winding, primary and secondary being put on together. On the completion of these double turns the primary is cut off and the secondary continued for a further 60 or 70 turns, assuming that the coil is intended for broadcast reception.

The simultaneous turns may be inserted at any point in the coil, a good form being that in which the double turns are placed at the midway point in the winding of the coil. A better method, in the author's experience, is to wind on first eight turns of the secondary, then one turn of the primary, another eight of the secondary, one primary, and so on until the coil is complete.

Honeycomb and duo-lateral coils also provide a convenient basis for simultaneously-wound aerial and secondary coils. The primary can be inserted at any convenient point during the winding, an example having been quoted above. The most effective way of doing this appears to be by winding simultaneously from two bobbins of wire, so that both primary and secondary are wound with the correct honeycomb formation where they lie side by side.

The impregnation of the finished winding is a more critical matter than in the case of coils of ordinary type, and it seems that it is essential to use the absolute minimum of good-quality shellac or paraffin wax.

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