The Design & Construction of Induction Coils

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AUTHOR'S STATEMENT.

For over fifty years the induction coil has held a preeminent place in the experimental laboratory for the production of high potential currents, but it did not become a commercial piece of apparatus until Roentgen announced his discovery of the X-rays in 1890.

Since these rays were most easily and effectively set up by the energy of the induction coil, there was an immediate and widespread demand for apparatus of this type capable of producing long disruptive discharges, and a further impetus was given the industry thus established when Marconi devised his wireless telegraph in 1896, while the output since that memorable time has increased with each succeeding year.

The art of coil making has been developed to a remarkable degree of perfection chiefly by the empirical methods employed by professional artisans, and while all of the theoretical data provided by physicists are easily enough obtainable, the actual processes of construction in accordance with modern practice have not been hitherto available.

I am aware that a number of books on induction coils have been published, but for the major portion these are small and valueless, while the more worthy ones contain information that is neither connected, thorough, nor specific. There is one exception, however, the work of Hare; but this admirable treatise is based on the construction of a single large coil and which is built on strictly orthodox English lines.

American methods differ materially from those employed in England and on the Continent, and while coils constructed by our makers are less expensive, they are certainly quite as efficient and mechanically stronger than those built by our friends across the Atlantic.

The present work treats of eight different sizes of coils, varying from a small one giving ½-inch sparks to a large one giving 12-inch sparks. These various sized coils are included in three specific designs, and I have tried to tell in easily comprehensible language each process in sequence, together with the dimensions of each part down to the smallest screw.

In this country, the smaller coils sold in the open market are usually wound with bare wire, while the larger sizes are wound with cotton-covered wire. It has been deemed unnecessary to treat of larger coils than the 12-inch, for there are no X-ray tubes made that will take care of the energy developed by coils giving a greater length of spark, while for wireless telegraph work where more power is required than a 12-inch coil can supply, a high tension transformer is more efficient and less liable to injury.

Much of the matter in this book has never been published before, as, for instance, the vacuum drying and impregnating processes, the making of adjustable mica condensers, the construction of interlocking reversing switches, the set of complete wiring diagrams, the cost and purchase of materials, etc., etc. Further, the construction of coils is proceeded with so that the amateur can make a creditable coil at a minimum cost, or the professional can build a coil that will stand on its merits in a competitive market. Owing to the large number of exacting tables, errors, doubtless, have crept in, and I shall greatly appreciate the favor if the reader will apprise me when these are found, so that I may be able to rectify them in another edition. Should the constructor meet with any difficulty, if he will write me fully I shall gladly try to assist him in order that a first-class coil may result, and, further, I shall be especially pleased to hear from those who build coils from the drawings and specifications herein contained.

In conclusion, I desire to acknowledge my indebtedness to Messrs. Charles R. Underhill and William Dubilier for the most excellent service they have rendered in going over the manuscript and the proofs.

A. FREDERICK COLLINS.

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The Design and Construction of Induction Coils.

CHAPTER I.

THE DEVELOPMENT OF THE INDUCTION COIL.

The modern induction coil, now so extensively used for the excitation of Crookes tubes in radiography and for the production of electric waves in wireless telegraphy, had its earliest beginnings when Oersted, the Danish physicist, demonstrated in 1819 that a current of electricity produced a magnetic field.

The experiment enabling him to make this remarkable discovery was performed by passing an electric current, generated by chemical action, through a wire held parallel

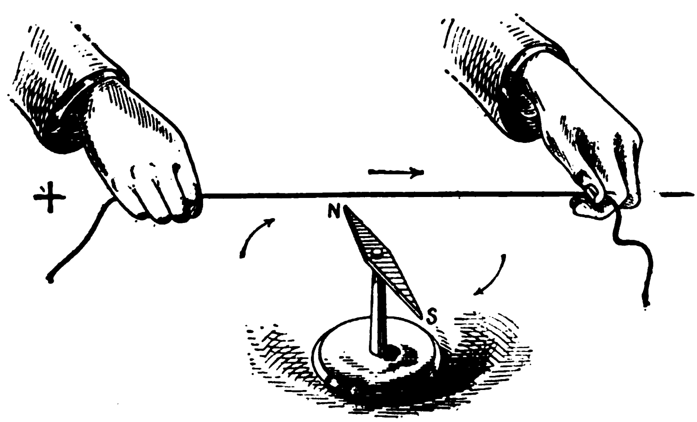


FIG. 1.—OERSTED'S DISCOVERY.

with and over a compass needle, as shown in Fig. 1, when the needle was deflected at right angles to the conductor carrying the energy. Oppositely when the current was cut off the magnetized needle returned to its original position, proving conclusively that electricity in locomotion possesses all the essential properties of the permanent magnet.

Many modifications of this simple experiment were tried, and in one of them the wire was given a rectangular form as in Fig. 2, when it was found that both the upper and lower portions became equally effective and consequently increased the magnetic force produced by it.

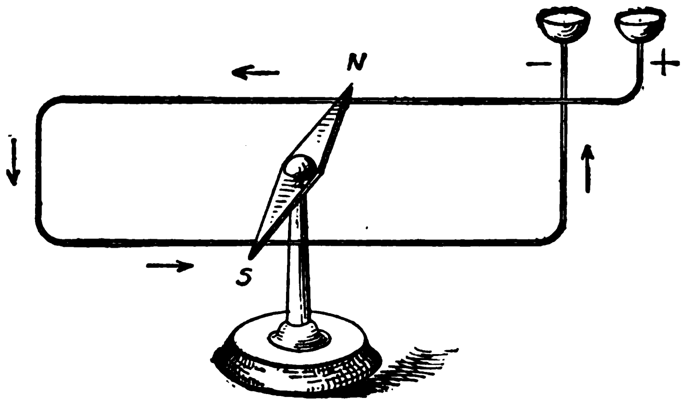


FIG. 2.—NEEDLE IN A LOOPED CIRCUIT.

This led Schweigger, a German investigator, to devise in 1820 his "multiplier," which consisted of a number of turns of insulated wire wound on a hollow cardboard rectangle while the magnetic needle was pivoted in the center, as in Fig. 3.

Davy, an English chemist, assumed that the wire conducting the current became magnetic on its passage through it, and to demonstrate this he brought the conducting wire near some iron filings sprinkled on a sheet of paper, showing that they were attracted to it, adhering

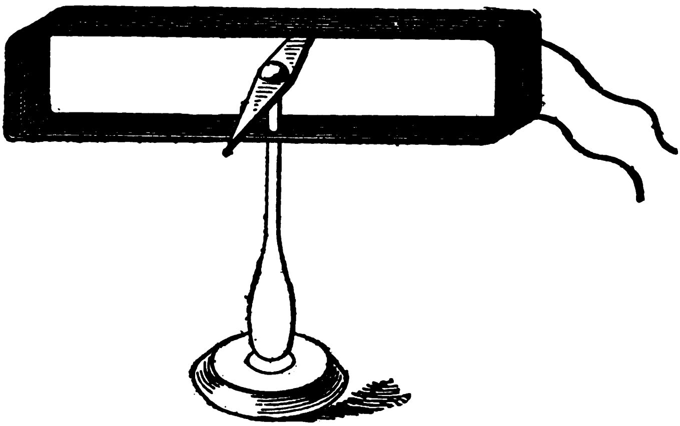


FIG. 3.—SCHWEIGGER'S MULTIPLIER.

in a mass around its circumference. In this way Davy proved that every part of a conducting wire had a magnetic field set up about it when the current was flowing.

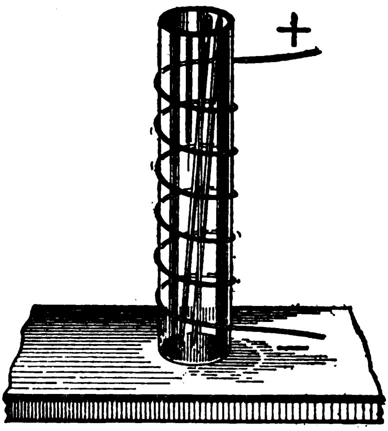


FIG. 4.—ARAGO'S EXPERIMENT.

Simultaneously with Davy, Arago, a French physicist, discovered independently the magnetic properties of the electric current. He carried the experiment still further, however, by winding a bare wire around a glass tube as in Fig. 4, and on inserting steel needles into the latter succeeded in permanently magnetizing them by causing an electric current to flow through the coil thus formed. This effect he announced the latter part of 1820.

After these epoch-making discoveries, the next result obtained having a material bearing on the evolution of the induction coil was made by Sturgeon, an English experi-

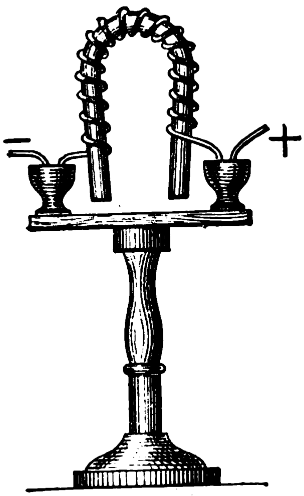


FIG. 5.—STURGEON'S MAGNET.

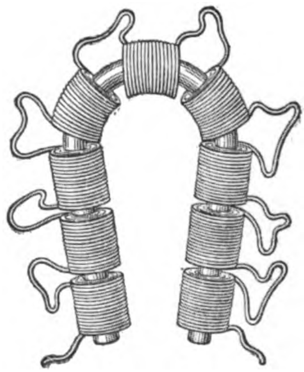


FIG. 6.—HENRY'S MAGNET.

mentalist, in 1825. He ascertained that soft iron behaved very differently under the magnetizing influence of a current than did steel, in that it would remain magnetic only while the current was flowing through the coil surrounding it. Sturgeon produced the first electro-magnet by winding eighteen turns of heavy wire around, but insulated from, a bar of soft iron bent into the shape of a horseshoe, and found that the magnetizing effect was greater than when the coil was used without the iron core. Sturgeon's magnet is shown in Fig. 5.

Following these researches our own Henry constructed an electro-magnet with silk-insulated copper wire on the principle of Schweigger's multiplier. In this magnet a round piece of soft iron a quarter of an inch in diameter was bent into the usual form of a horseshoe, but instead of loosely coiling a few feet of heavy wire around it, he wound it with thirty-five feet of fine wire, making nearly four hundred turns, as indicated in Fig. 6. When the

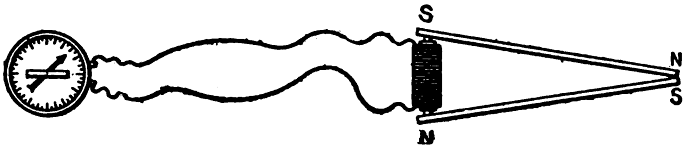


FIG. 7.—FARADAY'S APPARATUS.

terminals of this electro-magnet were connected with a single cell, it became more powerfully magnetized than another having a core of the same size wound with only a few turns and energized by a current from half a dozen cells.

Knowing full well from the foregoing experiments that magnetism could be produced by electricity, physicists believed the process to be reversible, and that electricity could in turn be developed by magnetism. All were unsuccessful until Faraday, an English scientist, accomplished it in 1831, and this discovery, exceeding in importance the one of Oersted, gave to the world not only the induction coil, but the alternating current transformer, the dynamo, and the electric motor.

In his first conclusive efforts to demonstrate the convertibility of magnetism into electricity, Faraday employed the simple apparatus shown in Fig. 7. It comprised a bar of soft iron wound with several layers of insulated wire, the terminals of which were connected to a galvanometer. Two permanent bar magnets were arranged so that the N pole of the lower one made contact with one of the ends of the core of the coil, while the S pole of the upper one likewise made contact with the other end of the core, thus bringing the N and S poles of the opposite ends of the magnets together.

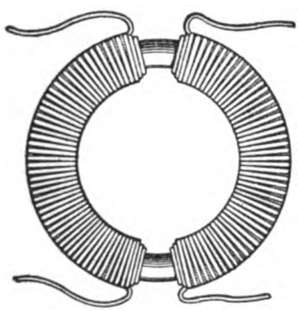


FIG. 8.—FARADAY'S INDUCTION RING.

The experimentalist found, as he had anticipated, that when the S pole of the upper steel bar magnet was brought near to or made contact with the core of the coil, the needle of the galvanometer was deflected to the right, and that when the magnet was removed, the needle swung to the left. Faraday also noted that the current generated in the coil in either case was of but momentary duration.

To Faraday must also be given the credit of constructing the first coil for producing secondary currents by induction. This he did by winding on the opposite semicircles of a soft iron ring, or a closed magnetic circuit as it is now termed, two distinct coils of wire as in Fig. 8.

The terminals of one of the coils were connected with a battery, and the opposite terminals to a galvanometer. As in the preceding experiment, he ascertained that when the primary circuit, in which the battery was included, was closed, the galvanometer needle would be deflected in one direction momentarily, and that when the circuit was broken, the needle likewise moved in the opposite direction.

Faraday then constructed an induction coil similar to

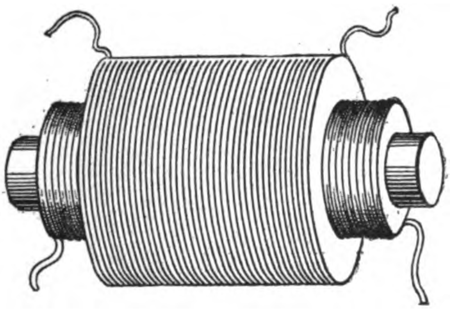


FIG. 9.—FARADAY'S INDUCTION COIL.

that shown in Fig. 9, in which the first, or primary coil, was wound around a straight bar of soft iron forming the core, with the next, or secondary coil, wound over the primary. To account for the production of one current from another by electro-magnetic induction, the physicist invented his curved lines of magnetic force, an explanation of which will be given in the succeeding chapter.

The induction coil having been evolved this far, its history relates chiefly to improvements rather than to further discoveries. Theory and practice now went hand in hand; the developments that followed finally resulting in induction coils that gave high potential currents, and therefore long and heavy disruptive discharges.

Lenz, a German mathematician, in 1833 deduced a law relating to the direction of currents set up by electro-magnetic induction based on the conservation of energy. Lenz's law says in substance, that the direction of a current produced by electro-magnetic induction is always

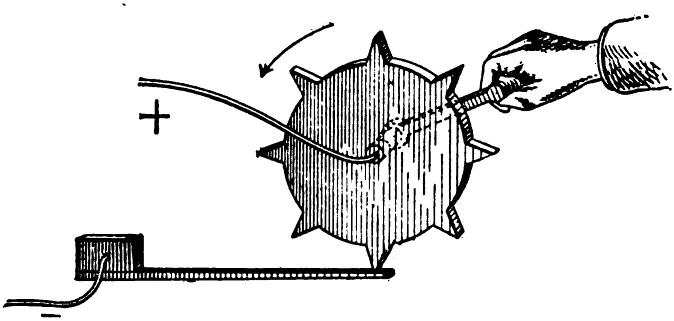


FIG. 10.—PAGE'S SPUR-WHEEL BREAK.

such as to cause it to oppose the motion by which such currents were produced.

The next advance of importance was practical rather than theoretical, and was made by Page, an electrician of Boston, who in 1836 introduced a rotating spur wheel in the primary circuit, thus enabling the current to be made and broken much more rapidly than was possible with the hand breaks then in use. This, if we except the simple plan of drawing one end of the battery terminal over a file, was the first mechanical interruptor made. It is illustrated in Fig. 10.

Other improvements in interruptors were now in order, and shortly after, Callan, of Ireland, devised a vibrating contact breaker. Sturgeon followed with a mechanical interruptor consisting of a wire dipping into a cup of mercury, and operated by a cam and lever movement that would make and break the current thirty-six times per second, and later by means of a disk arrangement produced a device that would interrupt the current five hundred and forty times per second. Callan was the first to employ a bundle of soft iron wires instead of a solid core, which increased the efficiency of the coil. In 1837 he introduced the scheme of drawing the secondary wire through a melted insulating compound while it was being wound. About this time Bachhoffer, of Germany, applied to his coil a self-acting make and break device, which is the earliest recorded instance of the use of an automatic interruptor.

Although to Poggendorf, of Germany, is usually given the credit of suggesting the subdivided coil, there is no question but that Page constructed the first induction coil having a secondary built up of a large number of thin, flat coils, which were wound separately and then connected in series. This not only greatly facilitated the process of winding, but considerably diminished the potential difference between the successive turns.

The year following, namely, 1838, this investigator designed and constructed the most powerful and efficient coil that had yet been made. It was provided with an automatic interruptor formed by a vibrating spring dipping in a cup of mercury. With this apparatus he showed that an electric spark could be enormously lengthened by heating the air of the spark gap, and demonstrated that all the effects obtainable with a frictional machine and Leyden jar could be repeated with an induction coil.

Neef, of Germany, devised in 1840, the familiar type of vibrating spring interruptor operated by the core and now in general use on small coils built in this country, and on the largest coils made in England. Since one end carries a heavy disk of soft iron, it is sometimes termed a

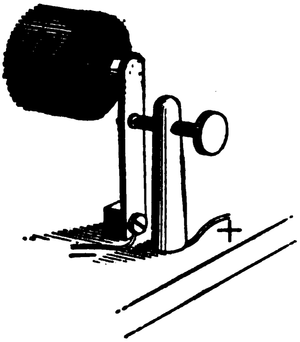


FIG. 11.—NEEF'S HAMMER INTERRUPTOR.

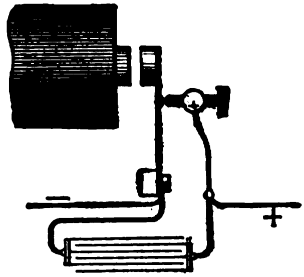


FIG. 12.—FIZEAU'S CONDENSER AROUND BREAK.

Neef hammer interruptor. It is shown in its simplest form in Fig. 11. Wagner, also of Germany, brought out the independent interruptor, and provided the contact points with platinum tips. The efficiency of the induction coil was greatly increased by Ruhmkorff, an instrument maker of France, in 1851, who insulated the secondary from the primary winding by a glass tube and the use of glass disks or cheeks at the ends of the coil to further protect it. To this maker is also due the commutator for reversing the current, and last but not least he built the best spark coils of his time.

The last great improvement in the induction coil was made by Fizeau, of France, in 1853, when he connected a condenser across the contact points of the interruptor as indicated in Fig. 12. Ruhmkorff at once adopted the idea, and made condensers for his coils of leaves of tin-foil insulated by sheets of oiled paper or squares of oiled silk. The cumulative experience that accrued to Ruhmkorff through the preceding discoveries of others and his own efforts enabled him to make a coil in 1867 that gave sparks sixteen inches long; it is illustrated in Fig. 13.

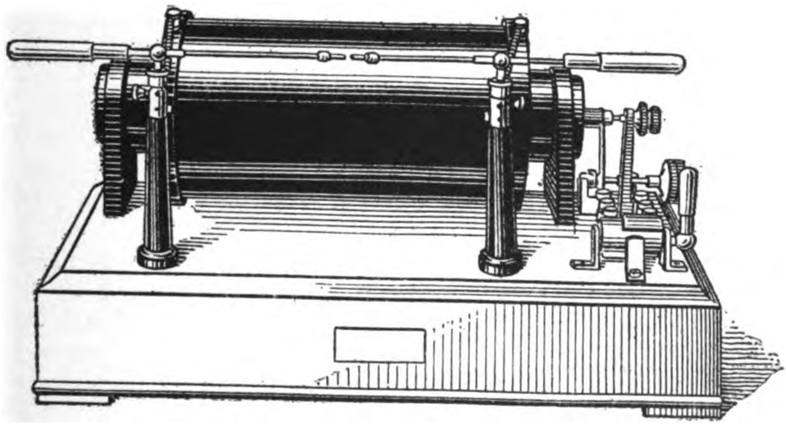


FIG. 13.—RUHMKORFF'S COIL COMPLETE.

During the past forty years there have been no striking innovations in the general design of induction coils, though much longer spark lengths have been obtained through a better understanding of the laws of mutual induction. Condensers having dielectrics of mica and made adjustable enable the maximum potentials the coil is capable of giving to be produced. Since the discovery of the X-rays and the advent of wireless telegraphy, several new types of make-and-break devices have been brought out, the mercury turbine interruptor introduced into this country by Tesla, and the electrolytic interruptor invented by Wehnelt having proved serviceable in solving the vexatious problem of a quick break. Finally, the improvements in batteries, and especially the utilization of continuous constant voltage currents generated by dynamos, have enabled makers to build coils capable of giving any length of spark up to fifty inches.

CHAPTER II.

THEORY OF THE INDUCTION COIL SIMPLY EXPLAINED.

In physics the word induction is used to indicate the electrification or the magnetization of a neutral body by bringing the latter into the neighborhood of an electrified or magnetized body without actual contact taking place between them.

There are several kinds of induction, and among these may be cited: (1) electrostatic induction, (2) magnetic induction, and (3) electro-magnetic induction; the latter may be subdivided into (*a*) mutual induction, and (*b*) self-induction.

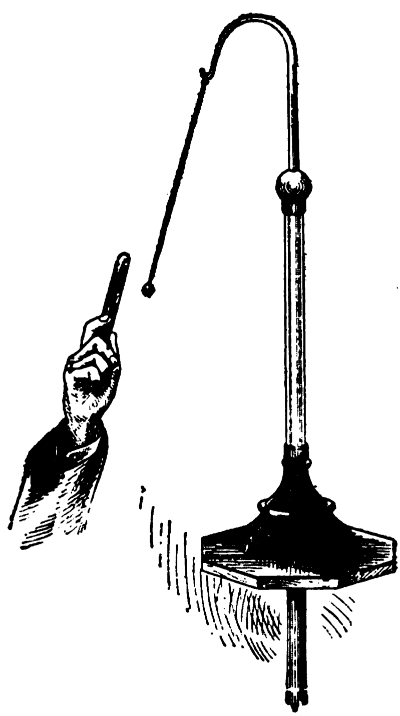


FIG. 14.—ELECTROSTATIC INDUCTION.

Electrostatic induction is produced by the action of one electrified or charged body on a second body. A simple apparatus to demonstrate this electric attraction is shown in Fig. 14. It is termed an electric pendulum, and consists of a pith ball the size of a pea suspended from an insulated support by a silk thread. If now a glass rod or tube is rubbed with a dry piece of cotton or silk, it will be positively electrified, and if, when in this state, it is brought near the pith ball, there will be induced in the latter a negative electric charge. While the glass rod and pith ball as masses do not touch each other, they are nevertheless intangibly connected through the medium of the ether, and it is in this that the static strains of electric energy are formed. When there is a considerable distance separating the two oppositely charged bodies, the outer lines curve away from the common axis as shown in Fig. 15, but as they approach each

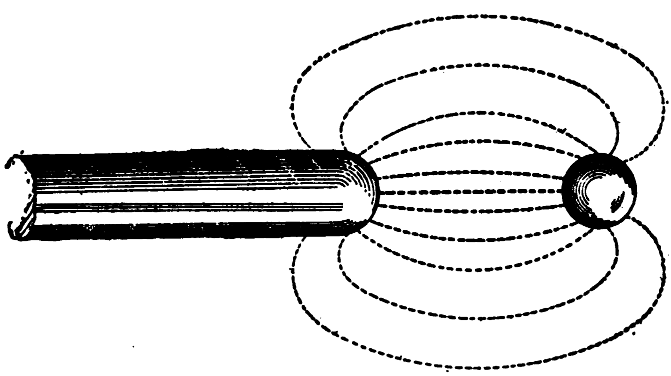


FIG. 15.—STATIC LINES OF FORCE.

other more closely the lines straighten out. In electrostatics induction must of course precede attraction, which is merely a manifestation of it.

In magnetic induction the curved lines of force follow paths quite like those set up between oppositely electrified bodies. If the N pole of a permanent steel bar magnet is held in close proximity to a bar of soft iron, as in Fig. 16, the latter is magnetized by induction, and will remain in the magnetic state until it is removed from the field of force. In this case the position of the lines may be made visible by placing the steel magnet and soft iron bar end to end, but separated a little distance, under a sheet of glass or paper, and sprinkling iron filings on its surface, when these will be definitely arranged as in Fig. 17, showing

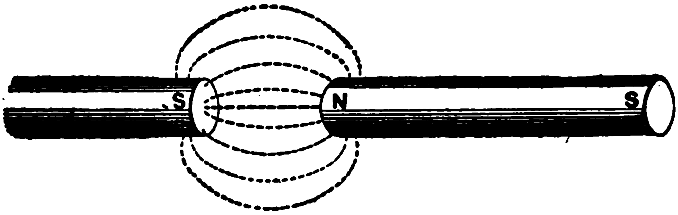


FIG. 16.—MAGNETIC INDUCTION.

clearly the curvature of the lines that magnetically link the two pieces of metal.

In electro-magnetic induction, which is the kind that chiefly concerns us in the theory of the induction coil, an

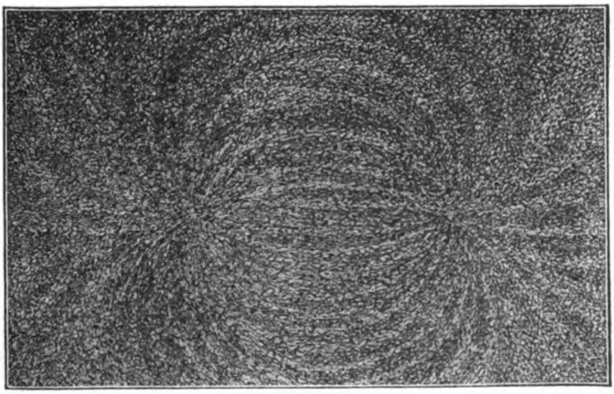


FIG. 17.—MAGNETIC LINES OF FORCE.

electric current flowing in a conductor is partially changed into magnetic lines of force rotating about it at right angles to its direction. The magnetic field thus set up exactly imitates the properties produced by a permanent steel magnet. In Fig. 18 the heavy line may be considered as an electric current with magnetic energy whirling about it, or as a magnetic line of force with electric whirls surrounding it.

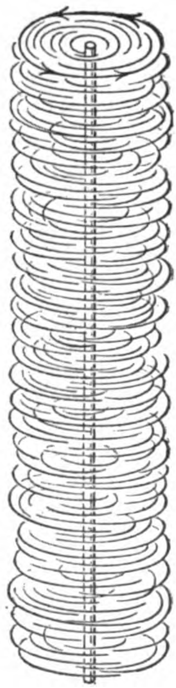


FIG. 18.—GRAPHIC REPRESENTATION OF ELECTRIC CURRENT AND MAGNETIC WHIRLS.

If, instead of a straight conductor, the wire is wound in a coil, the lines are naturally concentrated and the magnetizing force greatly intensified, for the current traverses the same space many times where before it traversed it only once. If the coil is placed near to and in alignment with one end of a bar of soft iron, or, better, if it is slipped over the bar, then the latter will become a temporary magnet by electro-magnetic induction, as shown in Fig. 19.

If two closed circuits formed of single loops of wire, or, as we have seen, what is more effective, two coils of wire, are brought near to each other in the same plane, and a current is sent through one of them, then a current lasting only a moment will be induced in the second coil; but at the instant the current is cut off in the first or primary coil, another current of momentary duration flowing in the opposite direction will be produced in the secondary coil. The explanation of these phenomena is that the primary coil is surrounded with the circular magnetic lines of force as previously described, and which is represented graphically as a closed dotted line in Fig. 20, and as these expand in diameter, some of them reach and impinge on the secondary coil, the turns of which intercept the lines of magnetic force, and the electric whirls rotating about them are conducted by the

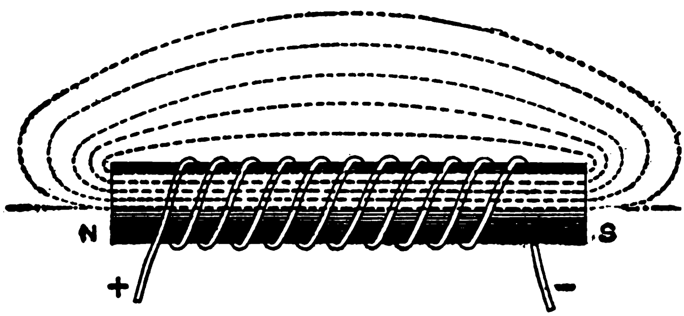


FIG. 19.—CONCENTRATED LINES OF MAGNETIC FORCE.

wire forming the coil. This action, however, takes place only when the magnetic lines are increasing in size, during which different lines are cutting different turns of the coil.

When the primary circuit is completely closed, and the direct current flowing through it is constant, the lines of magnetic force remain stationary, and hence no secondary currents are induced. On the contrary, the instant the primary circuit is broken, there is a decrease in the magnetizing force, and this sets the electric whirls into rotation in the opposite course, and another current is induced in the secondary coil the other way, as the magnetic lines again move across the windings of the coil in the reverse direction. The induction between two coils placed closely together is reactive, and there is an interchange of energies between them. For this reason the processes of transforming the energy of an electric current into magnetic lines of force and these back again into electric currents are termed mutual induction.

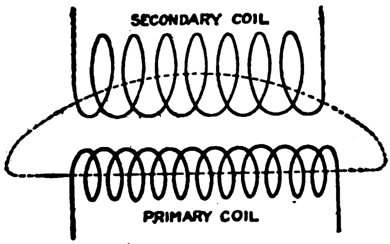


FIG. 20.—MUTUAL INDUCTION BETWEEN TWO COILS.

From the preceding statements it will be readily apparent that the expansion and contraction of the magnetic lines produced by an increasing or a diminishing current in a primary coil will cause the lines of force to impinge upon the turns of tne coil itself and in this way accentuate the electromotive force of the current flowing through it. These weakening and exalting effects of a current on itself are termed self-induction and the characteristics of a circuit which permit them to react on each other are called inductance. It is these factors that cause excessive sparking to take place on breaking the circuit, and none on making it. If an iron core is inserted in the coil the effects of self-induction are much more pronounced, exactly as it is in the case of mutual induction.

There are certain metals that conduct the magnetic lines of force better than air or other substances, just as some metals facilitate the flow of an electric current. For instance, as silver is the best conductor of electricity, so iron is the best conductor of magnetism. The most powerful magnetic field produced by a coil of wire is the space inside of it, and if a bar of soft iron large enough to completely fill its interior is inserted it is possible to greatly concentrate the magnetic lines and in this way to increase the magnetization nearly ten thousand times.

When the magnetizing energy is impressed upon the iron core, the lines of force are formed in and flow through it until the ends are reached when they pass out of the N pole into the air and find their way back again to the S pole where the loops of energy are completed, as in Fig. 19. The degree to which iron can be magnetized varies greatly and this property, called its permeability, ranges from 100 to 10,000 times as much as air, which is taken as unity. The permeability of the core decreases as its magnetization increases, and a point is soon reached where the core is completely saturated and further magnetization is impracticable.

In an induction coil the current is interrupted very rapidly and where a solid iron core is used the current varies from its lowest to its highest values and *vice versa* so quickly that the magnetizing flux developed does not have time to penetrate to its center, hence a core made of a large number of carefully annealed soft iron wires is productive of much better results than a single rod.

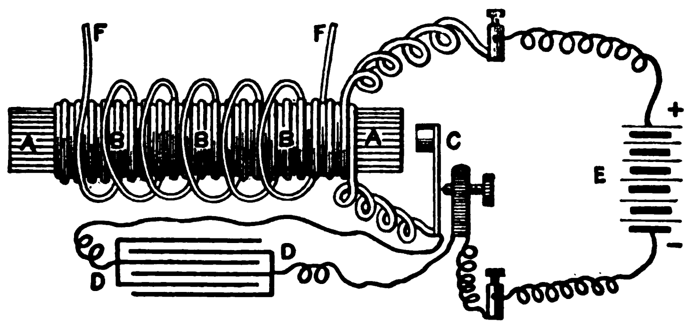
Where the primary and secondary coils are placed in a plane with each other as in the illustration, Fig. 20, only a few of the magnetic lines developed by the first, thread through the turns of the second. To utilize to the best advantage all the magnetic force, the turns of the secondary coil are wound outside of and around the primary winding, when, if the design is good, virtually all of the flux is transformed into secondary electric currents.

The purpose of the induction coil is to step-up the low-voltage direct current into a high-pressure alternating current, and this is done by winding the primary with two or three layers of large wire and the secondary with a great many turns of fine wire. If the primary and secondary coils are wound with equal lengths of wire having the same diameter the output at the terminals of the secondary would be practically equal to the current taken by the primary, when the ratio of transformation, as it is termed, would be unity.

The ratio of transformation is directly proportional to the number of turns of wire on the primary and secondary coils, if we except certain small losses that result in changing the electric into magnetic and the latter back again into electric energy. Thus if there are 10 turns of wire on the primary and 1,000 turns of wire on the secondary coil there will be 100 times as high an electromotive force developed at the terminals of the secondary as that employed in energizing the primary coil, while of course the current or amperage will be proportionately reduced.

To increase the intensity of the magnetic lines to the greatest degree it is necessary that the primary circuit should be broken as suddenly as possible and that the rate or number of interruptions per second should be as high as can be conveniently obtained. These requisites have led to many modifications of the vibrating spring interruptor, and the invention of some new types, as the mercury turbine and the electrolytic interruptors. The purpose of all interruptors, whatever their type, is the same, namely, to make and break the circuit to the best possible advantage.

The addition of the condenser shunted around the make



A, A, Core; *B, B, B,* Primary Coil; *C,* Interruptor; *D, D,* Condenser; *E,* Battery; *F, F,* Secondary Coil.

FIG. 21.—DIAGRAM OF INDUCTION COIL.

and break of an interruptor enables a much higher electromotive force to be obtained at the terminals of the secondary coil than without it, owing to the action of the primary current, which begins to rise in voltage, as we have seen, due to the inductance of the primary circuit. The excess current begins to charge the condenser the instant the break commences to take place, thus preventing it from discharging across the contact points of the interruptor as they break apart; otherwise the suddenness of the break would be destroyed and its efficiency impaired. It must be obvious, then, that the shorter the time required for the interruptor contacts to break apart the smaller the capacity of the condenser may be to counteract the effects of self-induction. Finally the difference of potential at the terminals of the secondary, and consequently the length of the spark produced, is due chiefly to these three factors—(*a*) the electromotive force impressed on the primary coil; (*b*) the relative number of turns of wire on the primary and secondary coils, and (*c*) the capacity of the condenser. Fig. 21 is a diagrammatic representation of an induction coil with a source of electromotive force and including the interruptor and condenser, which is connected across the make-and-break points.

CHAPTER III.

SOME PRELIMINARY CONSIDERATIONS.

While induction coils and alternating current transformers depend upon the same fundamental laws of mutual induction for their operation and both types are constructed upon the same general principles, since in either case two coils are so disposed that by varying the value of the current in the primary coil induced currents are set up in the secondary coil, the former is differentiated from the latter in that the first utilizes an interrupted direct current, whereas the second employs an alternating current as the initial source of inducing energy.

There are many modifications of design for induction coils, as well as various methods of construction, and therefore, notwithstanding the fact that the theory involved is in every instance the same, the product of some makers takes on a long and slender form, while that of others is short and thick, yet each constructor has valid reasons for believing his coils are the best that can be made. In this treatise eight different sizes of coils are given fulfilling the needs of all classes of experimental and practical work, while the plans and specifications submitted cover, in the opinion of the author at least, the most effective proportions and dimensions of the various parts. The calculations and other theoretical considerations incorporated in the following data have been thoroughly tested out in actual practice and long experience in designing heavy-duty coils has permitted many defects to be eliminated. Consequently the results have been found eminently satisfactory and the coils have given sparks that had a longer striking distance, or when cut down carried more energy than many coils made by professional constructors, the amount of wire forming the secondaries in either case being equal.

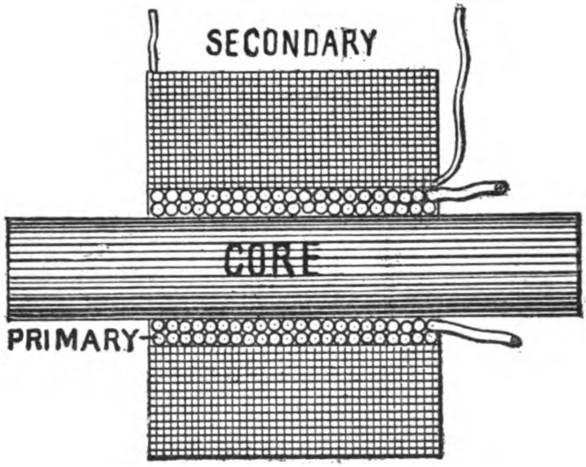


FIG. 22.—STRAIGHT CORE INDUCTION COIL.

Spark coils are rated by the length of the spark they give, and thus it is we speak of a ½-inch or a 12-inch coil, meaning that these distances are the maximum between the terminals of the secondary that the difference of potential established when the coil is in action is capable of breaking down. It must be obvious then that this is a very misleading and empirical method for determining the effectiveness of a coil, as it gives only one of the factors of the available energy set up and not the output in watts, for the electromotive force only is estimated and the current is neglected. It would be much more up-to-date if the induction coil had the voltage and the current stamped upon it as in the case of transformers, but it will in all probability be a long time before this is done, as the average purchaser of a coil is usually contented with knowing its spark-length.

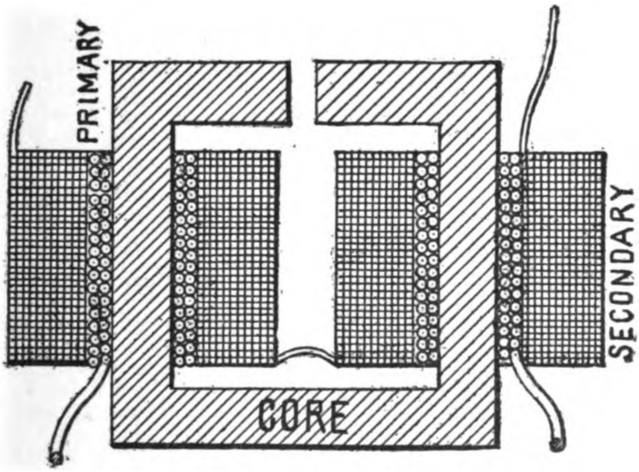


Fig. 23.—Closed Magnetic Circuit Coil.

The straight-core open magnetic circuit type of induction coil shown in Fig. 22 is the form universally adopted by makers, who have found that while not as efficient as the horseshoe type illustrated in Fig. 23, which has practically a closed magnetic circuit, it circumvents several objectionable features of the latter, as for instance sparking between the poles where high potentials are employed.

In many induction coils to be found in the open market the amount of iron in the cores is too small. The curve, Fig. 24, by Ives, shows that when the core of a coil is formed of a few wires and the number is then added to, the difference of potential at the terminals of the second-

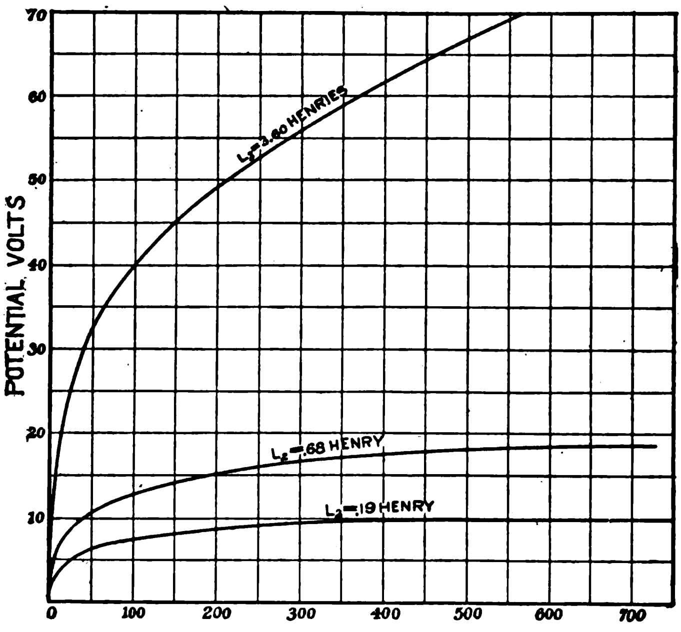


FIG. 24.—EFFECT OF INCREASING IRON IN CORE.

ary quickly increases up to a certain critical point; but when this is reached, instead of decreasing, it continues to rise, though much more slowly.

By enlarging the diameter of the core, and thus increasing the amount of iron in it, it becomes possible to make and break the primary circuit a greater number of times per minute than could otherwise be done, since a core of large cross-section decreases the reluctance it offers to the magnetic lines flowing through it, just as a large copper wire offers less resistance to the flow of an electric current than would a smaller one. This permits the magnetizing force to rise and fall very quickly in the core, an essential condition where the interruptions approximate several thousand per minute, as when a mercury turbine or electrolytic interruptor is used. It is also a well-known fact that in a coil where the core is long compared with the length of its secondary, that is to say, where the poles of the core extend several inches beyond the cheeks of the secondary, less wire is required, for the number of lines of magnetic force intersecting each turn of the secondary coil is greater at the middle of the core than at its ends.

In very small induction coils the primary or inductor is usually formed of three layers of wire, and while this practice is sometimes carried out in large coils, Hare has shown that the third layer possesses no inherent value and that a large coil having two layers with the break properly adjusted gave as long a spark as the same coil provided with three layers, while with a single layer the length of the spark was cut down not more than one inch in twelve. In another experiment he found that the heating effect of a short spark on a platinum wire attached to the negative electrode was decidedly greater with three layers connected in parallel than when two of the layers were working in parallel or all of the layers were in series.

Neither did the third layer present any advantage when the coil was used for X-ray observations with a fluorescent screen or for viewing visually the radiations with the spectroscope, the result being better with two layers than with three, since there is a greater rapidity of action at the break due to the diminished inductance of the primary.

Oppositely the author has found that three layers gave more effectual surgings than two layers when a coil of large size was used to set up electrical oscillations in a circuit, provided the capacity shunted around the break was optimum or exactly that required by circumstances; but if the capacity was too large or too small, though the difference was slight, then two layers worked to the best advantage.

As it is the adjacent turns of wire that produce the self-induction of the energizing current which gives rise to excessive sparking on breaking the circuit, the primary winding is sometimes formed of several small wires twisted together and having a total resistance that is not in excess of the single wire ordinarily used. This reduces to a certain extent the inductance of the primary, though the constructor need not resort to it, for with a good interruptor and an adjustable condenser he will have no difficulty in controlling the spark at the break.

A consideration of more importance is that the turns of the secondary coil are brought nearer the core where two layers of wire are used for the primary than where three are employed. The most efficient coils have their secondaries wound with single-covered silk insulated wire instead of double-covered cotton insulated wire. This result is not due so much to the more effective insulation offered by silk, but to the fact that the turns of wire on a large coil increase more rapidly than the length of spark it produces. For this reason neither the length of the secondary wire nor the diameter of its turns increases the potential at the terminals, but the rise in voltage depends upon the number of turns of fine wire and the mean strength of the magnetic field in which the turns are placed. Evidently, then, the smaller the secondary wire —and this depends largely upon the material insulating it—the larger the number of turns that can be wound in the strongest portion of the magnetic field, and this gives rise to a coil of comparatively short length and small diameter.

In X-ray work the development of high potentials is desirable, and a coil that has its secondary wound with a large number of turns of exceedingly fine wire, giving long attenuated sparks, is well suited to the operation of Crookes tubes, but in wireless telegraphy shorter spark lengths and a larger current output is much better adapted for the production of electric oscillations. For these reasons there are two sizes of wire given for the secondaries of the 10 and 12-inch coils. For use in wireless telegraphy the secondaries should be wound with wire having 50 per cent greater cross section than is used in ordinary coils, the number of turns remaining the same and the insulation double that generally employed.

While small coils, i. e., those giving 2-inch sparks or less, may have their secondaries wound with one continuous length of wire, it is the usual practice in this country to wind the secondaries of large coils in sections, a method which is at once simple, quickly done and effectual, since the wire need not be wound carefully with each turn up closely to the adjacent one, and high potential static strains between the layers in continuous secondaries are not nearly so apt to be set up, thereby lessening the probability of disruption from this untoward cause. Moreover, a sectionally-wound coil is easier repaired than one wound in successive layers, forming with its insulating compound a solid mass.

Where a current from a primary or a storage battery is used, a vibrating spring interruptor will give very satisfactory results; but if the current is derived from a 110-volt circuit, then a mercury turbine or electrolytic interruptor will give a sharper break and will prove more effective. An induction coil provided with either a mercury turbine or electrolytic interruptor may be operated by an alternating current if a direct current is not available. In the former interruptor the crest of each alternating current wave flowing in the same direction may be clipped off, the resultant current being equivalent to a periodic direct current. In the latter interruptor when an alternating current is used, the positive impulses only will electrolyze the solution, which form bubbles of gas, as though they were a portion of a direct current, while the negative impulses produce no appreciable effect. The drawback of using alternating current with these interruptors is that they are not at all economical in action.

The curves, Fig. 25, are by Mizuno, who plotted them to show how the spark lengths were affected by varying the capacity around the contacts of the interruptor. One of the sources of failure in constructing coils comes from the use of condensers having values of capacity that are too small to counteract the self-induction of the primary current. When the value is increased so that the spark has

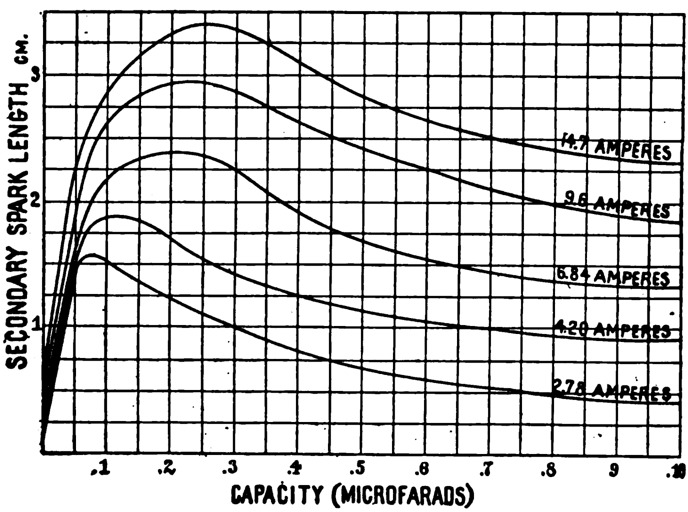


FIG. 25.—EFFECT OF CAPACITY AROUND BREAK.

its longest possible length, it is termed its *optimum capacity,* and if this value is further increased, the spark length is again decreased.

Paper condensers properly made will give fair satisfaction for small coils, and are by far the easiest and most inexpensive to make. By filling the pores of the paper used as dielectrics between the sheets of tinfoil with paraffin or other insulating compounds, its specific inductive capacity is increased, and consequently fewer sheets of tinfoil are required; this will be evident when it is stated that the specific inductive capacity of dry air is taken as 1.000, while that of paraffin is 1.996. Counteracting this favorable result to a large extent is the fact that a high dielectric hysteresis takes place in all such substances on an instantaneous charge.

A mica condenser acts differently in that a full charge may be given it on the break of the interruptor, and upon the make it will deliver practically all its stored-up energy almost instantaneously and without wasting it in useless action in the dielectric. Adjustable condensers are arranged in sections, so that the capacity can be varied within certain limits; if it has a total value of 1 microfarad, it may be subdivided into five parts, viz., 0.05, 0.05, 0.02, 0.2, and 0.5 of a microfarad; these are mounted in a box and lead to brass blocks on top, where connection is made by means of plugs or by a lever operating contact pins.

With these suggestions and the plans and specifications to follow, the constructor of an induction coil needs only to determine, first, the size of the coil he desires to make; second, if the wire is to be silk or cotton covered; third, if the secondary is to be wound with wire of small or large cross section, and fourth, if the condenser is to be of paper or mica, and fixed in its capacity or adjustable. The uses to which the coil is to be put and the amount of money to be spent will aid in solving these problems in the majority of cases. For lighting Geissler tubes, the production of Hertzian waves, wireless telegraph demonstrations, etc., a ½-inch coil will do; for electric spectrum analysis, wireless telegraph experiments out of doors, etc., a 1-inch coil will prove serviceable; for operating the smallest X-ray tubes a 4-inch coil will be necessary, while the largest tubes made and long-distance wireless telegraphy require all the energy developed by a 10 or a 12-inch coil.

CHAPTER IV.

FORMING THE SOFT IRON CORE.

The core of the coil should be made of carefully annealed soft iron wire, and it is important to get the best quality obtainable; for, as we have seen, its efficiency depends very largely upon its low reluctance, just as the conductivity of a circuit depends upon its low resistance.

After having decided upon the size of the coil to be built, a reference to the following table will show at a glance the dimensions of the core required. The size of the wire used for this purpose is not a matter of great moment, but it should not be larger than No. 18 Brown & Sharpe gage, nor need it be smaller than No. 22, the last-named size being well adapted for the cores of any of the coils herein enumerated.

As the diameter and the length of the core have a pronounced effect on the rapidity with which it is capable of being magnetized and demagnetized, the proportions of the core are of exceeding importance. The dimensions and the amount of iron best adapted to each of the different sized coils will be found in the following table:

TABLE I.

Proportions for Cores.

Spark Length of Coil.	No. of Wire (B. & S. Gage).	Approximate Weight of Core.		Diameter of Core.	Length of Core.
Inches.		Lbs.	Ozs.	Inches.	Inches.
½	20	..	3⅜	½	5⅛
1	20	..	14½	⅞	7¼
2	20	2	12	1¼	10½
4	22	7	0	1⅞	12
6	22	11	13	2¼	14
8	22	18	10	2½	18
10	22	25	13	2¾	22
12	22	38	10	3	26

Having fixed upon the dimensions of the core, the next step is to procure the wire needed. The weights given above for the various cores are approximate, but will serve to determine the amounts necessary. When purchasing, it is advisable to get from one-quarter to one pound more than the weights specified, which will allow for waste, etc., except in the cases of the small cores. The best kind for the purpose is a charcoal iron wire or a black iron wire, and this can generally be procured at first-class hardware stores. In any event use the softest wire obtainable.

After the wires are cut into the proper lengths, all the kinks must be removed and each piece straightened out. Some of the larger bends may be eliminated by simply drawing the wires through the hand, but the more abrupt twists will have to be gently hammered out, with a wooden mallet, on a hardwood block having a perfectly smooth surface. These preliminaries attended to, the wires should be rolled between two smooth hardwood boards.

However good and soft the iron wire may be when procured from the dealer, it can usually be improved by annealing. For the smaller coils this is not necessary, but for the intermediate and largest sizes it is quite essential. A simple method for annealing the wires of which the cores are to be formed is to provide a gas pipe one or two inches longer and one-half an inch larger in diameter than the core to be treated. The ends of the pipe are to be tapped and fitted with screw caps as shown in Fig. 26. The wires loosely arranged in a bundle are now inserted in the pipe and the caps screwed on, when it is placed in a charcoal fire and allowed to remain there until the pipe and its contents have been gradually brought to a cherry red, with plenty of charcoal on top, so that the fire will burn out very slowly. The fire is then permitted to burn out, and the pipe left in the ashes until perfectly cold. When the wires are taken out, they will be very soft, and their magnetic qualities greatly improved. The rods used in the intermediate and larger sized coils should likewise be annealed.

There are several methods by which the cut, straightened and annealed wires can be bound into a compact and cylindrical bundle forming the core, but those given below are the simplest and best adapted to the needs of the coil builder. For any one of the first three smaller coils, the core may be prepared by gathering the wires into a bundle of the size specified in Table I. for the coil desired, and then forcing them into a stout manila paper tube, the length of which is a trifle in excess of the length of the core to be made. By gently and carefully manipulating the wires, it will be found possible to force an additional number into the tube after the latter is apparently full,

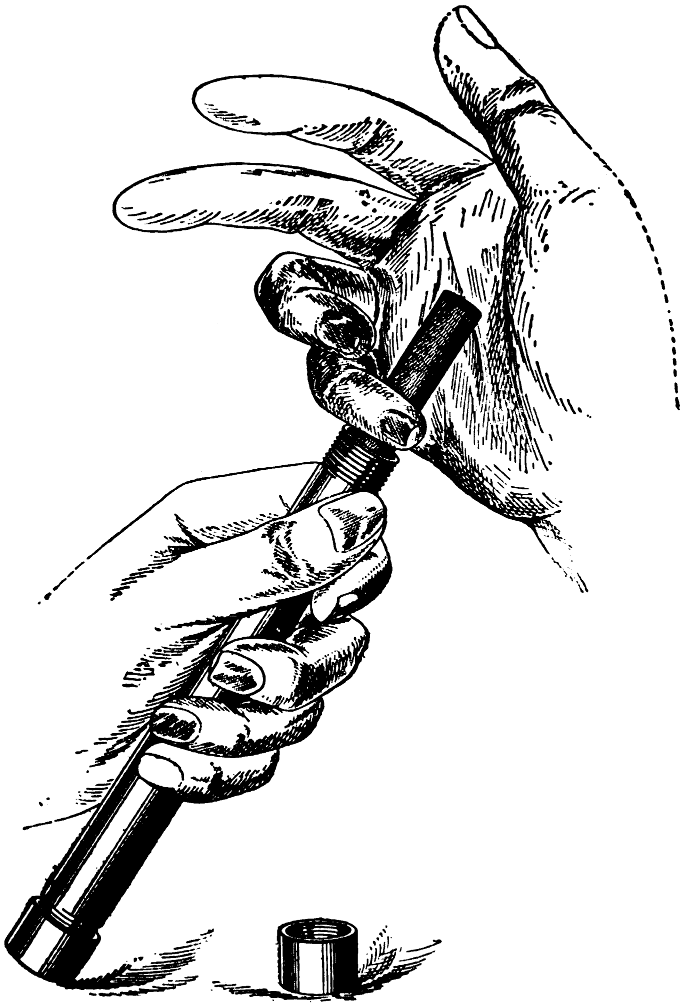


FIG. 26.—GAS PIPE WITH SCREW CAPS.

and a little sperm oil put on the wires will greatly facilitate this task.

The tube may be made of heavy manila paper cut into strips of the required width, while the inside diameter

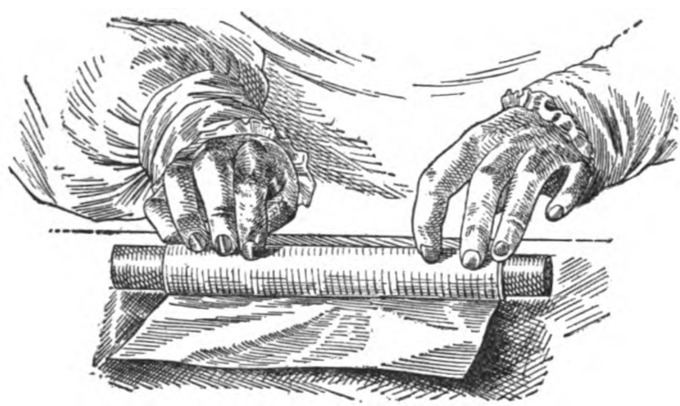


FIG. 27.—MAKING THE PAPER TUBE.

may be obtained by rolling it on a cylindrical piece of wood turned to the required size, as shown in Fig. 27. As the paper is wound round the wood it should be glued, paraffined, or shellacked to hold it intact and make it

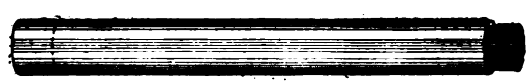


FIG. 28.—ARRANGEMENT OF CORE AND TUBE.

strong. When perfectly dry the tube will be hard, not easily bent out of shape, nor will it be affected to any extent by moisture. By referring to Table II. the inside diameter and length of the tubes may be ascertained, while

Table III. shows how far one of the poles of the core should project beyond one end of the tube, and the opposite end of the tube extend beyond the other pole of the core. This arrangement of the core and tube is shown in the drawing, Fig. 28, and its purpose will be obvious when the point is reached where the coil is assembled.

TABLE II.

Proportions for Small Tubes.

Spark Length of Coil.	Inside Diameter of Tube.	Length of Tube.
Inches.	Inches.	Inches.
1/2	1/2	5 1/4
1	7/8	6 3/4
2	1 1/4	10 11/16

TABLE III.

Table of Core Projections.

Spark Length of Coil.	Projection of Core from End of Tube.	Projection of Tube from Opposite End of Core.
Inches.	Inch.	Inch.
1/2	5/16	7/16
1	1/2	5/8
2	5/8	3/4

Thickness of paper tube 1/16 inch.

For coils of larger size, namely, those ranging from 4 inches up to 12 inches, much greater care should be exercised in their construction, and the core is equally as important as any of the other parts. The wire for any of the above sizes is made into a bundle, as in the case of the smaller cores, but axially through the center of the core a rod of soft iron is inserted, and projects beyond the poles as shown in Fig. 29. This is to hold the hard rubber tube and ends in place. The bar is tapped and fitted with nuts on both ends, and of course must be placed in

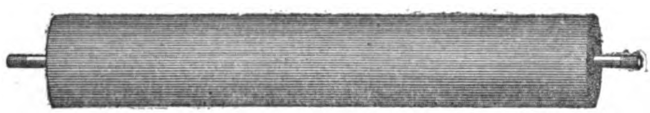


FIG. 29.—BAR OF IRON THROUGH CORE.

the core before the latter is put into the tube. The lengths and diameters of the rods are given in Table IV.

TABLE IV.

Lengths and Diameters of Rods.

Spark Length of Coil.	Length of Core.	Diameter of Rod.	Length of Rod.
Inches.	Inches.	Inch.	Inches.
4	12	1/4	14
6	14	1/4	16 1/8
8	18	5/16	20 3/8
10	22	3/8	24 3/8
12	26	3/8	28 3/8

For any one of the intermediate sizes the core can be forced into the tube, which should be 1-16 inch in thickness, in the same manner as previously described for the smaller coils; but for the larger sizes, that is for the 10 and 12-inch coils, it is better to proceed as follows: Procure a sheet of brass, say 1/8 of an inch in thickness and 3 inches on the side, and have a hole drilled in it exactly the diameter of the core to be used. It should then be countersunk on one side as shown in Fig. 30, so that the wires forming the core will not meet with so much opposition on being forced through. The wires are now laid parallel with and around the rod of iron, and bound together in a bundle with some fine wire. The ends of the wires are inserted in the hole in the plate, and as many added as can possibly be forced through. This process is rendered easier by supporting the plate in a vise, as in the illustration, Fig. 31. As the ends of the wires emerge from the hole on the other side, they are tightly wound with adhesive tape, so that when the job is completed the core formed will be very compact and straight and true in shape and size. It can then be wound with

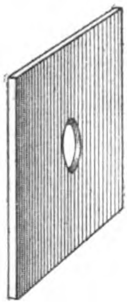


FIG. 30. PLATE FOR FORMING CORE.

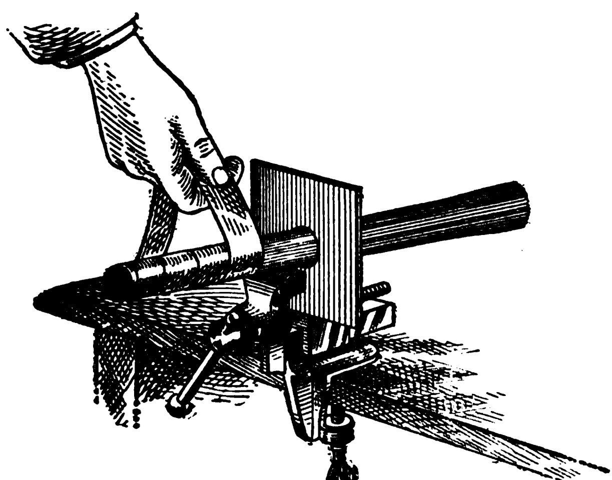


FIG. 31.—FORMING THE CORE.

successive layers of manila paper until it is incased in a covering 1/8 inch thick, and extending the entire length of the core.

While it is not absolutely necessary, it is considered good practice to heat the core to expel all the moisture—this can be done in an oven—and then immerse it in melted paraffin or a compound of beeswax and rosin. Fig. 32 shows a simple method of holding the core during the process. After the core has remained a few minutes in the melted compound, the tin vessel containing it should be removed from the heat, permitting the wax to cool.

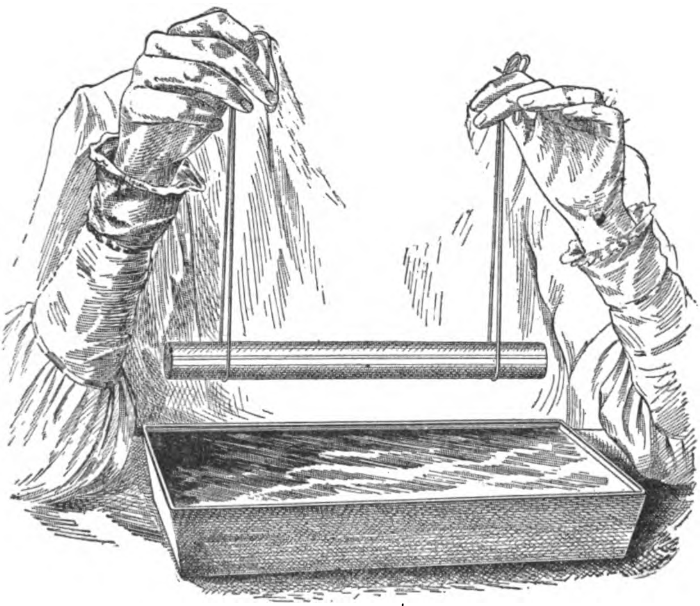


FIG. 32.—IMMERSING THE CORE IN INSULATING BATH.

When it has begun to solidify, the core can be removed by the strings supporting it, and suspended in a convenient place to harden. After it becomes thoroughly cool, it is ready to receive the primary winding.

CHAPTER V.

WINDING THE PRIMARY COIL.

The wire for the primary coil should be as nearly pure copper as can be obtained. Much of the insulated wire sold by dealers in electrical supplies is alloyed with inferior metals, and hence its conductivity is greatly impaired. Pure copper wire is very soft and pliable, while wire drawn from copper alloy is more or less hard and brittle, depending upon the percentage of other metals in it. Annunciator and bell wire, office and electric light wire should consequently never be used for the primary of a coil, as all of these wires have a relatively high resistance, but the kind known under the trade name of *magnet wire* is more nearly pure, and will give the best results.

In English-made coils the primaries as well as the secondaries are wound with silk-covered wire, but in American-made coils cotton-covered wire is almost altogether used. The only advantage the writer has found in employing silk-covered wire for the primary is that the ratio of copper to winding space is greater. There is a slight difference in the diameters of silk and cotton-covered wires for the same sizes, but as there are only two layers on the primary, the dimensions of the latter are not altered to any considerable extent in either case. Assuming that double cotton-covered magnet wire is to be used, the number of the gage and the amount required may be ascertained from the following table:

TABLE V.

Magnet Wire for the Primary Coil.

Spark Length of Coil.	No. of Wire (B. & S. Gage).	Approximate Number of Feet Required.
Inches.		
½	16	25
1	14	47
2	14	97
4	13	156
6	13	215
8	12	262
10	12	376
12	10	376

If the coil is to be small, that is one giving a 2-inch spark or less, the cheeks or wooden ends of the coil must be provided at this stage of the work. These cheeks may

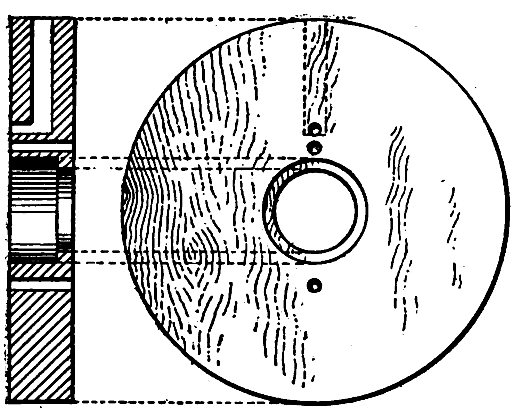


FIG. 33.—CHEEK OF COIL SHOWING CORE HOLE.

be of any ornamental design, but those circular in form and japanned to look like hard rubber have found much favor with makers in this country, and instructions for preparing them together with the required dimensions will be found in Chapter XV. Suffice it to say here that in the cheek to be used nearest the interruptor, and which we shall designate henceforth as the front cheek, a hole is bored through its center just large enough to admit the end of the core projecting from the tube of paper, as described in the preceding chapter. For three-fourths the distance from the inside of the cheek the hole is bored out a trifle larger, so that this portion will fit snugly over

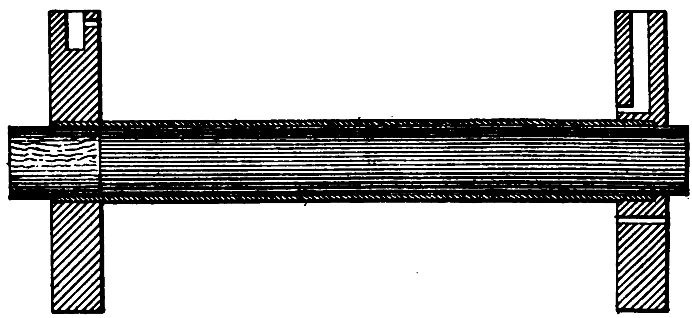


FIG. 34.—SPOOL READY FOR WINDING PRIMARY COIL.

the paper tube. A cross-section as well as a side elevation of the front cheek is shown in Fig. 33, the dotted lines indicating how the diameter of the hole is enlarged to receive the paper tube.

The rear cheek has an aperture of uniform diameter cut through its center large enough to slip over the paper tube, but to fit it tightly; before the cheeks are set to the ends of the tube the latter is well smeared with good adhesive glue, and a spool is thus formed as shown in cross section, Fig. 34. Before the spool is laid away to dry, the rear end of the paper tube, which alone sustains the cheek, should have a cylindrical block of wood inserted tightly into it, so that the paper and the cheek may be firmly secured to each other.

When the spool is perfectly dry, it is mounted in a lathe, the projecting core being inserted in the chuck, the wooden end receiving the point of the back center. The

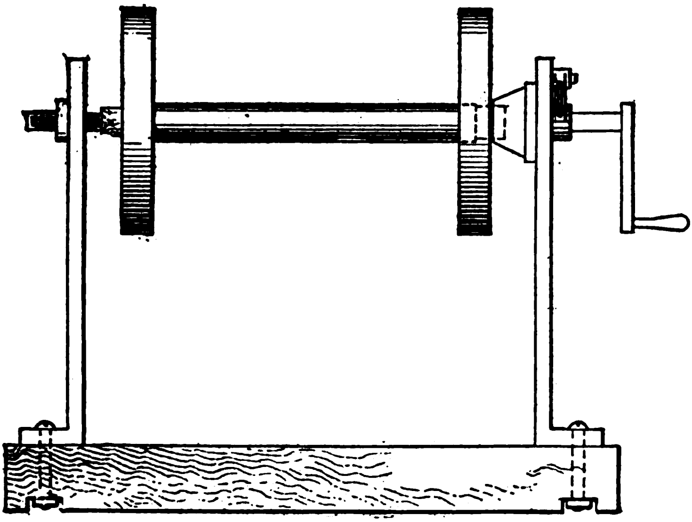


FIG. 35.—SIDE ELEVATION OF WINDING DEVICE.

roll of magnet wire may be laid flat on a board or shelf extending in front of the lathe bed. Through the front cheek two small holes are bored, and these are a little larger than the insulated wire used for the primary, since short lengths of rubber tubing are slipped over the terminals of the primary where these lead to the base of the coil, for the purpose of protecting the insulation.

One end of the primary wire is passed through one of the holes of the front cheek from the inside preparatory to winding, and all being in readiness, the mandrel is revolved slowly by a winch, or if the lathe is not equipped with one, then it must be turned by the belt. The turns of wire are wound closely together, and tightly on the core clear up to the inside surface of the opposite cheek. It is then given a heavy coating of shellac varnish—made by dissolving yellow shellac in alcohol until a saturated solution results—and the second layer wound on top of the first. When the cheek where the winding was begun is reached, the wire is cut off, leaving the ends projecting through the holes about 4 inches. A second coating of shellac is given it, when it is once more permitted to dry.

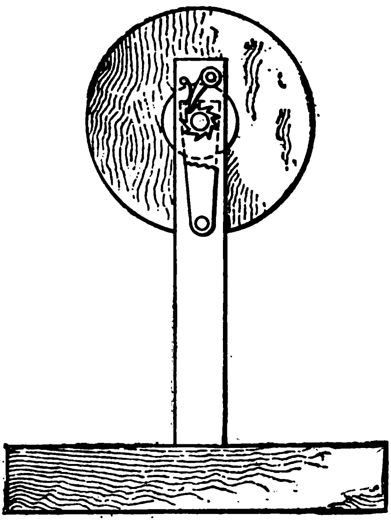


FIG. 36.—END ELEVATION OF WINDING DEVICE.

If a lathe is not available, a winding device may be constructed at a small cost. An arrangement of this kind is shown in the side elevation in Fig. 35 and in the end elevation in Fig. 36. Two standards of iron, the lower ends of which are bent at right angles, are procured and screwed or bolted to a heavy baseboard. Near the upper end of each standard a hole is drilled, and in the left-hand one a screw thread is cut with a tap. Into this is screwed a rod of pointed iron which serves as a back center. Through the hole of the right-hand standard is fitted a spindle carrying on the outside a ratchet-wheel with its pawl, while on the extreme outer end there is a winch or crank provided with a handle. On the inside of the standard the spindle is fitted with a disk of brass or iron, and the extreme inner end is provided with a chuck, all of which are clearly shown in the illustrations. The dimensions of the winder should be in accordance with the size of the coil to be made, and these will be found in Table VI. As the lengths of chucks vary the exact distance between the standards cannot well be given, nor does it matter within certain limits, as the back center may be screwed in or out as the case requires.

TABLE VI.

Winding Device.

Size of Coil.	Length of Core with Projecting Wooden End (Approximately).	Standards.			Size of Bearings.	Opening of Chuck.	Baseboards.		
		Height.	Width.	Thickness.			Length.	Width.	Thickness.
Inch.	Inches.	Inches.	Inch.	Inch.	Inch.	Inches.	Inches.	Inches.	Inches.
½	6	6	¾	¼	¼	⅝	9½	6	1
1	8½	8	1	⅜	$\frac{5}{16}$	1	12½	9	1¼
2	12	10	1¼	½	⅜	1⅜	15½	12	1½

The method of winding the primary with the device is the same as where a lathe is used. If it is not feasible to construct a winding device, the primary may be wound by hand, although the work is much more laborious, and unless care is exercised the layers will not be wound on the core as tightly as they should be.

While the winding device described is serviceable for the smaller sized coils, and may even be utilized for the larger ones if the dimensions are proportionately increased, the writer strongly recommends a lathe for winding all coils that are to give more than a 2-inch spark. The cores, beginning with the 4-inch size, must be prepared for receiving the primary winding by gluing upon the extreme ends of the paper tube cylindrical rings of wood having a thickness exactly equal to the thickness of the two layers of wire of which the primary is to be formed. The rings serve to retain the turns of wire in their proper places. The ring on the right-hand end has a wide groove cut circumferentially into its surface, as well as two grooves on the opposite side of the ring at right angles to its circumference, as shown in Fig. 37. This ring is put on the end of the core where the ends of the primary are to come out.

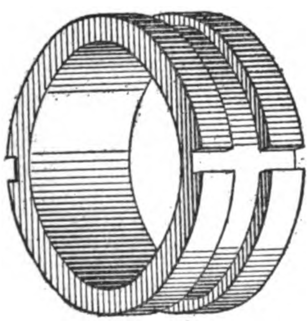


FIG. 37.—WOOD RING FOR INDUCTOR.

As the cores, beginning with the 4-inch coil and on up to the 12-inch coil, have iron rods in their centers,

TABLE VII.

Sizes of Wood End Rings.

Size of Coil.	Diameter of Core.	Diameter of Core with Paper Covering.	Inside Diameter of Rings.	Outside Diameter of Rings.	Thickness of Rings.	Width of Rings.	Width of Circular Groove.	Depth of Circular Groove.
Inches.	Inches.	Inches.	Inches.	Inches.	Inch.	Inches.	Inch.	Inch.
4	2	2	2	$2\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{4}$	$\frac{1}{4}$	$\frac{15}{100}$
6	$2\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{7}{8}$	$\frac{1}{4}$	$\frac{3}{4}$	$\frac{1}{4}$	$\frac{15}{100}$
8	$2\frac{5}{8}$	$2\frac{5}{8}$	$2\frac{5}{8}$	$3\frac{1}{4}$	$\frac{5}{16}$	1	$\frac{3}{8}$	$\frac{3}{16}$
10	$3\frac{1}{16}$	$3\frac{1}{16}$	$3\frac{1}{16}$	$3\frac{5}{8}$	$\frac{9}{32}$	1	$\frac{1}{2}$	$\frac{3}{16}$
12	$3\frac{5}{16}$	$3\frac{5}{16}$	$3\frac{5}{16}$	$4\frac{1}{8}$	$\frac{11}{32}$	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{1}{4}$

the tapped ends of which protrude an inch or so, it becomes necessary to prepare these for their reception in the lathe. This is done by screwing over the ends of the bar of iron projecting from the core ends two cylindrical blocks of wood, $1\frac{1}{2}$ inches in length and 1 inch in diameter. The core is then ready to be put in the lathe, and may be secured either by means of a face plate or a chuck. The belt of the lathe may be removed, and a crank handle attached to the end of the mandrel, if this is possible, when the winding is done as previously described.

As this work goes on, the insulation must be looked after very closely, and especially is this true if the coil is an 8, 10, or 12 inch one. Shellac or insulating varnish must be used freely, and if there are any weak spots in the insulation of the wire, small pieces of mica should be inserted to prevent possible leakage. After the layers are wound, the turns of the wire where the terminals emerge must likewise be insulated with mica; the termi-

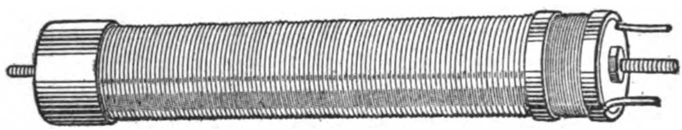


FIG. 38.—CORE AND PRIMARY COIL.

nals are then placed in the grooves cut across the wooden ring, and bound there by means of fine twine wound round the groove in the circumference, when the core with the primary upon it will take on the appearance shown in Fig. 38.

CHAPTER VI.

THE INSULATION BETWEEN THE COILS.

In the smaller coils the insulation between the primary and the secondary windings may be formed of good manila paper and this can be coated with melted paraffin or with shellac during the time it is being wound on the spool. The following table will show the thickness required to prevent the strains developed by the different sized coils from breaking through and disrupting the insulation of the primary.

TABLE VIII.

Thickness of Paper Insulation.

Size of Coil.	Thickness of Insulation.
Inches.	Inch.
$\frac{1}{2}$	$\frac{1}{16}$
1	$\frac{1}{8}$
2	$\frac{3}{16}$

The width of the paper should be exactly that of the distance between the inside cheeks of the coil, and should be carefully and evenly placed, so that when it is finished it will present a smooth and uniformly cylindrical surface upon which the secondary can be wound direct.

For the larger coils a different procedure is resorted to. A hard-rubber tube of the requisite thickness furnishes the best insulating medium between the primary and secondary coils, and by adhering to the following plan the result will be not only a well-insulated coil, which insures its owner to a large extent against breakdowns, but one that is pleasing to look upon. The length, diameter, and thickness of the hard-rubber tube will of course depend, like the other parts, on the size of the coil that is in the process of making, but the dimensions may be ascertained by a reference to Table IX.

TABLE IX.

Hard Rubber Insulating Tubes.

Size of Coils.	Length of Tube.	Inside Diameter of Tube.	Thickness of Tube.	Outside Diameter of Tube.
Inches.	Inches.	Inches.	Inch.	Inches.
4	12 1/2	2 1/2	1/8	2 3/4
6	14 1/2	2 7/8	3/16	3 1/4
8	18 5/8	3 1/4	1/4	3 3/4
10	22 7/8	3 5/8	5/16	4 1/4
12	27 1/4	4 1/8	3/8	4 7/8

The tube indicated for the coil under construction is slipped on over the primary coil, and while the dimensions of the tube given may make it fit rather closely, it need not be too tight. Having procured the tube, it will be necessary to turn or have turned a pair of caps for the ends. While these may be made of the kind of wood that is to be used for the cheeks and base of the instrument, hard rubber is preferable, as it is more durable and presents a neater appearance. These caps have holes drilled through their centers, to permit the iron rod in the core to pass through to the outside, and two holes oppositely disposed are also drilled and tapped in the cap, to be used on

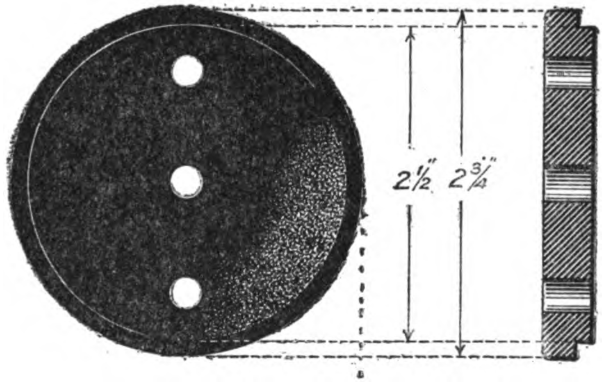


FIG. 39.—END AND CROSS-SECTION OF CAP.

the end where the terminals of the primary emerge. Into these holes are screwed brass connectors, into which the ends of the primary are inserted and secured. Fig. 39 shows an end view and a cross section of the cap and the positions of the holes.

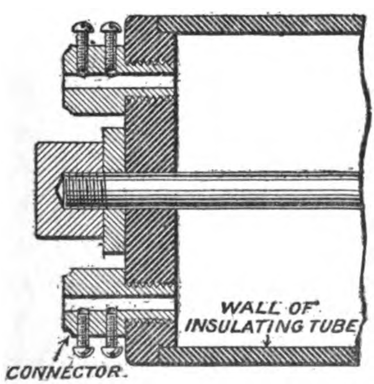


FIG. 40.—END OF INDUCTOR IN CROSS-SECTION.

The caps have shoulders turned on their inner surfaces at the circumference; this permits the smaller portion to set into the end of the insulating tube, while the extreme periphery is flush with the outside of the tube, as in Fig. 40. The sizes of the caps are given in Table X.

TABLE X.

Sizes of End Caps.

Spark Length of Coil.	Diameter of Outside Surface.	Diameter of Inside Surface.	Thickness of Cap.	Diameter of Rod Hole.	Diameter of Holes for Brass Connectors.	Distance of Center of Connector Holes from Center of Rod Hole.
Inches.	Inches.	Inches	Inch.	Inch.	Inch.	Inches.
4	$2\frac{3}{4}$	$2\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{7}{8}$
6	$3\frac{1}{4}$	$2\frac{7}{8}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	1
8	$3\frac{3}{4}$	$3\frac{1}{4}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$1\frac{1}{4}$
10	$4\frac{3}{4}$	$3\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$1\frac{1}{4}$
12	$4\frac{7}{8}$	$4\frac{1}{8}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$1\frac{1}{2}$

The brass connectors mentioned above are used as binding posts to couple the ends of the primary coil to the other parts of the instrument without bringing the terminals outside of the caps. The drawing, Fig. 41, shows the design, while the dimensions are given in Table XI. It will be observed that these connectors are turned from solid brass rods, the shanks of which are threaded to fit those tapped in the caps. A hole slightly larger than the diameter of the primary wire is drilled entirely through the axis of each connector, as well as two screw holes at right angles to the one through the axis, and these are provided with machine screws; the sizes and distances of the latter from the ends are also given in the following table. Occasionally the finished connectors can be purchased, but it is more satisfactory to make them according to the specifications given, though if these are difficult to make, ordinary binding posts may be used instead.

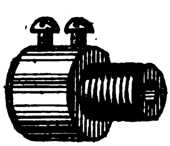


FIG. 41.—BRASS CONNECTOR.

TABLE XI.

Dimensions of Brass Connectors.

Spark Length of Coil.	Length of Connector Body.	Diameter of Body.	Length of Shank.	Diameter of Hole Through Axis.	Diameter of Set Screws.	Distance of Screw Holes from Ends.
Inches.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
4	1/2	1/2	3/8	0.072	3/32	3/32
6	1/2	1/2	3/8	0.072	3/32	5/32
8	1/2	1/2	7/16	0.081	3/32	5/32
10	5/8	5/8	1/2	0.081	1/8	3/16
12	5/8	5/8	5/8	0.102	1/8	3/16

After the inductor, of which the core and primary form integral parts, is inserted in the hard-rubber tube and the end caps have been brought into position, large brass washers neatly finished and lacquered are slipped over the ends of the core rods, the sizes of which may be had by referring to Table XII.

TABLE XII.

Brass Finishing Washers.

Spark Length of Coil.	Diameter of Disk.	Thickness of Disk.	Diameter of Hole.
Inches.	Inches.	Inch.	Inch.
4	1	3/16	1/4
6	1	3/16	1/4
8	1 1/4	1/4	5/16
10	1 1/2	1/4	3/8
12	2	3/8	3/8

If a 4, 6, or 8 inch coil is under construction, then on one end over the brass washer a hexagonal nut is screwed, or to give it a more finished appearance, a brass cap nut may be used similar to that illustrated in Fig. 42. Since in an intermediate sized coil a vibrating spring interruptor is employed, the opposite end of the inductor is arranged a little differently, in that instead of a hexagonal nut or a cap nut to hold the hard-rubber cap in place, a cylindrical nut of soft iron, illustrated in Fig. 43, is drilled

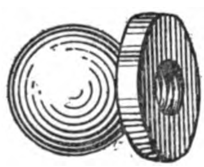


FIG. 42.—BRASS CAP NUT.

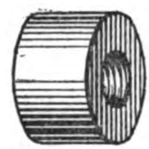


FIG. 43.—POLAR PROJECTION NUT.

half way through and tapped to fit the iron rod, and screwed on, and this not only serves the purpose of the former, but acts as the pole for the armature of the interruptor. The size of the polar projection nut required will be found in the succeeding table.

TABLE XIII.

Dimensions of Polar Projections.

Spark Length of Coil.	Diameter of Pole.	Thickness of Pole.
Inches.	Inch.	Inch.
4	3/4	1/2
6	3/4	1/2
8	1	3/4

In the 10 and 12-inch coils the hexagonal nuts or cap nuts are screwed into place on both ends of the inductor, since an independent interruptor is used. This completes the inductor as shown in Fig. 44, and when these parts have been finished and fitted, they may be taken apart, as the hard-rubber tube is used on which to assemble the secondary coil.

CHAPTER VII.

WINDING THE SECONDARY COIL.

The statements made in Chapter V relative to the purity of the copper wire hold equally good for the secondary coil. Silk-covered insulated wire brings the turns nearer to the inductor, and hence into the most intense part of the magnetic field, but cotton-covered wire makes the strongest coil mechanically, although the external diameter is considerably increased. This is the cause of the disparity in the sizes of some of the foreign and domestic coils giving the same length of spark.

The exact amount of wire required to produce a given length of spark is a difficult matter to predetermine by calculation, since in every case there are a large number of factors to be taken into consideration. Some writers advocate the use of a mile of wire on the secondary for every inch of spark length desired, while others suggest that a pound of wire per inch of spark length is about the right amount. Obviously, in neither instance can these figures be very accurate, for a mile of wire would make a great many more turns on a small than on a large coil, while the ratio between the weight of wire and the diameter of the turns would not remain anywhere nearly constant in the construction of large secondaries. The total amount of wire either by length or by weight, however, can be given approximately, and a reference to Table XIV will indicate the sizes and the amounts required for small coils.

TABLE XIV.

Size and Amount of Wire for Small Secondary Coils.

Spark Length of Coil. Inches.	Size of Wire, B. and S. Gage.	Pounds Required.		Number of Threads to Inch for Bare Wire.
		Bare.	Cotton Covered.	
½	40	½	¾	32
1	40	¾	1¼	24
2	38	1¾	3	16

In many of the smaller-sized coils found in the open market the wire of the secondary is bare, the insulation being provided by leaving a small space between the turns. Bare wire is, of course, very much cheaper than double or even single cotton-covered wire, and if a screw-cutting lathe is at the disposal of the constructor, any of the coils up to and including the 2-inch size may be easily wound with it. The slide rest should be set at the number of threads per inch given in the last column of Table XIV, and a guide fastened in the tool holder of the rest, the wire leading from the spool on which it is purchased to the spool in the lathe, as indicated in Fig. 45. In starting, a hole should be drilled radially in one of the cheeks, that is, from its circumference through to its center, where another hole should be drilled from the inside to meet it, as shown in the side elevation, Fig. 33.

The end of the wire is brought through this hole to the outside of the cheek, forming one of the terminals, and if bare wire is used, it must be insulated with a bit of rubber tubing. In small coils it is quite unnecessary to wind them in sections, the successive layers being continuous and separated by sheets of paper. As the winding progresses the turns should be insulated with shellac applied with a brush. When a layer has been wound to within half an inch of the surface of the cheek, it should

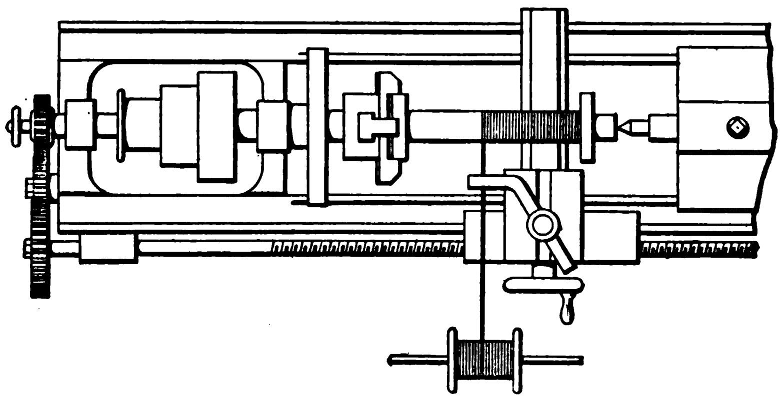
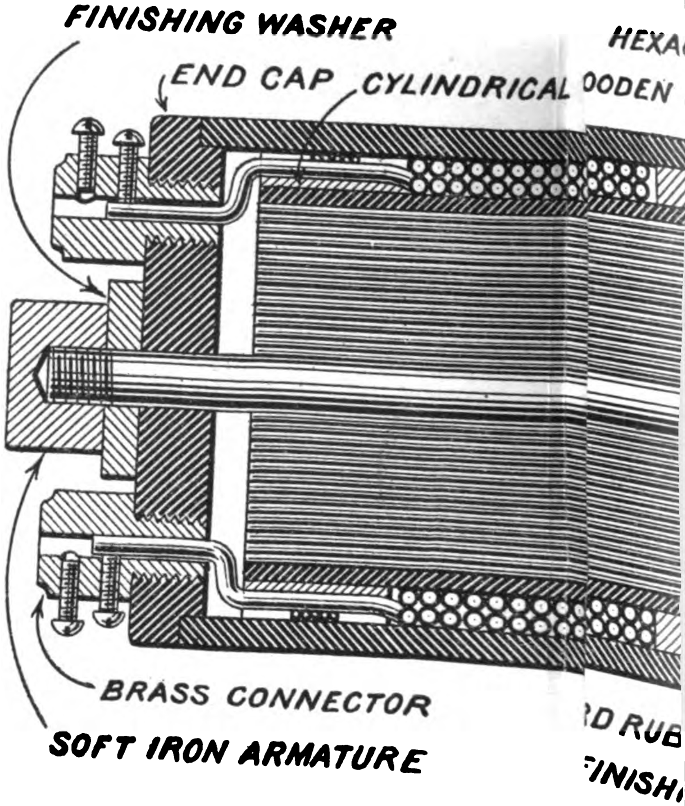


FIG. 45.—WINDING A SECONDARY IN A LATHE.

be examined closely to see that the turns are properly spaced, for if any two adjacent turns touch each other, the coil will be short-circuited. Around the layer of wire a sheet of calendered paper, such as the better class of trade journals are printed on, is tightly wrapped, another layer of wire is wound and shellacked, and the process repeated until the requisite amount of wire has been put on.

A better coil may be made by using single cotton-cov-



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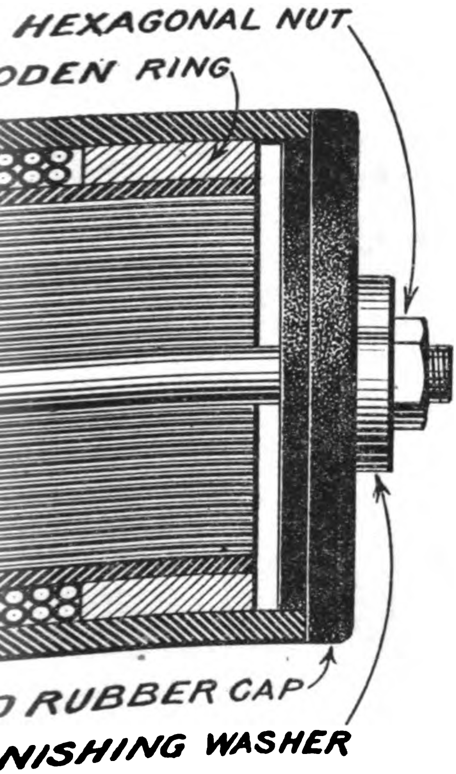

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ered wire of the size given in the preceding table for the length of spark required, and instead of calendered paper using a good quality of blank newspaper that has been soaked in melted paraffin. The wire should be coated with paraffin applied with a brush while in a melted state, and instead of spacing the turns these may be wound closely together. When the winding is completed, the free terminals are reinforced with No. 18 wire which is insulated and brought out through the periphery of the cheek as before. The coil is then ready to be covered with a sheet of hard rubber. If a lathe is not available, the device used for winding the primary may be utilized, but the process will be much slower, since the wire must be guided by hand.

TABLE XV.

Size and Amount of Wire for Intermediate and Large Secondary Coils.

Spark Length of Coils, Inches.	No. of Single Cotton-Covered Wire for Ordinary Coils.	Pounds of Wire for Ordinary Coils	No. of Wire for Wireless Telegraph Coils.	Pounds of Wire for Wireless Telegraph Coils.
4	36	6	32	16
6	36	9	32	24
8	36	12	32	28
10	34	15	30	42
12	34	18	30	44

For all coils giving a 4-inch spark or over it is better practice to wind the secondaries in sections. The amounts of wire given in the above table are maximum for the coils cited, but coils have been constructed with much less wire where all the conditions were satisfied, the chief one of which is to have the turns effectively placed. The number of turns of wire for secondaries designed for wireless telegraph transmitters and other work where a large current output is required should be the same as for ordinary coils giving the same length of spark. This will make it necessary to increase the diameter of the sectional disks or *pies,* as they are called, or to increase the length of the core and the primary coil, or both, which would give better results.

While a lathe properly equipped will serve the purpose best, a winding machine similar to the one designed by Hare will prove eminently satisfactory and can be constructed at a small cost. The machine, of which a vertical cross-section is shown in Fig. 46, consists of a base of cast iron or wood to which are screwed two standards. These are drilled and tapped to receive oppositely-disposed iron or steel centers; the latter should screw in and out easily, as they will have to be adjusted frequently while the pies are being wound. To prevent them from becoming loose while the device is in operation, check nuts should be provided to tighten them up.

A spindle having countersunk ends is arranged to rotate between the centers; if the number of turns of wire is to be kept account of, a projecting bar is screwed to the left-hand collar of the spindle to work an automatic counter. A brass disk a little larger than the diameter of the section to be wound, and having a shoulder on one side, the opposite side being turned perfectly true, is mounted on the spindle by means of a set screw; a small brass disk having a thickness equal to the section to be wound and a diameter ½ inch larger than the diameter of the insulating tube of the inductor to be used (see Table XVI) is slipped on the spindle; a third brass disk of the same size and design as the first is now put on, so

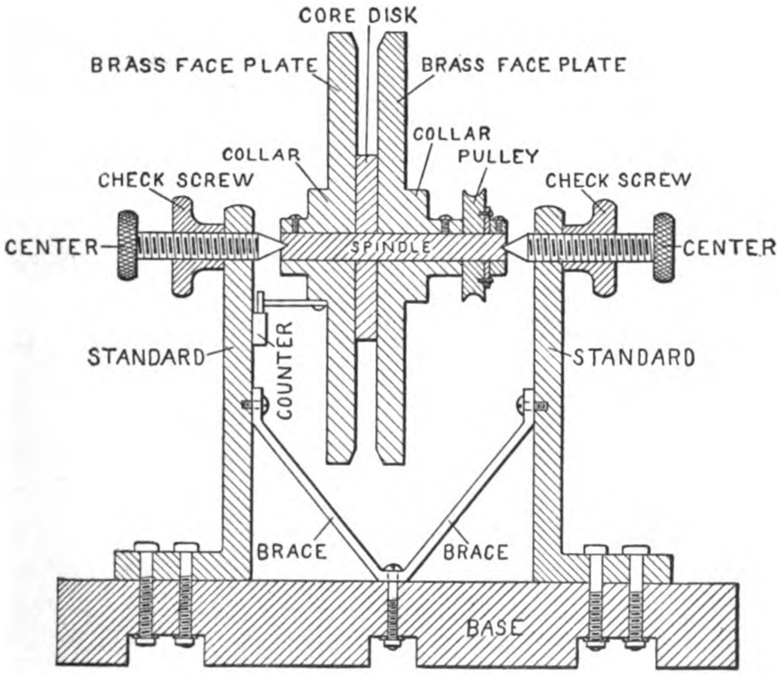


FIG. 46.—CROSS SECTION OF WINDING MACHINE.

that the turned and trued surfaces face each other; a small pulley is finally screwed into place against the shoulder of the latter disk. The dimensions of the machine are as follows:

TABLE XVI.

Dimensions of Winding Machine.

Spark Length of Coil, Inches.	Height of Standards, Inches.	Distance Between Standards, Inches.	Diameter of Face Disks, Inches.	Diameter of Core Disks, Inches.	Thickness of Core Disks, Inches.
4	7	5	5⅞	3⅜	3/16
6	7	5	6½	3⅞	3/16
8	7	5	7⅛	4⅜	⅛
10	7	5	7⅜	4⅞	⅛
12	7	5	7⅞	5½	⅛

Base length, 12 inches. Width, 12 inches. Thickness, 1⅛ inches.

Having procured this essential piece of apparatus, it may be operated by means of a small electric motor belted to it or turned by hand, a wheel having a small crank being mounted separately for the purpose. The other accessories of the winding outfit comprise a shallow pan supported on metal angle irons or rods, so that the paraffin wax or insulation compound may be heated and kept in a melted condition. Inside the pan are soldered projections that carry at right angles to them a heavy brass wire which keeps the fine wire submerged in the melted wax or compound and yet permits it to run smoothly from the spool to the winding machine.

A support for the spool of wire is made by attaching two standards of flat iron 6¾ inches in height, 1 inch in width, and 3-16 inch thick to a base board, the lower ends being bent at right angles and holes drilled in them for this purpose. The upper ends are also drilled to receive a rod to carry the spool of wire. One end of a flat steel or brass spring 3 or 4 inches long should be attached to one of the standards, while the other and free end is arranged to press against the cheek of the spool; this is to prevent the wire from unwinding too rapidly, especially when the winder is suddenly stopped in its action. The whole arrangement is illustrated in Fig. 47. It will be observed that the pan containing the insulating wax or compound is considerably lower than the center of the winding machine and the spool of wire. This permits the wire from the spool to pass directly into the wax under the wire guide and to the pie that is being wound without touching any part of the pan.

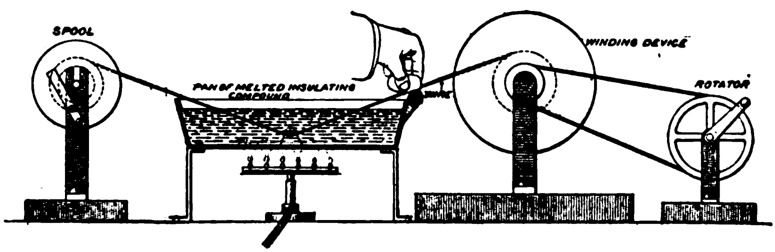


FIG. 47.—WINDING EQUIPMENT COMPLETE.

In this manner the wire of the secondary pies is given a thin insulating coat of wax or composition, and while the latter is yet hot the wire is wound in the space between the brass surfaces, but before winding, a paper disk is attached by a little paraffin to each of the brass cheeks, so that it can be easily removed when cool; the pie will then be a practically solid body.

The choice of insulating mediums is next to be considered. Paraffin is excellent, and some very large coils have been successfully built in which it was used throughout for the secondary; it is an exceedingly pleasant substance to work with, and possesses a high dielectric strength if not subjected to excessive temperatures. Under such conditions it deteriorates and changes from its clear white color to a yellowish brown, when its insulating qualities are greatly impaired. Another disadvantageous feature of paraffin is that it tends to collect moisture, and this too lessens its value as an insulator where high potentials are produced.

The best insulating compound for the secondaries of induction coils is made of equal parts of rosin and beeswax, but as beeswax is expensive compared with paraffin, the amount may be cut down and a very excellent composition, good enough for all practical purposes, may be made by incorporating one part of beeswax with three parts of rosin. This compound possesses many advantages over paraffin, and among its admirable qualities it may be cited that it does not suffer injury from overheating; its melting point is higher than paraffin; it does not become brittle unless too much rosin is used, and it does not collect moisture. It is, however, more difficult to handle than paraffin; whether paraffin or beeswax and rosin are used, the purity of the materials must be insisted upon. If the coil is to be made up in the simplest manner, either paraffin wax or the compound of rosin and beeswax may be used for winding the pies and building up the secondary; but if it is manufactured for the market, it should be further improved by subjecting it to the vacuum drying and impregnating process. In the latter case it is customary to wind up the pies with paraffin.

Before commencing to wind the pies the wire should be thoroughly dried out, and this may be accomplished by placing the spools in an oven at a low temperature for several hours, taking care not to burn the insulation. Another method is to place the spools of wire, together with a dish containing a pound or two of calcium chloride, under a large bell jar. The property which gives to this salt its value is its power to absorb moisture; and to exclude the air from the outside of the jar, the latter may be set in a shallow pan containing a little oil. Another way is to utilize one of the brass disks of the winding machine and smearing the edge with grease, so that the edge of the jar will set in it.

CHAPTER VIII.

WINDING THE SECONDARY COIL (CONTINUED).

The next step is to cut out a number of paper disks having the same external diameter as that of the secondary to be wound and with apertures somewhat larger than the outside diameter of the insulation tube. These disks are to be placed between the pies to insulate them from each other, and may be cut from thin white unsized paper by means of metal dies, or forms, or with a pair of shears. The approximate diameter of the pies and the paper disks and their inner cut-outs may be obtained from the following tables, as well as the number required.

TABLE XVII.

Number, Diameter and Aperture of Secondary Pies.

Spark Length of Coil, Inches.	Thickness of Pie, Inches.	Diameter of Pie Aperture, Inches.	External Diameter of Pies. Inches.		Number of Pies
			Ordinary.	Wireless.	
4	3/16	2⅞	5⅝	6¾	30
6	3/16	3⅜	6¼	7½	37
8	⅛	3⅞	6⅞	8	64
10	⅛	4⅜	7⅛	8½	80
12	⅛	5	7⅝	8¾	90

TABLE XVIII.

Number, Diameter and Aperture of Paper Disks.

Spark Length of Coil, Inches.	Diameter of Aperture, Inches.	External Diameter Inches.	Disks Between Each Pie.	Total Number of Disks.
4	2⅞	5⅝	6	186
6	3⅜	6¼	6	228
8	3⅞	6⅞	6	390
10	4⅜	7⅛	6	486
12	5	7⅝	6	570

The paper disks must be thoroughly dried out in an oven or otherwise, and then immersed while hot in melted paraffin or compound and allowed to remain in the bath until thoroughly saturated; this done, the disks are removed and either placed on japanned tin plates, such as tintypes are made on, or they may be suspended by spring clips from a line to dry.

Where a number of paper disks are placed between the pies, the danger of breaking down from pinholes and

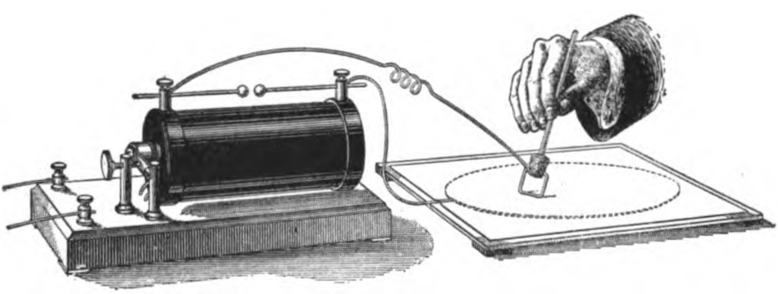


FIG. 48.—TESTING PAPER DISKS.

inherent defects is minimized; but if the constructor cares to take the additional time and trouble, the disks may be

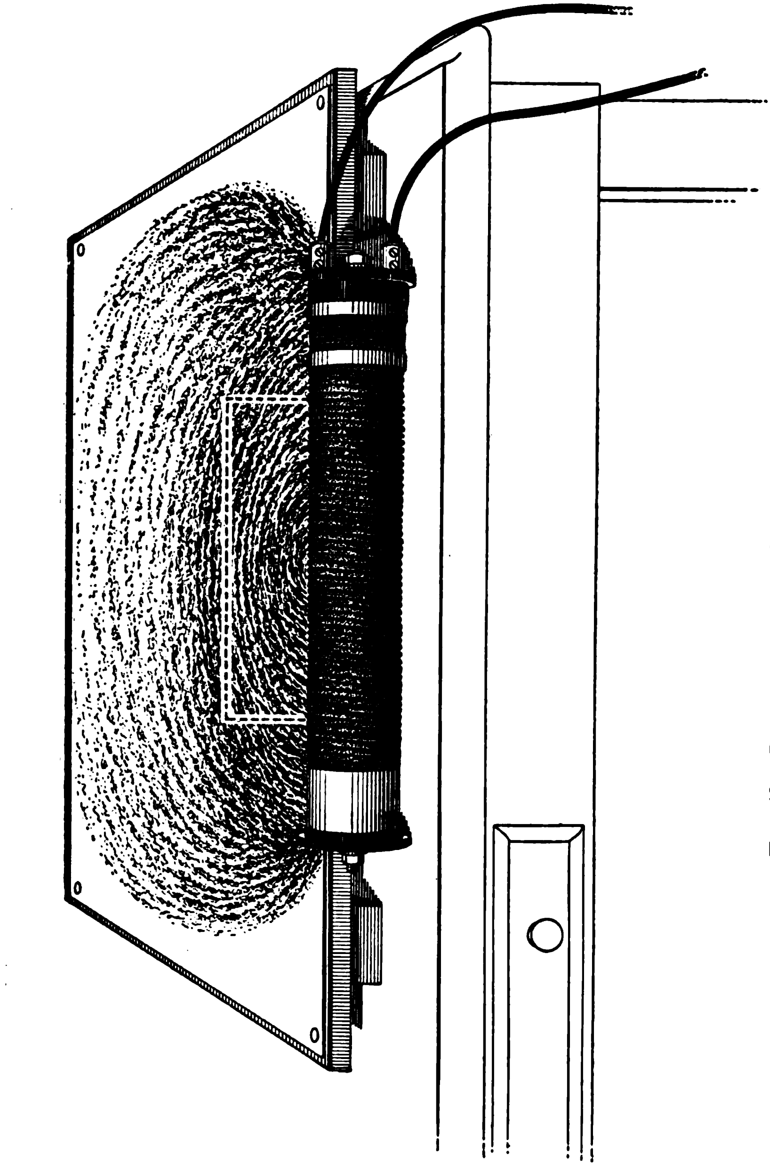


Fig. 49.—Determination of Size of Pies and Paper Disks.

thoroughly tested by the following modification of a method described by Hare: One of the circular brass plates of the winding machine may be laid on a sheet of glass and connected to one of the secondary terminals of a small induction coil giving a ½-inch spark. The opposite terminal of the coil connects with a device formed of a glass rod, one end of which is inserted in a cork, the latter carrying a rectangle of copper wire, all of which is clearly indicated in the illustration, Fig. 48. The paper to be tested is placed on the brass plate while it is yet in sheet form, so that the edges overlap that of the former; the wire rectangle is then drawn over every portion of its surface. If there are minute holes, air bubbles, or other weak spots, the difference of potential will quickly puncture it, and a spark will result.

If the constructor desires to ascertain the exact size of the paper disks rather than to use the approximate size given in the preceding table, he may proceed as follows: The completed primary coil and core, or inductor, is placed parallel with the edge of a drawing board on which is secured a sheet of paper, as in Fig. 49, and its terminals connected with a battery or other source of electromotive force. Iron filings are now sprinkled on the paper, when these will assume definite positions, indicating clearly the paths of the curved magnetic lines of force. Selecting the most intense portion of the magnetic field, a curve should be drawn after the manner of that shown in Fig. 50, when the diameter of the pies and paper disks will be obvious. While this procedure is not absolutely essential, it is well to follow it, since the different qualities of iron affect to some extent the contour of the lines of force.

One of the paper disks having been slipped over the spindle of the winding machine, and secured to one of the brass face plates with a little paraffin, all is in readiness to wind the wire. The wax or compound being melted—and it must be kept in a highly fluid state—the wire is put under the guide wire in the pan containing it, drawn through, and looped around a layer of paper attached to the brass core disk with a little paraffin, if the pie is a

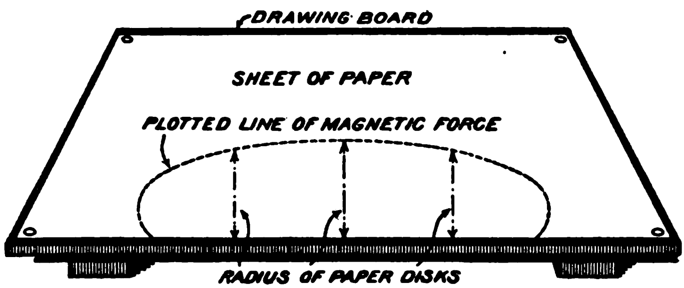


FIG. 50.—PLOTTING RADIUS OF PAPER DISKS.

middle or zero one, or around an insulating ring of cotton, to be described shortly, if the pie is an outside one.

The end of the wire thus secured, the winding disks are rotated as rapidly as may be practicable; the wire as it is being fed between the plates may be guided by a small ivory paper cutter with a hole drilled in the end for the wire to pass through, or it may be held down on the curved edge of the pan by a woolen pad, and must be constantly scrutinized for breaks, etc. The pad serves a triple purpose in that it also wipes away any excess of the wax or compound, and applies enough tension to the wire to wind it tightly.

Should the wire break, a neat and smooth joint must be made; this may be done by scraping about ½ inch of the cotton insulation from the ends of each wire and then twisting them together as in Fig. 51. However well the joint may be made, it must be soldered; again, the soldering must not be done with acid but with rosin, and applying the solder with a small jeweler's copper or by heating the juncture in an alcohol flame, care being taken not to char the insulation. The joint must be insulated by wrapping with thread or by winding about it a band of thin

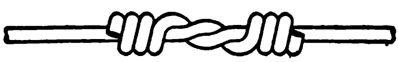


Fig. 51.—Making a Joint.

silk ⅛ inch wide, and then immersing this in the insulating compound until it is thoroughly saturated.

When completed the pie must be permitted to remain between the brass plates of the winding machine until the insulation has cooled and set. It is then removed by simply unscrewing the check nut and one of the centers, when the spindle will be released. Having wound the first pie, the process is repeated; but for the second pie, instead of turning the spindle to the *right,* it is turned to the *left*; the same effect may be had by winding the pies in the same direction and reversing each alternate one. This makes the first pie a right-handed helix and the second a left-handed helix, as shown in Fig. 52; the third pie is, of course, a right-handed one, and so on to the end. The object of winding each alternate pie in the

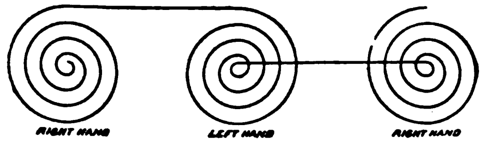


FIG. 52.—NEW METHOD OF CONNECTING PIES.

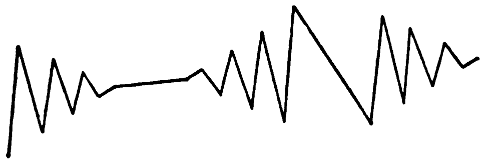


FIG. 53.—NEW METHOD OF CONNECTING PIES.

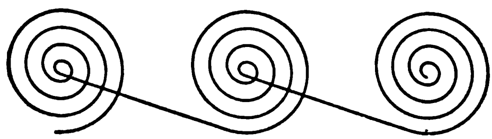


FIG. 54.—OLD METHOD OF CONNECTING PIES.

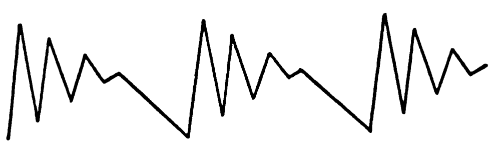


FIG. 55.—OLD METHOD OF CONNECTING PIES.

opposite direction is so that when the turns of the pies are connected together, the inner terminals of the first two adjacent and the outer terminals of the next two adjacent ones may be connected together, as the diagram Fig. 53 illustrates. This method of winding obviates the objectionable connections formerly employed, wherein the outer terminal of one coil is brought down between the sections, so that it may be connected with the inner terminal of the next section to it, as in Figs. 54 and 55, a procedure that tends to produce short-circuiting and sparking between the individual pies and sections.

As the right and the left handed pies are wound, their inner terminals should be connected, soldered, and insulated. The wires connecting the adjacent secondary pies should not lie in a plane parallel with the axis of the inductor, but should be of such lengths, say from 2 to 6 inches each, that they may be wound helically around it. Each pair of pies, that is a right and a left handed one, should be connected together as they are wound, and a unit formed by joining them with some of the insulation medium smeared along the line of juncture, so that when all the disks are finished, there will be no confusion as to the direction of their windings.

It is not absolutely essential, though it is considered good practice, to increase the diameter of the apertures of the pies that are to be placed near the ends of the core. The object of this is not only to bring the greatest number of turns in the middle of the coil, where the magnetic field is strongest, but also in virtue of the fact that at the middle the voltage is practically zero, while at its ends it

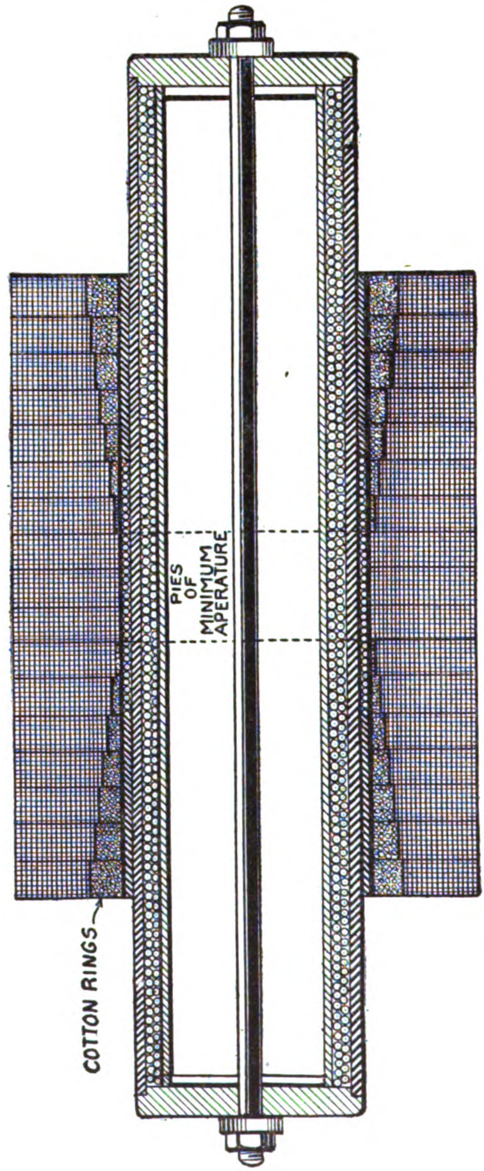


FIG. 56.—DISTRIBUTION OF COTTON RINGS.

rises to its maximum pressure; and though many turns of wire are lost, it prevents the possibility of sparking between the ends of the secondary coil and the inductor.

To provide for this clearance, which may range from ¼ inch at the middle to ½ inch for a 12-inch coil at the ends, as shown in the cross-sectional drawing, Fig. 56, the outer pies are begun by winding with cotton thread, No. 40 or 50, and run through the paraffin or compound as in the case of the wire, until the desired diameter is obtained, when the wire is wound on over it. The proper diameters of the cotton rings may be had by winding the thread on the brass core disk to a depth given in the following table:

TABLE XIX.

Number, Depth, and Thickness of Insulating Rings.

4-Inch Coil, Thickness of Rings 3/16 Inch.		6-Inch Coil, Thickness of Rings 3/16 Inch.		8-Inch Coil, Thickness of Rings ⅛ Inch.	
Number of Rings.	Radial Depth of Rings, Inches.	Number of Rings.	Radial Depth of Rings, Inches.	Number of Rings.	Radial Depth of Rings, Inches.
6	¼	8	¼	10	⅜
6	3/16	8	3/16	10	5/16
6	⅛	8	⅛	10	¼
6	1/16	8	1/16	10	3/16
..	..	..	..	10	⅛
..	..	..	..	10	1/16
Total number of rings 24 Number of pies of minimum aperture 6 Total number of pies 30		Total number of rings 32 Number of pies of minimum aperture 5 Total number of pies 37		Total number rings 60 Number of pies of minimum aperture 4 Total number of pies 64	

Data for Insulating Rings (Continued).

10-Inch Coil, Thickness of Rings 1/8 Inch.		12-Inch Coil, Thickness of Rings 1/8 Inch.	
Number of Rings.	Radial Depth of Rings, Inches.	Number of Rings.	Radial Depth of Rings, Inches.
12	3/8	10	1/2
12	5/16	10	3/16
12	1/4	10	3/8
12	3/16	10	5/16
12	1/8	10	1/4
12	1/16	10	3/16
..	..	10	1/8
..	..	10	1/16
Total number of rings............72		Total number of rings............80	
Number of pies of minimum aperture........................ 8		Number of pies of minimum aperture.............14	
Total number of pies.............80		Total number of pies............94	

Note.—One-half of each of the number given are placed on one end, and the other half on the opposite end of the secondary coil.

After the pies are prepared, the wire of each should be tested to ascertain if it is continuous as well as for other untoward defects, such as loops and inherent weaknesses of insulation. Likewise the resistance of the pies should be measured if the constants of the coil are to be preserved for future use. Testing the continuity of the wire may be done by connecting one terminal of the pie with a dry cell and a galvanometer, or if the latter is not at hand by touching the terminals to the tongue. Faulty construction may be detected by slipping each pair of pies over the inductor and testing with the interruptor, condenser, and source of current as previously described.

A part of the number of pies, say three-fourths the total number for the coil to be built, had better be wound first, leaving the remainder until the exact number required can be determined by experiment. This is performed by assembling a number of pies, say 20 or 25, for the 4 and 6-inch coils, 40 or 50 for the 8 and 10-inch coils, and 60 or 70 for the 12-inch coil, into a section and slipping it over the inductor. It is then tried out with the voltage, current strength, interruptor and condenser it is intended to use with the completed coil. The terminals of the secondary are brought together until the spark passes between them. In this way it is possible to more accurately ascertain the number of pies necessary, and not only may wire be saved by this method, but the efficiency of the coil increased, for each additional turn of wire on the secondary that is not needed increases its resistance and cuts down the current without greatly increasing the length of spark.

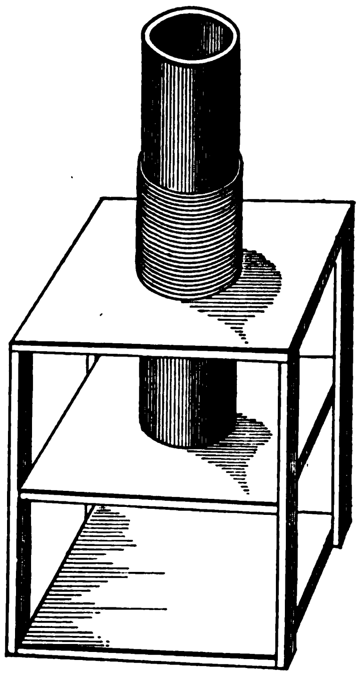


FIG. 57.—SUPPORTING STAND FOR SECONDARY.

If the coil is to be built up as simply as possible, the procedure is as follows: After the requisite number of pies have been wound and tested individually and collectively, they are formed into the secondary coil by inserting between them the number of paper disks designated in Table XIX and mounting them on the insulating tube inclosing the primary coil. This work is begun by removing the primary coil and its core from the hard-rubber tube. That portion of the tube the secondary coil is secured to should have its surface roughened with a coarse file and winding a fine and strong fish-line helically around it, so that each turn of the line lies closely together. Care must be taken to wind the line tightly, for on this depends to a considerable extent the fixed relations between the tube and the secondary coil.

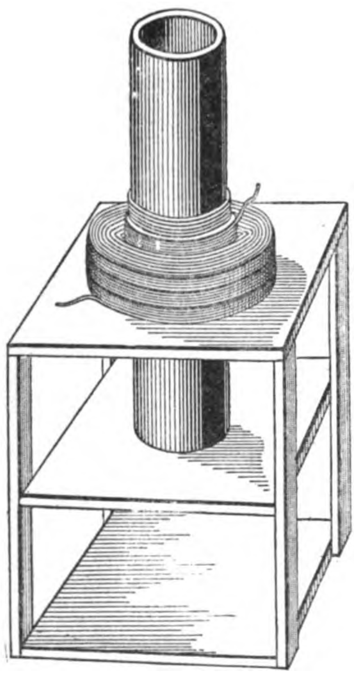


FIG. 58.—BUILDING UP THE SECONDARY.

Having marked off the position of the secondary on the tube, it is placed in a supporting stand as shown in Fig. 57, and must be adjusted so that it is exactly perpendicular to the surface of the top of the stand, and the tube must fit snugly into the aperture of the latter. Over the tube the pairs of pies with the paper disks are placed, as in Fig. 58. The projecting terminals are next soldered and the joints insulated, while the leads formed by the terminals at the ends of the secondary coil are left

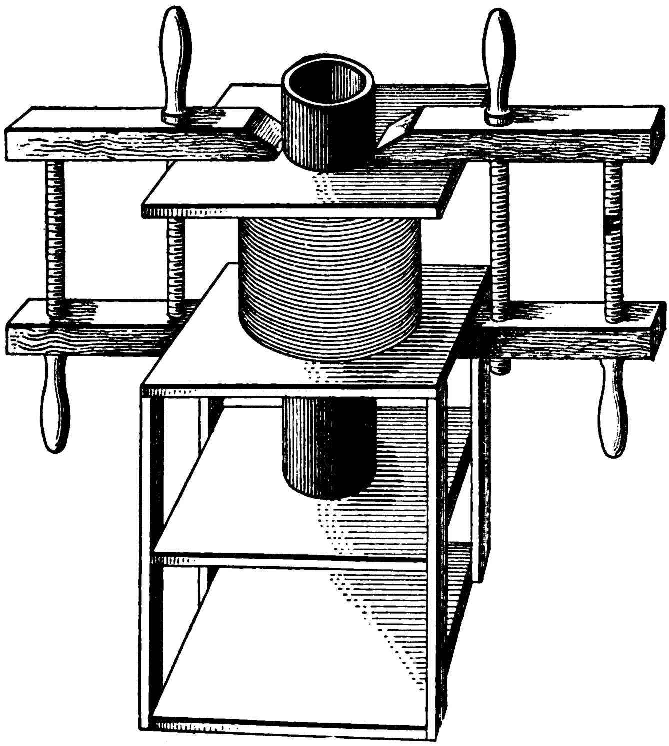


FIG. 59.—THE SECONDARY COIL UNDER PRESSURE.

free. A board the size of the top of the stand, with a hole in its center and four large cabinet maker's wood clamps, should be at hand, as well as a cylinder made of heavy tin, the diameter of which is ½ to 1 inch larger and in length a trifle shorter than that of the secondary. The former is placed over the latter, and all is in readiness to pour the hot insulating material in the space between the internal surface of the secondary coil and the tube, and the external surface of the coil and the tin cylinder. When all the spaces have been filled and the fluid reaches the top, the board is dropped over the tube, the wood screws are quickly adjusted and tightened up to bring an even pressure to bear on the ends of the coil, as shown in Fig. 59. When the paraffin or compound has set, the screws and the cylinder may be removed. It will then be found that the insulating tube of the inductor is surrounded with a hard and compact mass joining it to the secondary coil and to which it is rigidly fixed. The completed secondary mounted on the insulator tube. together with the inductor, is shown in Fig. 60.

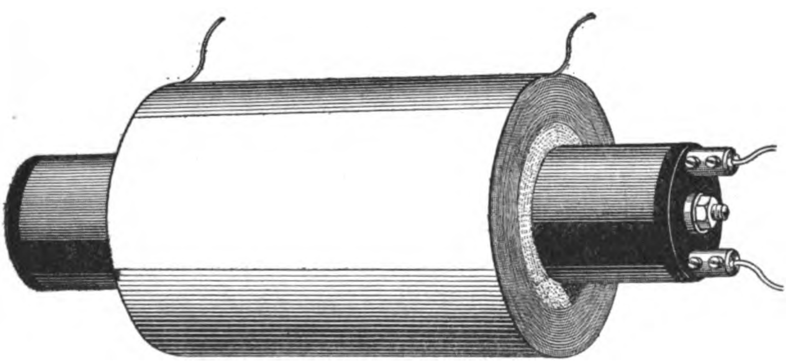


FIG. 60.—THE COMPLETED SECONDARY COIL.

CHAPTER IX.

VACUUM DRYING AND IMPREGNATING APPARATUS.

The methods cited in the preceding and succeeding chapters for treating secondary coils and condensers require only such appliances as are easily obtainable by the amateur constructor wherever he may abide. Apparatus built up in accordance with these instructions will give excellent service if not subjected to overloads and careless handling, but where the coils and condensers are made in quantities for the competitive market, and the maker's reputation must stand upon the excellence of his product, greater precaution in applying the insulation is necessary.

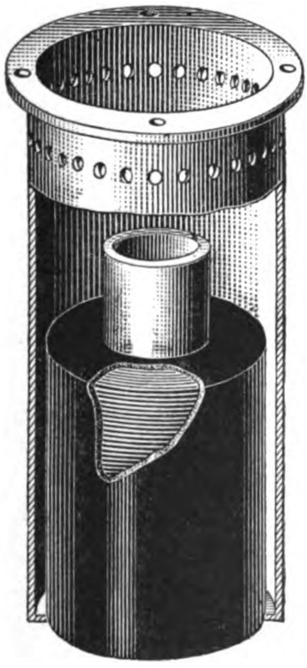


FIG. 61.—IMPREGNATING VESSEL.

Nearly all professional manufacturers of induction coils have equipments of some kind for securing a higher insulation than by the simple processes that have been described, although some of the less particular ones resort to the expedient of placing the built-up secondary in a vessel formed of heavy tin or sheet iron and having an iron top which may be screwed or clamped down, as shown in Fig. 61; the top or cover, Fig. 62, which should have ventilating holes, is provided with two, three, or four long screws, so that the secondary coil may be compressed.

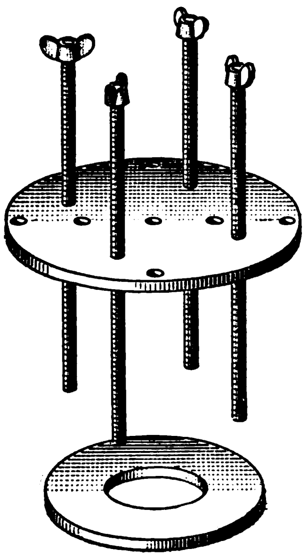


FIG. 62.—TOP WITH COMPRESSION SCREWS AND RING.

After the secondary is put into the vessel, a brass tube having an external diameter equivalent to the diameter of the aperture formed by the pies is inserted, to prevent the wax from filling up the hole. A brass plate, also shown in Fig. 62, is placed over the top of the coil, and the screws tightened up; the vessel with its inclosed secondary is then put into an oven and heated to a temperature low enough to prevent the paraffin or the compound from igniting. Heating will of course melt the insulating medium in the coil, but it will also drive out to a considerable extent the minute particles of air that were sealed in the insulation when it was wound. When the vessel is taken from the oven, the screws are released, the cover taken off, and the plate removed; hot melted paraffin or compound is poured in the vessel, which will penetrate the spaces and pores and effectually prevent further absorption of moisture and air. The brass plate is replaced over the top of the coil, the cover put on, and the screws again tightened up. The vessel is returned to the oven for an hour or two, and then permitted to cool.

A steam-heated vacuum drying apparatus gives much better results than the foregoing vessel. A simple type of this apparatus is shown in Fig. 63; it comprises a vessel

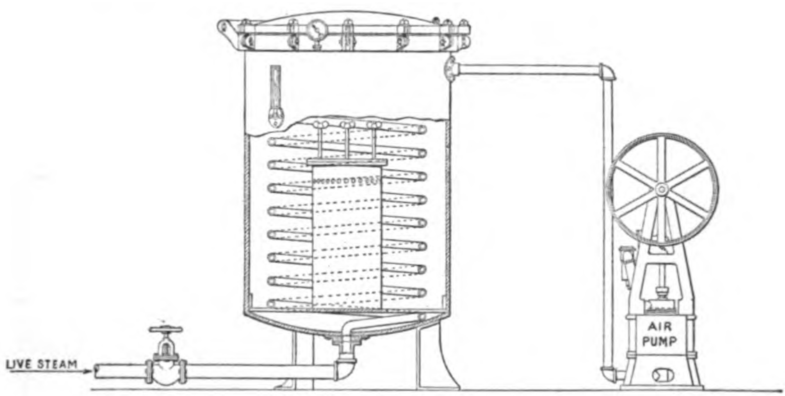


FIG. 63.—SIMPLE VACUUM DRYING APPARATUS.

of heavy sheet or cast iron, and having a cover which can be bolted down, forming an air-tight chamber. Inside the chamber is a coil of piping, and this is brought out through the bottom, where it connects with a boiler, so that live steam can be passed through it. An air pump capable of bringing the vacuum down to one-quarter of an inch is connected to the chamber through a pipe near the top. The chamber should be provided with a thermometer for determining the temperature and a manometric gage for indicating the degree of vacuum produced. Where this apparatus is used, the secondary coil is placed in the adjustable brass or iron frame illustrated in Fig. 64. It is formed of four or six upright brass or iron rods set into a brass or iron plate, and of such proportions that the pies and disks will fit in snugly. When all the pies are connected with each other, a circular brass plate, with holes to accommodate the projecting rods, is put on, and thumb nuts are screwed on and down until the secondary coil is under considerable pressure.

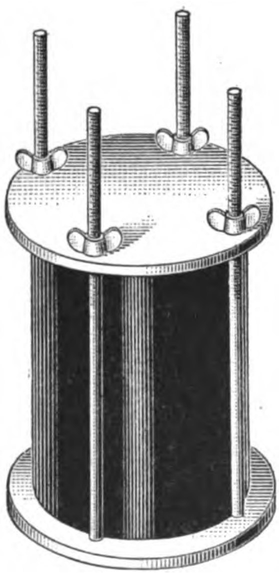


FIG. 64.—BRASS FRAME.

The frame with the coil in it is then put into the vacuum chamber, the head is screwed down, steam is turned on in the pipe, and the air pump set into operation. After the heat and the vacuum are maintained for from two to six hours, the chamber is opened, and the insulating compound is poured into the containing vessel as before, when it is again placed in the chamber and the air exhausted. When the vacuum has reached 28 inches, the heat is turned on and the compound brought to a high state of fluidity. In another hour the heat is shut off, and when the compound is nearly cold the air is admitted, and this serves to drive the compound more tightly into the pores. When cold the coil will be imbedded in a

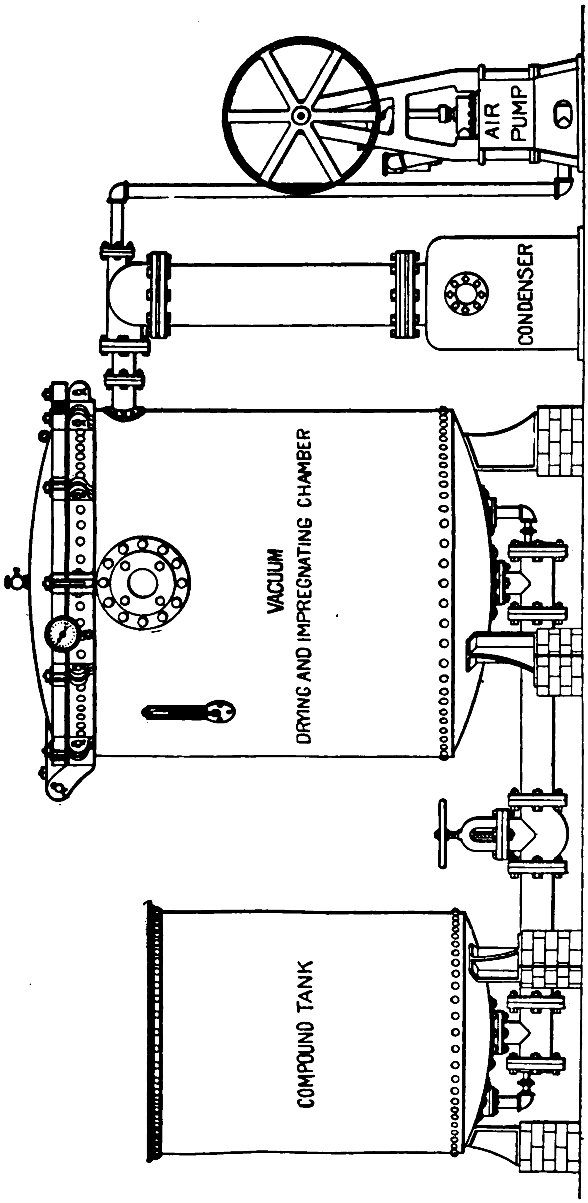


FIG. 65.—IMPROVED VACUUM DRYING AND IMPREGNATING EQUIPMENT.

hard mass of insulation, with the greater portion of the air and moisture removed.

In the more recent types of vacuum drying and impregnating apparatus, the arrangement is such that the insulation compound is allowed to enter the vacuum chamber without breaking the vacuum, and in this way all possibility of the dried coils absorbing moisture or air, as in the previously described processes, is effectually eliminated.

The apparatus comprises an open tank in which the insulating compound is kept in a melted state, and this is connected, by means of a pipe having a valve, with a vacuum chamber, where the drying and the impregnation takes place, while the vacuum chamber is connected with a condenser which liquefies the moisture as it comes from the chamber. A pump for exhausting the air completes the apparatus, and is shown in Fig. 65. The operation consists of assembling the pies and paper disks in a frame as before and placing it in the impregnating chamber.

After it has been thoroughly dried out the valve is opened, permitting the melted compound to flow from the containing tank into the impregnating chamber, which absolutely excludes from the coil every molecule of air or moisture before the insulating compound reaches it. After the melted insulation has run into the impregnating chamber, and it has flowed into and around the coil, the air pump is reversed and converted into a condensing pump, when air will be admitted to the chamber under a pressure of 60 pounds to the square inch, and which not only forces the compound back into the tank, but also drives that portion on and in the coil into the pores of the covering of the wire.

The principal advantage of vacuum drying and impregnating is the thorough evaporation of the water out of the insulating material. In the older processes of drying with hot air the latter always carried a certain amount of moisture, hence a thoroughly dry coil was practically impossible; again, in the ordinary impregnating processes it is necessary for the compound to remove the air contained in the insulating material before it can replace it. Where the coil is dried in a vacuum all the air is removed, and where the impregnating is done in vacuum the compound has not only free access to the evacuated pores of the cotton covering, but is moreover forced into it under pressure.

CHAPTER X.

CONSTRUCTING THE INTERRUPTOR.

Having completed the coil in so far as the inductor and secondary are concerned, a suitable interruptor for automatically making and breaking the circuit is the next requirement.

There are many kinds of interruptors in use, but those having a vibrating spring element, one end of which is rigid while its opposite and free end carries an armature operated by the core of the coil, is not only extremely simple in design and operation, but reliable where the coil is of small dimensions, and moreover it is easy to keep in adjustment; for these reasons it is a very good interruptor for all ordinary classes of work.

There are three different types of spring interruptors in general use, namely (1) those having a single spring and a single break, (2) those having double springs and a single break, and (3) those having double springs and double breaks. Interruptors of the first and second types are placed in series with the primary winding and source of electro-motive force, and are worked from one of the poles of the core, while in the third, termed an independent interruptor, the main contacts are placed in series with the inductor and source of electromotive force, the break being operated by a magnet placed in a shunt circuit.

The simple single-spring interruptor is used on coils in this country up to and including those giving an 8-inch

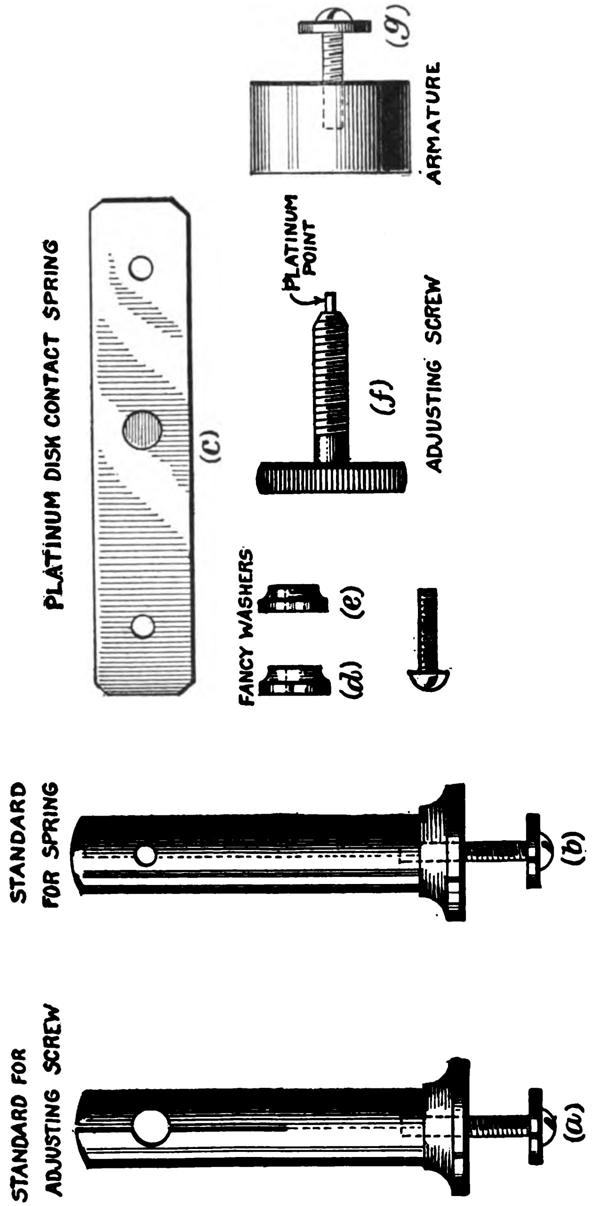


FIG. 66.—PARTS OF SINGLE SPRING INTERRUPTOR.

spark, though in England it is extensively employed in coils giving 12-inch sparks and over. The double-spring interruptor gives a more sudden break, owing to its peculiar construction, and hence it may be applied with ad-

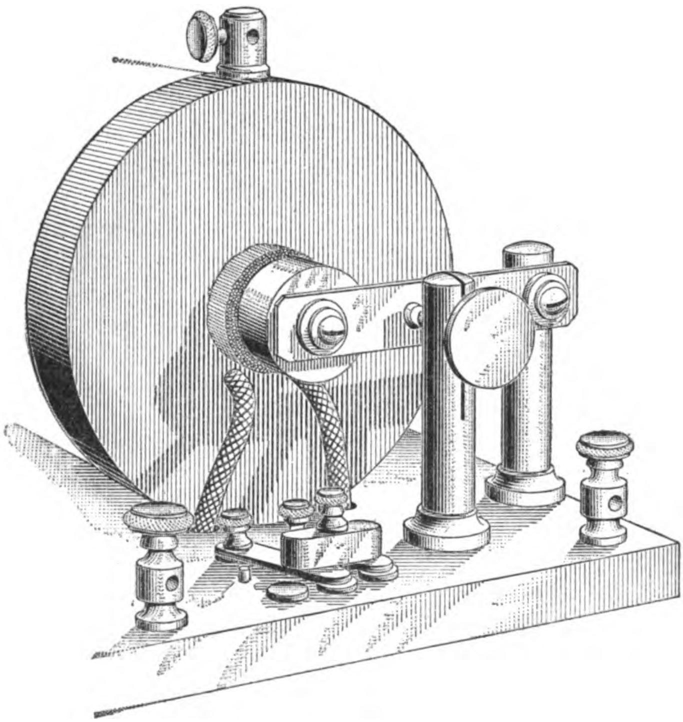


FIG. 67.—SINGLE SPRING INTERRUPTOR, ASSEMBLED.

vantage to coils of the intermediate sizes, that is those giving 4, 6, and 8-inch sparks; while the double-spring, double-break interruptor, which is independent of the current flowing through the main circuit, is the most effective of the vibrating-spring make and breaks, and should be used with the 10 and 12-inch coils.

The single-spring vibrating interruptor consists essentially of five parts, viz., the standard supporting the spring, the spring with its platinum contact, the armature carried by the free end of the spring, the standard supporting the adjustable screw, and the adjustable screw with its platinum contact point. Fig. 66 shows the interruptor dissected, and Fig. 67 illustrates it assembled at the end of the coil. The dimensions of the different parts may be ascertained from the following table:

TABLE XX.

Sizes of Single-Spring Interruptor Parts.

Spark Length of Coil, Inches.	Standards.					Springs.			Adjusting Screws.		
	Diameters, Inches. Top.	Diameters, Inches. Base.	Height, Inches.	Diameter of Hole for Adjusting Screw, Inches.	Distance of Hole (Center) from Top, Inches.	Length, Inches.	Width, Inches.	Thickness, Inches.	Length, Inches.	Diameter of Screw, Inches.	Diameter of Milled Head, Inches.
1/2	1/4	1/2	1 1/8	1/8	1/4	1 3/4	5/16	1/64	11/16	1/8	1/2
1	3/8	3/4	2	3/16	3/8	2 3/4	1/2	1/32	13/16	3/16	3/4
2	1/2	1	2 3/4	1/4	1/2	3 5/8	11/16	1/16	15/16	1/4	1

Armatures.		Platinum Disks for Spring Contact.		Platinum Wire for Stationary Contact.	
Diameter. Inches.	Thickness. Inches.	Diameter. Inches.	Thickness. Inches.	Diameter. Inches.	Length. Inches.
1/2	5/16	3/16	1/64	1/16	1/8
3/4	7/16	1/4	1/32	3/32	1/8
1 1/8	5/8	5/16	1/32	1/8	3/16

The standards, as well as the adjusting screw, are turned of brass; the former having holes drilled and tapped in the lower end in which machine screws are fitted, so that they may be secured to the base of the coil. A hole is drilled and tapped diametrically through the upper end of each of the standards, to receive the adjusting screw and the screw holding the spring respectively. The adjusting screw standard has a slot sawed longitudinally from the top to the screw hole, as shown in Fig. 66, to render the adjustment easier and yet hold the screw firmly; the end of the screw is drilled and tapped to receive a bit of platinum wire for the contact point.

The spring may be of steel or spring brass, and a small disk or square of platinum should be soldered about half way between the centers of the holes at either end of the vibrating element, and by which it is secured to the standard on the one hand and the armature attached to it on the other. The armature is made of a disk of annealed soft iron and neatly finished, and finally all the brass work should be lacquered. This may be done by cleaning the brass work, thoroughly removing every trace of grease and dirt and then applying the lacquer with a brush.

There are many kinds of lacquer for brass, but the following formula is one of the best and is largely used for optical and other fine instruments. The lacquer is prepared by placing in a tin or earthen vessel these ingredients: Seed lac, 6 ounces; dragon's blood, 40 grains; amber and copal pulverized, 2 ounces; extract of red sanders, ½ drachm; oriental saffron, 36 grains; coarsely powdered glass, 4 ounces; and absolute alcohol, 40 ounces. Mix the

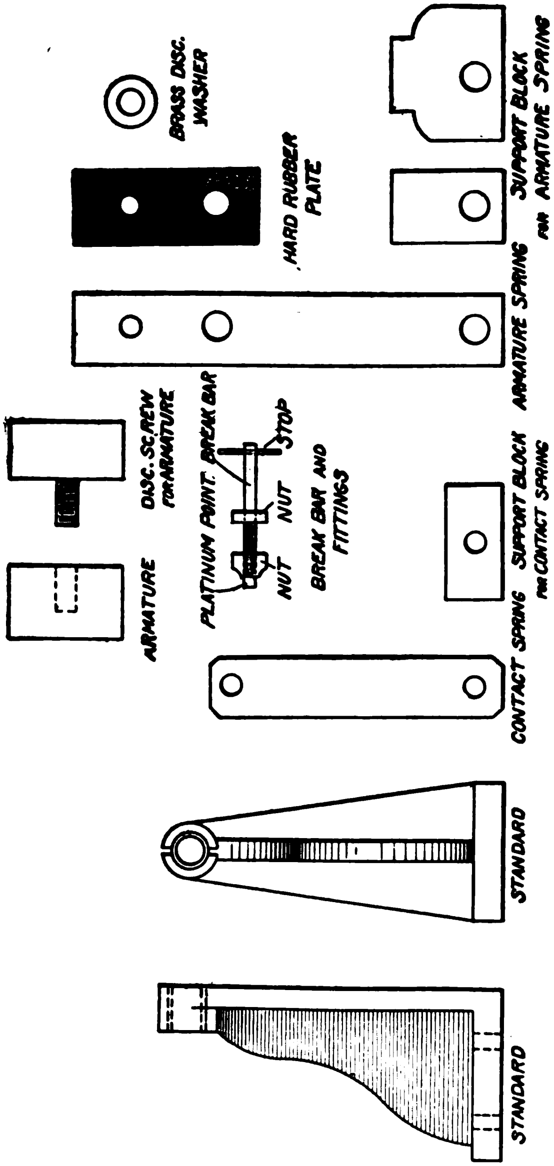


FIG. 68.—PARTS OF DOUBLE SPRING SINGLE BREAK INTERRUPTOR.

ingredients and let the vessel stand in a slightly warmed place for three or four days, shaking frequently until the gum is thoroughly dissolved, after which let it settle for

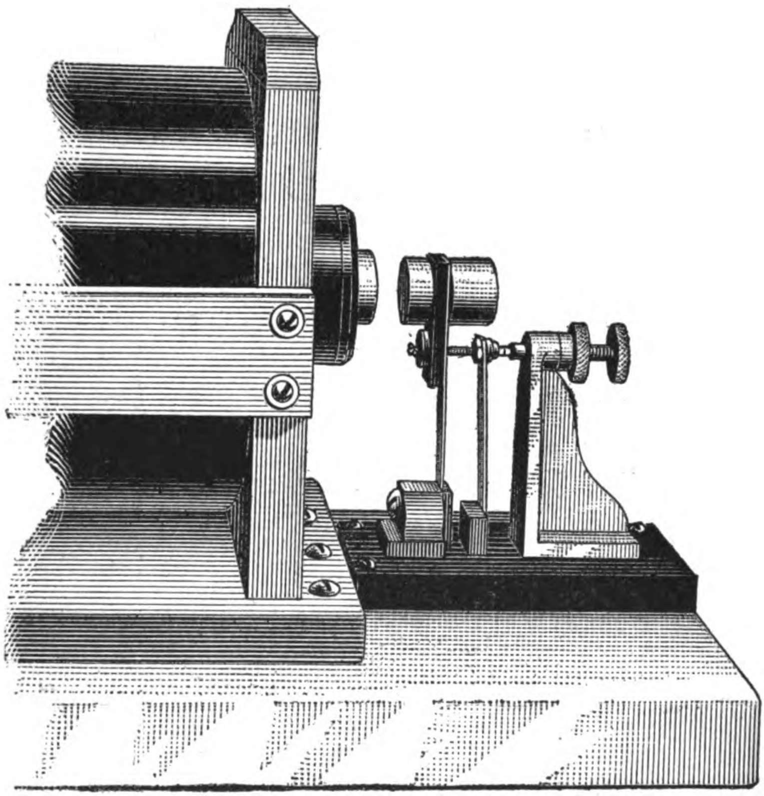


FIG. 69.—DOUBLE SPRING SINGLE BREAK INTERRUPTOR ASSEMBLED.

24 to 48 hours; by this time the liquid will be clear enough to pour off, when it is ready to use. The cleaned metal must be heated to a point where the lacquer dries as rap-

idly as it is applied with a brush. The pulverized glass is used to shake down the impurities.

The double-spring, single-break interruptors, for the 4, 6, and 8-inch coils, are in all their proportions, excepting the length and thickness of the springs, exactly alike. The different parts are shown separately in Fig. 68 and assembled in Fig. 69, while in Table XXI will be found the necessary dimensions.

TABLE XXI.

Sizes of Parts for Double-Spring Single-Break Interruptors.

		Dimensions, Front and Rear Elevation. Inches.		Dimensions Side Elevation. Inches.	
	Height.	Top.	Base.	Top.	Base.
Standard	2⅞	¼	1⅛	⅜	1½
	Length.	Diameter of Screw.		Diameter of Milled Head.	
Contact Adjusting Screw	5/16		3/16	¾	
	Length.	Diameter.			
Platinum Wire for Adjusting Screw	¼	⅛			
	Length.	Width.	Thickness.		
Brass Support for Contact Spring	1	½	¼		
	Length.	Width.	Thickness.	NOTE: 3/32 inch hole drilled in contact end ⅛ inch from top, ⅛ inch hole drilled in fixed end ¼ inch from bottom.	
Steel Contact Spring	2¾	⅜	1/64		
	Length.	Width.	Thickness.		
Brass Support for Armature Spring	1¼	½	⅞		

Sizes of Parts for Double-Spring Single-Break Interruptors (Continued).

	For 4 Inch Coil.			For 6 Inch Coil.			For 8 Inch Coil.		
	Length.	Width.	Thickness.	Length.	Width.	Thickness.	Length.	Width.	Thickness.
*Armature Springs......	5	$\frac{1}{2}$	$\frac{1}{16}$	6	$\frac{9}{16}$	$\frac{1}{16}$	7	$\frac{5}{8}$	$\frac{1}{16}$
Hard Rubber Plates.....	$2\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{16}$	$3\frac{3}{4}$	$\frac{9}{16}$	$\frac{3}{16}$	$4\frac{3}{4}$	$\frac{5}{8}$	$\frac{3}{16}$

	For 4 Inch Coil.		For 6 Inch Coil.		For 8 Inch Coil.	
	Diameter.	Thickness.	Diameter.	Thickness.	Diameter.	Thickness.
Soft Iron Disk Armature............	1	$\frac{5}{8}$	$1\frac{1}{4}$	$\frac{3}{4}$	$1\frac{1}{2}$	1
	Diameter.	Thickness.	Diameter.	Thickness.	Diameter.	Thickness.
Disk Screw for Armatures.........	1	$\frac{1}{2}$	$1\frac{1}{4}$	$\frac{5}{8}$	$1\frac{1}{2}$	$\frac{3}{4}$

	Length.	Width.	Thickness.
Hard Rubber Base.	$4\frac{1}{2}$	3	$\frac{1}{2}$

* NOTE: $\frac{1}{8}$ inch hole drilled in armature end so that periphery of armature is flush with top. $\frac{1}{8}$ inch hole drilled in fixed end $\frac{3}{16}$ inch from base. $\frac{1}{4}$ inch hole drilled $2\frac{5}{8}$ inches from + base.

The standard is of cast brass finished in lacquer. A hole is drilled through the top, which is slotted, for the adjusting screw; two holes are drilled and tapped in the bottom of the standard and the base, so that the former will set on the latter $\frac{5}{8}$ inch from one end, $2\frac{1}{4}$ inches from the opposite end, and $\frac{3}{4}$ inch from either side. The contact spring carries a nut on both sides of its free end, and in the inner one a platinum wire is screwed; in the outer nut and halfway in the inner one—the spring is between them—is screwed a wire connection; the free end of the connecting wire projects through the hole in the armature spring and the stiffening brace of hard rubber; the end of the wire is tapped, and on it two nuts, one of them of hard rubber and one of brass, are screwed.

The springs are screwed to their respective supporting

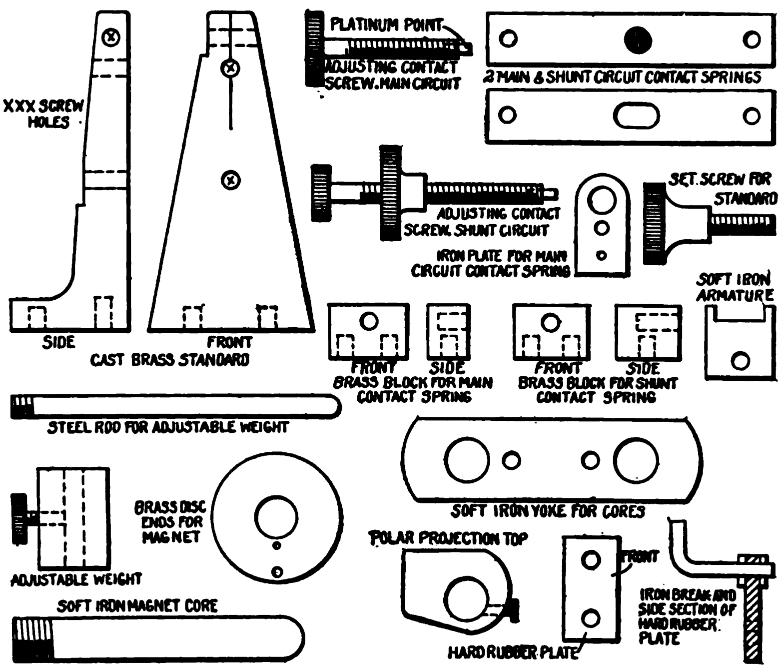


FIG. 70.—PARTS OF INDEPENDENT INTERRUPTOR.

brass blocks, and these in turn as well as the standard are secured to the base, holes having been drilled through the base and drilled and tapped in the blocks for the purpose. The contact spring should stand parallel and in a line with the face of the standard, and at a distance of ½ inch in front of it, while the spring carrying the armature should be mounted ½ inch in front of the contact spring. This will bring the armature disk very nearly in a line with the end of the base and in a position where it can be

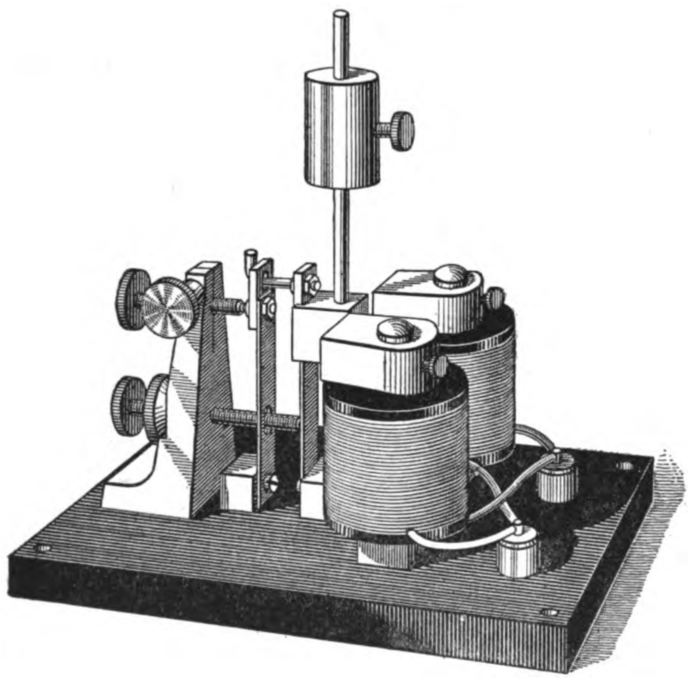


FIG. 71.—INDEPENDENT INTERRUPTOR ASSEMBLED.

placed conveniently near the polar projection of the core of the coil. To one of the screws holding the standard to the base a heavy wire is led off, the opposite terminal being connected with the screw holding the support of the contact spring in position.

Since the independent interruptor does not depend on the magnetization of the core for its operation, it is particularly well adapted for use with large coils, and many manufacturers are equipping the intermediate sizes with them. Different from the double-spring, single-break type just described, it may be used in connection with all sized coils without modifying any of its parts. The individual parts of the device are shown in Fig. 70 and collectively in Fig. 71, while the dimensions may be obtained from Table XXII.

TABLE XXII.

Dimensions of Parts for Independent Interruptor.

		Dimensions, Front and Rear Elevations. Inches.		Dimensions, Side Elevation. Inches.	
	Height.	Top.	Base.	Top.	Base.
[1] Standard	3	1/4	1 1/8	3/8	1 1/2
	Length.	Diameter.	Diameter of Milled Head.	Diameter of Check Nut.	
[2] Adjusting Contact Screw for Main Circuit	1 1/2	3/16	5/8	7/8	
	For Main Circuit Screw.			For Shunt Circuit Screw.	
	Diameter.	Length.		Length.	Diameter.
Platinum Contact Points for Adjusting Screws.	1/8	1/4		3/16	1/16
	Length.	Diameter.	Diameter of Milled Head.	Diameter of Check Nut.	
Adjusting Contact Screw for Shunt Circuit	2 1/4	3/16	1/2	7/8	

[1] 3/16 inch hole drilled and tapped from face to back 1/2 inch from top. Ditto 1 1/8 inches from bottom. 1/8 inch hole drilled and tapped through on side 1/4 inch from top.

[2] End drilled and tapped out and platinum point inserted.

Dimensions of Parts for Independent Interruptor (Continued).

	Length.	Width.	Thickness.		
[3] Main Circuit Contact Spring..............	$2\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{32}$		
	Length.	Width.	Thickness.		
[4] Iron Plate for Main Circuit Contact Spring	1	$\frac{1}{2}$	$\frac{3}{32}$		
	Length of Screw.	Diameter of Screw.	Diameter of Milled Head.		
Set Screw for Standard ..	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{3}{4}$		
	Length.	Width.	Thickness.		
[5] Shunt Circuit Contact Spring......	$2\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{32}$		
[6] Brass Block for Main Contact Spring.......	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{2}$		
[7] Brass Block for Shunt Contact Spring......	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{2}$		
[8] Soft Iron Armature....	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$		

[3] Spring is of steel. $\frac{1}{8}$ inch hole drilled and tapped $\frac{1}{4}$ inch from each end; $\frac{1}{4}$ inch hole cut out $1\frac{1}{8}$ inches from bottom.

[4] Rounded top. $\frac{1}{4}$ inch hole drilled $\frac{1}{4}$ inch from top. $\frac{1}{8}$ inch hole drilled and tapped $\frac{9}{16}$ inch from top. $\frac{1}{16}$ inch hole drilled and tapped $\frac{1}{16}$ inch from bottom; screw is turned with a shoulder making its total length $1\frac{1}{4}$ inches.

[5] $\frac{1}{8}$ inch hole drilled $\frac{1}{4}$ inch from each end. Platinum contact disk soldered to the spring $1\frac{1}{8}$ inches from bottom.

[6] $\frac{1}{8}$ inch hole drilled and tapped in center of side. Ditto in bottom.

[7] $\frac{1}{8}$ inch hole in side and bottom as above.

[8] Slotted to depth. $\frac{1}{8}$ inch on one side and $\frac{1}{8}$ inch across, to receive spring. $\frac{1}{8}$ inch hole drilled in center of slotted side. $\frac{1}{8}$ inch hole drilled and $\frac{1}{8}$ tapped in top $\frac{1}{16}$ of edge opposite slot.

Dimensions of Parts for Independent Interruptor (Continued).

	Length.	Diameter.			
Steel Rod for Carrying Sliding Weight ...	8	3/16			
		Diameter.			
[9] Sliding Weight........	1	3/4			
[10] Soft Iron Magnet Cores (2).............	2 3/4	3/8			
				Distance from Core Ends.	
	Outside Diameter.	Diameter of Aperture.	Thickness.	Tapped End	Rounded End.
[11] Brass Disk ends for Magnet Cores (4).....	1 1/4	3/8	1/16	5/8	3/4
	Length.	Width.	Thickness.		
[12] Soft Iron Yoke for Cores	2 7/8	3/4	1/2		
				Polar Ends.	
[13] Polar Projections.	1	From 5/8 at polar end to 3/4 at rounded end.	5/8	5/8 x 5/8	
	No.	Amount.	Number of turns on each spool. (Approx.)		
Wire for Magnet (Double Cotton Covered).....	26	6 ounces	1300		

[9] Hole 3/16 inch drilled longitudinally through center. 1/8 inch hole drilled and tapped at right angles to above hole until they meet; this is for set screw.

[10] Threads cut on one end; other end rounded.

[11] 1/32 inch holes drilled in two lower disks, one within 1/32 inch of aperture, the other same distance from edge. The magnet wire passes through these.

[12] Holes drilled and tapped 5/8 inch from each end to receive magnet cores. 1/8 inch holes near middle to screw yoke to base.

[13] 3/8 inch hole drilled through from top to bottom 5/8 inch from polar end 1/8 inch hole drilled and tapped for set screw in rounded end. This permits poles to be adjusted.

Dimensions of Parts for Independent Interruptor (Continued).

	Length.	Width.	Thickness.		
Hard Rubber Base.......	6	8½	½		
[14] Hard Rubber Plate for Armature of Shunt Circuit.........	⅞	½	⅛		
	Length.	Diameter.			
[15] Iron Break Rod.......	¾	⅛			

[14] ⅛ inch hole drilled 3/16 inch from bottom. Litto 3/32 inch from top.
[15] Bent up at one end ¼ inch. End of longest portion threaded.

When all of the above parts have been prepared, the interruptor may be assembled. To one end of the main contact spring, which is the thin one, the iron plate is secured by means of ⅛-inch screw and a nut 3/16 inch thick; the length of the screw is such that the nut projects 3/32 inch over its end, and into this is screwed and soldered the platinum contact point. A small screw passes through the spring and into the plate to keep the latter from turning. This leaves the end of the plate with the large hole projecting above the end of the spring, while the opposite end is screwed to its brass support, and the latter to the hard-rubber base; it should set at a distance of 2¼ inches from one end of the latter and 1½ inches from either side.

The shunt circuit spring is placed in the groove of the cubical armature, and on the opposite side of the spring, and likewise mounted in the groove with it, is the hard-rubber plate, when the three pieces are screwed together.

The bent iron break rod with a stop nut screwed on it $\frac{5}{16}$ inch is then inserted through the upper hole in the hard-rubber plate, which projects above the armature, and this is rigidly attached by a nut on the opposite side. In the top of the armature the brass rod for carrying the adjustable weight is screwed. The lower end of the spring is then screwed to its brass block support, and the latter in turn to the hard-rubber base, when the spring should set ½ inch in front of the shunt circuit spring, or 2¾ inches from the front end. To the screw holding the support of the spring to the base a few inches of insulated wire, about No. 16, is connected, as this is a portion of the shunt circuit.

The standard is secured to the base by two screws, and the face of this should be exactly ½ inch back of the main circuit contact spring, or 2 inches from the front of the base. To one of the screws, a No. 12 insulated wire is attached, having a length of several inches, for the current for both the main and shunt circuits passes through it. Into the extreme upper hole on the side of the standard the set screw is inserted, and in the hole just below and at right angles to it is inserted the adjusting contact screw of the main circuit break. Into the lower hole the adjusting contact screw is inserted and screwed in, so that it passes through the aperture in the main circuit spring—but care must be taken that it clears the spring, or otherwise the interruptor will be short-circuited—until it makes contact with the platinum disk soldered to the shunt-circuit spring.

The yoke of the magnet is screwed to the base; and assuming the magnet coils have been wound—and it may here be said that if double cotton-covered magnet wire is used, there is no necessity for shellacking the layers—the cores of the magnet are screwed into the yoke, and the polar projection slipped over the upper ends of the cores, which should be adjusted so that when the spring carrying the armature is drawn to the magnet, the cube of soft iron forming it will pass between them without touching either of the poles. This precludes the possibility of the armature sticking to the magnet.

The binding posts are screwed into their respective holes in the end of the base, and from these underneath are connected terminals of No. 16 insulated wire. The terminals of the magnet between the coils and the posts are protected by rubber tubing, and are connected in parallel instead of in series, so both ends of each coil are brought out and the two outer ends are connected to the posts nearest them, while the two inner ends are crossed over and connected to the posts. The interruptor is now ready for use.

In double-spring interruptors the break is much more sudden than in the single-spring type. This is due to the fact that the armature and weight are carried on the thick spring and the main circuit contact on the thin spring. With this arrangement, when the armature is drawing toward the magnets, the iron break rod does not begin to pull the contacts of the main circuit apart until the armature has gotten under full speed. The momentum of the armature by this time is so great that it precludes the possibility of the platinum contacts, which are sometimes welded together by the heavy current, from sticking, as they do when the break is dependent on the magnetic pull alone where a single spring is used.

CHAPTER XI.

BUILDING UP THE CONDENSER.

The effectiveness and efficiency of a coil depend equally as much upon the condenser connected across the make and break contacts as upon the inductor, the secondary, and the interruptor. If the condenser is poorly made, or if it has too large or too small a value, as a reference to the theory of its operation will show, the spark length of the coil will be greatly reduced.

For the smaller-sized coils the making of a condenser is a very simple matter, since it is only necessary to use any kind of paper that is free from pinholes; but for the intermediate-sized coils, if paper is used as the dielectric, it must be carefully treated and the condenser built up and insulated, so that every particle of air is excluded. For the two largest coils, it is advisable to use mica condensers, and it is desirable that these should be adjustable.

The exact size of the condenser for a coil of given spark length is, like the determination of the amount of wire for a secondary, best obtained by building up the device in sections and trying them out with the interruptor and source of electromotive force it is intended to use. The following table will, however, give the sizes of the sheets of paper and of the tinfoil as well as a fair approximation of the number required for the ½, 1, and 2-inch coils:

TABLE XXIII.

Sizes of Condensers for Small Coils.

Spark Length of Coil, Inches.	Size of Sheets of Tinfoil, Inches.		Size of Sheets of Paper, Ins.		Number of Sheets of Tinfoil.	Number of Sheets of Paper.	Capacity (Approximate).	Amount of Tinfoil Required in Lbs.	Square Inches of Surface.
	Length.	Width.	Length.	Width.					
1/2	7 1/2	2 1/2	7 1/4	3	80	166	1/3	1/2	1500
1	10	3 1/8	9 1/2	4	120	246	1/2	1, 2oz.	3750
2	12	4 1/2	11 1/2	5 3/4	150	306	1	2, 7oz.	8100

In condensers for induction coils, the sheets of tinfoil alternate in position, as shown in Fig. 72; that is, the end

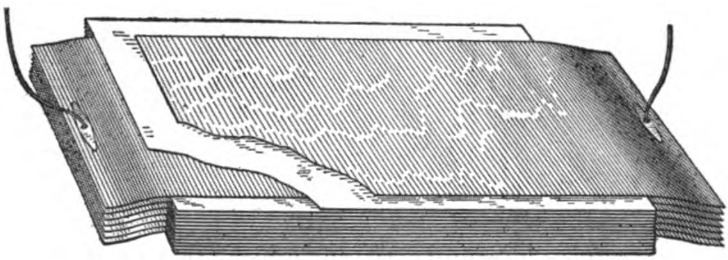


FIG. 72.—PAPER AND TINFOIL CONDENSER.

of the first sheet projects over the paper dielectric to the right, while the next sheet of foil projects over the intervening paper to the left. By building up the condenser in this manner, each of the alternate sheets of foil is insulated from the next adjacent one by a sheet of paper with a goodly margin, when all of those projecting from the right are coupled together, and all of those of the left are likewise attached to each other.

For the ½-inch coil the dielectric may be made of thin writing paper free from pinholes and thoroughly dried out; it need not be further treated. When the condenser is completed, it may be held intact by slipping rubber bands around it. For the 1 and 2-inch coils a good typewriting paper impregnated with paraffin may be used, and the condenser held firmly together with tape bound around it in two or three places. The capacity of a condenser made with paraffined paper will increase in value per square foot of surface area as against a condenser made with plain paper, for paraffin has a higher dielectric constant than air, which fills the pores of the former. Paper that has been treated with the beeswax and rosin compound is even better, while mica, in virtue of its high dielectric constant and the exceeding thinness of the plates that may be stripped off, is the best known for this purpose. The following table will show the difference in the values of some of the substances used as dielectrics in condensers:

TABLE XXIV.

Inductivities of Dielectric Constants.

Air	1.00
Paraffin (solid)	1.68 to 2.30
Beeswax	1.86
Rosin	1.95
Petroleum	2.00 to 2.25
Paraffin Oil	2.71
Shellac	2.95 to 3.60
Olive Oil	3.58
Glass	3.00 to 10.00
Mica	4.00 to 8.00
Castor Oil	4.97

A method for building up paper condensers that practically precludes the possibility of forgetting to alternate the sheets of tinfoil is to divide the total number of sheets into two equal portions. One of the ends of each lot is folded over ¼ inch, and this is repeated two or three times until the divided portions assume a book-like form, as in Fig. 73. The papers having been cut and paraffined, it is only necessary to place the books of foil on either side, lay two sheets of the prepared paper between them, and turn a sheet of foil from the right-hand book over on it, leaving a margin of an inch on the free edge, place two

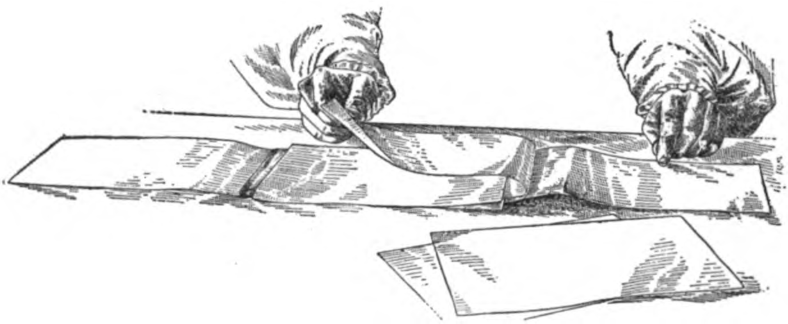


FIG. 73.—MAKING A SIMPLE CONDENSER.

more sheets of paper over it, and then turn a sheet of foil over and on top of the latter from the left-hand book, and so on until the condenser is completely built up. Care must be exercised in placing the sheets of paper and the foil evenly, so that the margins will be equal on both sides.

For the intermediate-sized coils paraffin may likewise be used to increase the inductive capacity as well as to strengthen the paper, but here again beeswax and rosin in equal proportions, or in the ratio of 1 part of the first and 3 of the second substance, is preferable, the last-named formula to be used where economy is an object. In any case, the paper sheets should be thoroughly dried out prior to immersing them in the bath. The method employed for drying may be either of those indicated for similarly treating the secondary wire, namely, in an oven or in a bell jar with chloride of calcium.

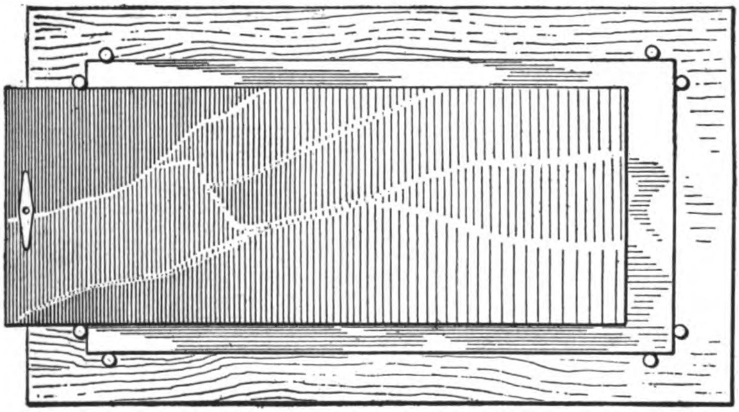


FIG. 74.—DEVICE FOR BUILDING UP A CONDENSER.

A couple of sheets at a time should be removed from the drying chamber and plunged into the melted substance. They should remain there until thoroughly impregnated, then withdrawn and permitted to drain for a moment, when they are placed between the guide rods formed of tin, brass, or wood screwed to a baseboard, as shown in Fig. 74, and a sheet of tinfoil is turned over it and pressed down with the smooth edge of a rule. Two more papers are prepared, laid on top of the foil, and another sheet of the foil from the opposite side is brought into position.

The whole condenser should be built up as rapidly as possible, and when the requisite number have been laid, a board one inch thick is placed on top, when the wood screws are put on; but before any pressure is exerted, the edges of the condenser are brushed over with the melted insulation, so that every crevice is filled with it, and the screws are screwed down tight. The pressure will exclude almost if not quite all the air, and the condenser will, when the screws are removed, be a hard and integrate mass. This type of condenser may be further improved by building it up in the manner to be presently described for the making of mica condensers. The dimensions of the sheets of tinfoil and paper suitable for the intermediate sizes of coils are given in the succeeding table:

TABLE XXV.

Sizes of Condensers for Intermediate Coils.

Spark Length of Coil, Inches.	Size of Sheets of Tinfoil, Inches.		Size of Sheets of Paper, Ins.		Number of Sheets of Tinfoil.	Number of Sheets of Paper.	Square Inches of Surface.	Capacity (Approximate).	Amount of Tinfoil Required in Lbs.	Approximate Weight.
	Length.	Width.	Length.	Width.					lb. oz.	lb. oz.
4	5½	3½	6	4	300	606	5775	1½	1 1	1 14
6	5½	3½	6	4	500	1006	9625	2	1 12	3 3
8	5½	3½	6	4	800	1600	15400	2½	2 13	5 2

CHAPTER XII.

ADJUSTABLE MICA CONDENSERS.

In the 10 and 12-inch coils, especially where these are designed for heavy duty, mica condensers should be used if possible, and these should be made adjustable. Mica condensers are usually made in very small sizes, not only because this laminated mineral has a high dielectric capacity, but for the reason that its price rapidly runs up as the size of the plates increases.

A good size to use for induction coils is made of plate mica about 3 x 3 or 3 x 4 inches square, since smaller sizes require much more labor to build them, while the larger sizes are prohibitively expensive. The sizes of plate mica are given in the abridged table below, but intermediate sizes can be obtained, as there are about three hundred different sizes quoted by dealers; and beginning at the smallest size, each half inch adds from 25 to 50 cents per pound to its value.

A fairly good plate may be obtained that bears the trade name of *electric mica,* but it is not nearly as clear as the better grade, though it is much used nevertheless by manufacturing electricians, owing to the fact that it is quite cheap, selling as it does for from 50 cents to $2.50 per pound. Good mica can be split into sheets as thin as $\frac{1}{1000}$ of an inch, and it must be borne in mind that the nearer the sheets of foil are placed together, i. e., the thinner the insulating medium between them, the greater will be the capacity of the condenser.

TABLE XXVI.

Sizes and Amount of Plate Mica.

Size of Plates in Inches.	Approximate Number of Sheets per Pound.	Size of Plates in Inches.	Approximate Number of Sheets per Pound.
1 × 4	1350	6 × 6...........	150
2 × 4.............	675	8 × 8	85
3 × 3.............	610	8 × 10	68
4 × 4	338	10 × 12..........	55
5 × 5	216		

To build up a mica condenser having a capacity of one microfarad, about 3,500 square inches of tinfoil are required, the exact surface area depending of course upon the thickness of the mica plates separating them. If the plates of mica are 3 x 4 inches, and the sheets of tinfoil are 2½ x 3¾, then it will require 466 sheets of tinfoil, each having 7½ square inches of surface, to build up a condenser of one microfarad capacity. In the 10 and 12-inch coils, the safest plan is to provide each with a condenser having a capacity of five microfarads, and to subdivide this into ten sections, hence each section will require 233 sheets of foil if the fractions are neglected. Table XXVII. summarizes the above figures.

TABLE XXVII.

Summarized Data for a 5-Microfarad Condenser for 10 and 12-inch Coils.

Total capacity	5 microfarads
No. of sub-divisions	10
Size of mica plates	3 x 4 inches
Total No. of mica plates	2,340
No. of mica plates in each sub-division	234
No. of pounds of mica required	5 pounds
Size of tinfoil sheets	2½ x 3¾
No. of square inches in each sheet of foil	7½
No. of sheets of foil required for 1 microfarad	466
Total No. of sheets of foil required	2,330
Total No. of sheets of foil required in each sub-division	233
No. of pounds of tin foil required	4 pounds 6 ounces

The easiest and most effectual method for making a good condenser is to take the requisite number of mica plates and tinfoil sheets and build them up alternately as previously described, but with even greater care, for each sheet of foil must be exactly ¼ inch from the edges of the mica, except that edge where it is connected with its complementary sheets.

The section of the condenser is then laid flat on a thin board in a small tin pan having a height of an inch or less. In one end of the pan a tin spout ½ inch in diameter is soldered, and this is fitted with a cork. On top of the condenser a smooth board thick enough to extend above the edges of the pan by ¼ inch should be placed, and a weight of 2 or 3 pounds—a flatiron will answer admirably—set on top of this. In the pan, which should be kept moderately heated by means of a Bunsen burner or a stove, the insulating compound of rosin and beeswax, which has been brought to a high state of fluidity, is poured in the pan and around the condenser, where it is permitted to remain until it has soaked in all the spaces. It is then drawn off through the spout. This done, the pan with the condenser in it, the latter being thoroughly heated throughout, is placed in a letter press, as shown in Fig. 75, and as great a pressure applied as may be practicable. If a letter press

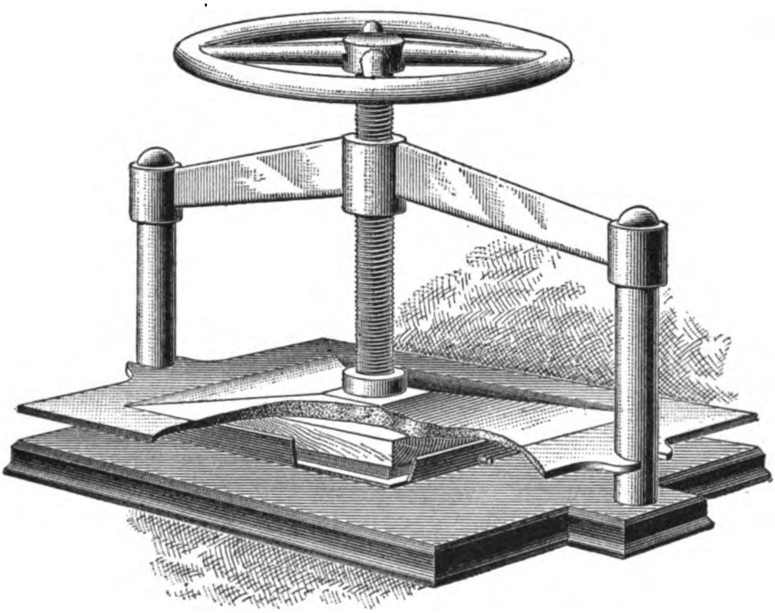


FIG. 75.—SECTION OF CONDENSER IN PRESS.

is not available, then cabinet maker's wood screws may be resorted to.

After the compound has set and is perfectly cold, the condenser may be removed, when it will be found to be a hard and compact body. The opposite edges of the tinfoil are soldered together with a number of short lengths of wire for the terminals. When ten of these sections have been thus prepared, they are ready to be mounted, and to make the condenser adjustable, the sections are secured in a box that is usually screwed on the base of the coil, and one of the two following arrangements is provided.

In Fig. 76 the first arrangement is shown, and this also serves to illustrate how the sections are connected in paral-

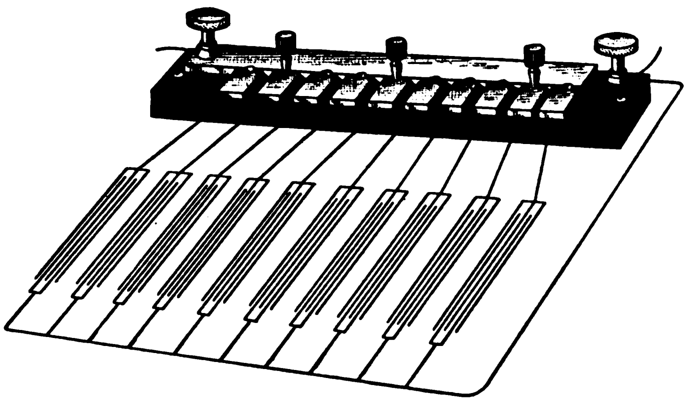


FIG. 76.—ADJUSTABLE BLOCK AND PLUG CONDENSER.

lel, and when thus arranged, the total capacity of the condenser is equal to the sum of the capacities of each individual section. On top of the condenser box, which should measure 6 x 6 x 10 inches outside, a hard-rubber bedplate 6½ inches long, 1½ inches wide, and ½ inch thick is drilled and mounted to receive a brass bar 6⅛ inches long, ½ inch wide, and $\frac{5}{16}$ inch thick and having ten semicircular arcs cut out on the side at equidistant points, and which is screwed to it. To one end of this bar is attached a binding post. Opposite each arc in the bar is a block of brass $\frac{1}{2}$ inch in length, $\frac{5}{16}$ inch thick, and these likewise have arcs cut out on their sides, so that when the blocks are oppositely disposed, a hole is formed that is $\frac{7}{32}$ of an inch in diameter, and tapered down to $\frac{3}{16}$ inch at the bottom. Tapering plugs are provided that are $\frac{3}{16}$ inch diameter at the extreme end and $\frac{1}{4}$ inch at the shoulder, carrying a screw end to which is fitted a hard-rubber cap $\frac{7}{16}$ inch in diameter and $\frac{1}{2}$ inch in length.

TABLE XXVIII.

Sizes of Parts for Adjustable Plug Condenser.

	Length, Inches.	Width, Inches.	Thickness, Inches
Hard rubber bed plate.	$6\frac{1}{2}$	$1\frac{1}{2}$	$\frac{1}{2}$
Brass bar	$6\frac{1}{8}$	$\frac{1}{2}$	$\frac{6}{16}$
Brass blocks (ten)	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{16}$
	Diameter at Extreme End.	Diameter at Shoulder.	Length of Screw End.
Tapering plugs	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{1}{4}$
	Diameter.	Length.	
Hard rubber caps.	$\frac{7}{16}$	$\frac{1}{2}$	..

The condenser sections are connected to their respective brass blocks on one side, while the opposite sheets of foil of all the sections lead to a binding post on the box. It is obvious that if $\frac{1}{2}$ microfarad is desired, it is only necessary to put a plug in the first hole which connects in the first condenser between the binding posts, all the other sections being out of circuit. In a like manner a part or all of the sections may be brought into active service by plugging up the other holes, and hence to obtain the proper value of capacity for the operation of the coil, it is only necessary to insert or remove the plugs.

The sections are mounted in the box by building them in

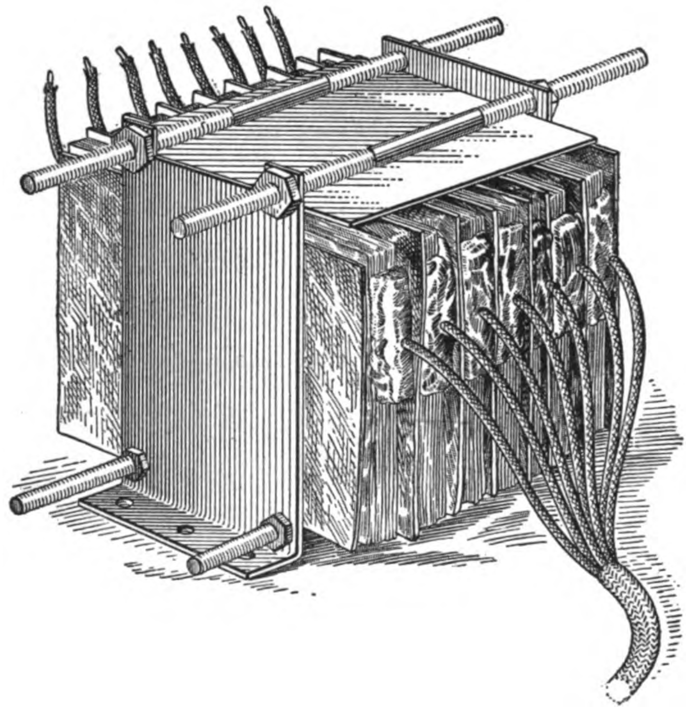


FIG. 77.—SECTIONS OF MICA CONDENSER IN BRASS FRAME.

a pile with partitions of hard rubber or pasteboard impregnated with insulating compound between them, and securing them in a brass frame as shown in Fig. 77. The latter, it will be observed, is arranged so that it can be screwed to the bottom of the box, and this avoids all possible danger from mechanical jars.

Another scheme for adjusting the capacity of a condenser, and one that is largely used by manufacturers in America, is by means of a revolving switch, the different parts of which are shown in Figs. 78 to 85, but which will

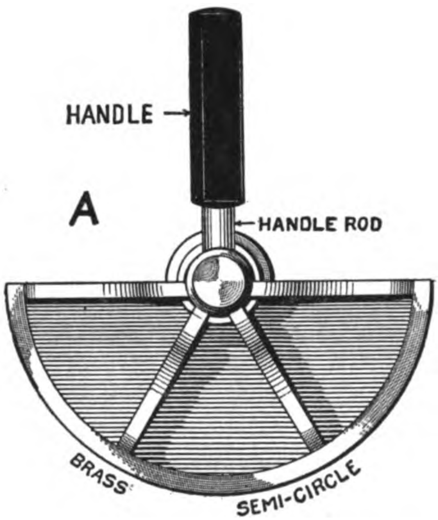


FIG. 78.—CONTACT PLATE OF REVOLVING SWITCH. TOP VIEW.

be designated, for the sake of lucidity, by the letters *A, B, C, D, E, F, G,* and *H* respectively. It may be constructed by procuring a semicircle of brass $3\frac{1}{4}$ inches in diameter, $\frac{1}{8}$ inch thick at the circumference and $\frac{5}{8}$ inch thick at the axis. This may be made of thick sheet brass, though it is usually formed of brass cast from a pattern and faced on its lower surface and upper side at right angles to its axis; to the latter a brass rod 1¼ inches in length and ½ inch in diameter is screwed to a depth of ¼ inch, and into this at right angles to it and to the straight edge of the brass semicircle, ½ inch from the end,

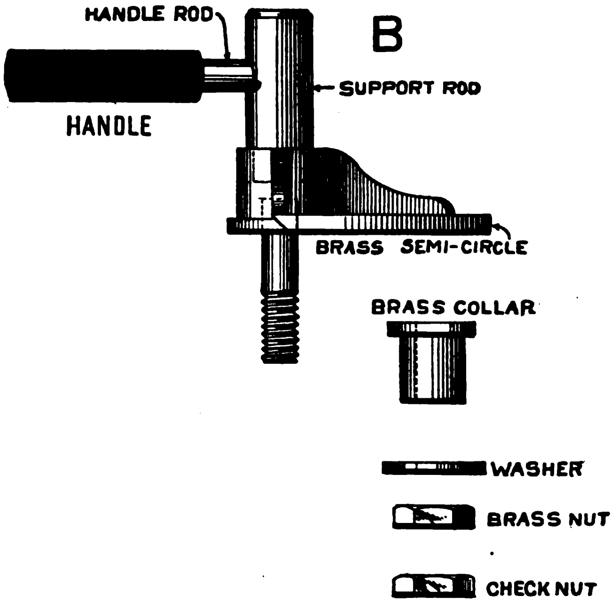


FIG. 79.—CONTACT PLATE OF REVOLVING SWITCH. SIDE ELEVATION.

a brass rod 1⅛ inches in length is screwed in to a depth of ¼ inch, while on its opposite end is screwed a bar of hard rubber 1½ inches in length, ⅜ inch in diameter, and rounded at the ends, thus forming a handle. On the under side and in line with its axis a brass spindle 1¼ inches long, ¼ inch in diameter, and tapped on both ends is screwed to a depth of ¼ inch. This part of the switch is shown assembled at *A* and *B*.

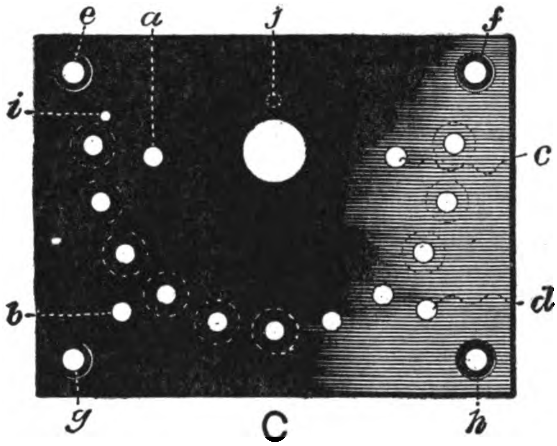


FIG. 80.—HARD RUBBER BLOCK OF REVOLVING SWITCH. TOP VIEW.

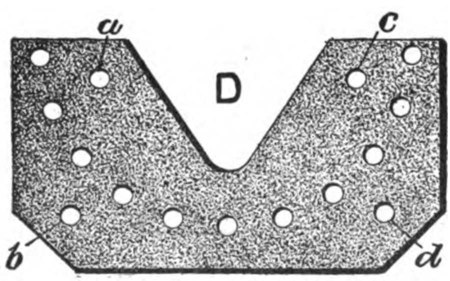


FIG. 81.—HARD FIBER PLATE. TOP VIEW.

A hard-rubber bed block 3⅝ inches long, 2¾ inches wide, and ½ inch thick is prepared by drilling a hole ½ inch in diameter 1 13/16 inches from either end and ⅞ inch from one of the sides. Into this hole a brass collar is fitted, and this has a hole drilled through it 1/4 inch in diameter and through which the rod carrying the semicircle of brass is rotated. From the center of this bearing the arc of a circle is struck, the radius being 1 3/8 inches. Ten holes 5/16 inch in diameter are drilled in the bottom on the line of the arc, 7/16 inch apart, until a depth of 3/8

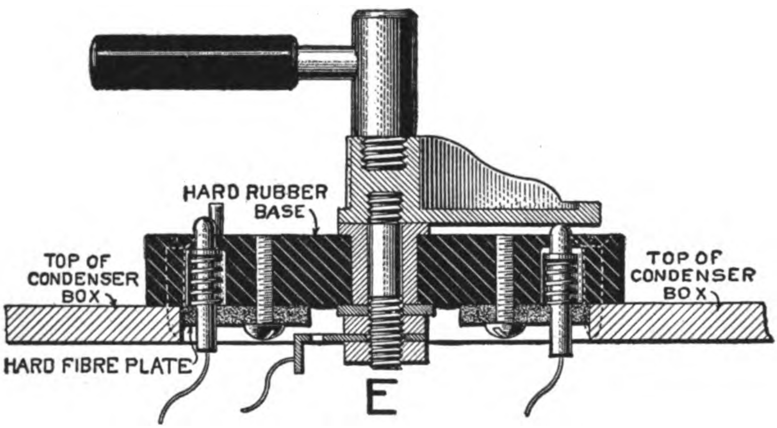


FIG. 82.—CROSS SECTION OF REVOLVING SWITCH.

inch is reached, when a drill 5/32 inch is used on through, Four holes 1/8 inch in diameter are drilled and tapped to fit 1/8-inch screws at points marked *a, b, c, d,* and four holes 5/32 inch in diameter are drilled at *e, f, g, h.* A brass pin 3/8 inch in length and 3/32 inch in diameter is set in on top of the block at *i,* while on the bottom a pin is set in at *j.* A top view of this block is shown in *C,* Fig. 80.

A piece of hard rubber, or preferably of hard fiber, as it is termed, and which is not so easily broken, $3\frac{1}{8}$ inches long, $1\frac{3}{4}$ inches wide, and $\frac{1}{8}$ inch thick, has ten holes cut through on the line of arc of the same radius, diameter, and distance apart as those in the hard-rubber block, and four other holes corresponding to those designated as *a, b,*

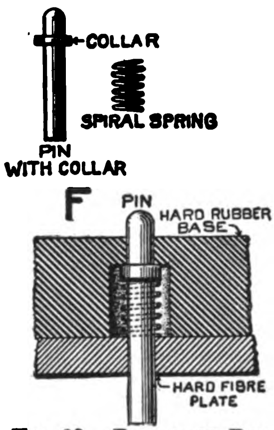


FIG. 83.—DETAIL OF PIN AND SPRING.

FIG. 85.—ANGLE PLATE.

FIG. 84.—PLAN VIEW OF HARD FIBER PLATE IN COVER OF BOX.

c, d are drilled, all of which are $\frac{5}{32}$ inch in diameter. This piece is shown at *D,* Fig. 81. Ten pins, each of which is 1 inch long and $\frac{9}{64}$ inch in diameter, so that it will slide through the holes intended for it in the hard-rubber block and fiber plate, is provided with a brass collar, $\frac{1}{4}$ inch in diameter and $\frac{1}{16}$ inch thick, soldered $\frac{5}{16}$ inch from its rounded, or top, end. A compressional spiral spring, $\frac{1}{4}$

inch in diameter and ⅜ inch in length, is slipped over the long part of the pin when the ends are inserted through the holes in the fiber plate as shown in the cross-section *E*, Fig. 82, and in detailed drawing *F*, Fig. 83. To the end of each pin projecting through the plate a flexible insulated wire conductor, say 8 inches in length, is soldered, the opposite end being connected with one side of one of the sections of the condenser; all of the opposite sides of the sections are connected together by means of a flexible conductor. The top of the box has a hole cut through its center, 3¼ inches long and 1¼ inches wide, as shown at *G*, Fig. 84.

TABLE XXIX.

Sizes of Parts for Revolving Switch.

	Diameter, Inches.	Thickness at Circumference, Inches.	Thickness of Axis.
Brass Semicircle	3¼	⅛	⅝
Brass Support Rod	¼	Length. 1¼	..
Brass Handle Rod	¼	1⅛	..
Hard Rubber Handle	⅜	1½	..
Brass Spindle Rod	½	1¼	..
Hard Rubber Bed Block	Width. 2¾	3⅝	Thickness. ½
Brass Collar	Diameter. ½	Diam. of Hole. ¼	½
Brass Stop Pins (2)	Length. ⅜	Diameter. $\frac{3}{32}$	..
Hard Fiber Plates	3⅛	Width. 1¾	⅛
Brass Contact Pins	1	$\frac{9}{64}$	
Brass Collar for Contact Pins	Diameter. ¼	Diam. of Hole. $\frac{9}{64}$	$\frac{1}{16}$
Brass Spiral Springs	Length. ⅜	¼	Number of Convolutions. 4
Brass Washer	Diameter. ¾	Thickness. $\frac{1}{16}$	..
Brass Angle Plate	Length. 1¼	Width. ½	Thickness. $\frac{1}{32}$

The revolving switch is now ready to be assembled. Over the rod of the rotating semi-circle of brass is slipped a brass washer, $\frac{3}{4}$ inch in diameter and $\frac{1}{16}$ inch thick, and the rod inserted in its bearing in the hard-rubber block. A brass angle plate shown at *H*, Fig. 85, and having a length before being bent into shape of $1\frac{1}{4}$ inches, a width of $\frac{1}{2}$ inch, having a hole $\frac{1}{4}$ inch in diameter drilled near its end and another $\frac{3}{32}$ inch in diameter, is drilled $\frac{3}{8}$ inch from the first. The large hole is placed over the rotating rod that projects through the hard-rubber block, while the small hole engages the pin. The plate and the brass contact semicircle are then secured in position by two nuts screwed to the rod. To the free end of the angle plate is soldered a flexible conductor, say 8 inches in length.

The hard-rubber block is then screwed to the top of the condenser box with $\frac{3}{4}$-inch wood screws, the holes having been countersunk so that the heads of the screws will be flush with the surface of the block. The pins carried by the hard-fiber plate are inserted through the semicircular rows of holes in the hard-rubber base, the plate being small enough so that it will set in the aperture cut in the top of the box; the shoulders on the pins prevent them from projecting entirely through, since the larger holes in the base are drilled to a depth of $\frac{3}{8}$ inch, while the ends of the pins are free to pass through the smaller holes that go entirely through. The spiral springs rest therefore between the shoulders of the springs on the one side and the hard-fiber plate on the other, and in this way it keeps the ends of the pins projecting beyond the face of the hard-rubber block $\frac{3}{16}$ inch when the switch is open. The fiber plate is attached to the bottom of the rubber block by four machine screws, 1/8 inch in diameter and 5/8 inch long.

When the semicircular brass contact plate is turned by means of the handle, its edge, which strikes the contact pins, being beveled, forces them down 1/8 of an inch against the action of the springs, the latter serving to force

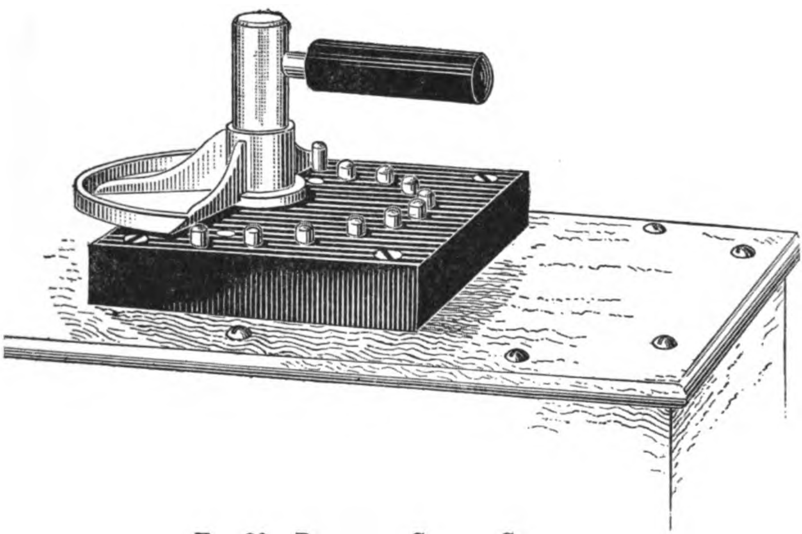


FIG. 86.—REVOLVING SWITCH COMPLETE.

the pins upward with considerable pressure, making good contacts with the rotating contact plate. The condensers are mounted in their box as previously described, but in this case the binding posts are inserted in the end of the box, the flexible conductor from the angle plate leading to one, and the sides of the sections of the condenser coupled together leading to the other. The binding posts or brass connectors should be uniform with those designated in

Table XI. for the sized coil the condenser is to be used with. When completed, the revolving switch presents a neat appearance, as shown in Fig. 86. A wiring diagram of the switch is given in Fig. 122.

CHAPTER XIII.

REVERSING SWITCHES AND COMMUTATORS.

A coil, however small, should be provided with a switch for making and breaking the primary circuit; and as it is often desirable to change the direction of the current through the inductor, it may be further improved by the employment of a reversing switch or commutator.

In nearly all small coils found in the open market the pole-changing switch is of the three-point pattern. In this switch there are two levers made of spring brass; in the larger end of each a $\frac{1}{8}$-inch hole is drilled and a $\frac{3}{32}$-inch hole $\frac{1}{2}$ inch from the small end. The levers are connected together by a bar of hard rubber, which is screwed to them through the small holes. The levers and the posts may be mounted on a base of hard rubber or directly on the bed of the induction coil. The posts are to be set into the base $\frac{5}{8}$ inch from each other, measuring from the centers, thus leaving a space of $\frac{1}{8}$ inch between them, while the centers of the large ends of the levers are mounted $\frac{5}{8}$ inch from each other. Fig. 87 shows the three-point switch assembled, while Table XXX. gives the sizes of the different parts.

A four-point switch is better than one with only three points, for in the former the current can be cut off as well

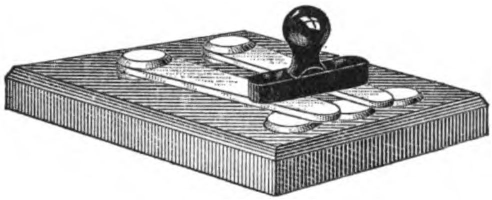


FIG. 87.—THREE POINT SWITCH.

as reversed. In this switch the points of each lever are placed 1 inch apart, and the two inside points ½ inch from center to center, while the pivotal points of the levers are 1½ inches center to center. The dimensions of the parts

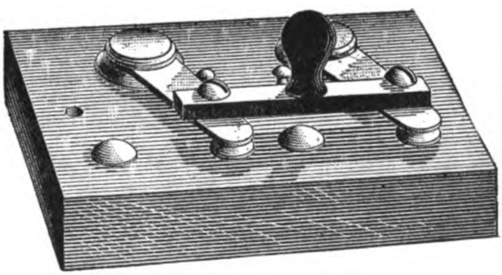


FIG. 88.—FOUR POINT SWITCH.

for this switch will likewise be found in Table XXX. One size of either the three or four-point switch will serve equally well for the ½, 1 and 2-inch coils. Fig. 88 illustrates a four-point switch complete.

TABLE XXX.

Sizes of Parts for 3- and 4-Point Switches.

	Length. Inches.	Width. Inches.		
Levers	$1\frac{5}{8}$	$\frac{1}{2}$ tapering to $\frac{3}{8}$	$\frac{1}{32}$	
Connecting Bar for 8-Point Switch	1	$\frac{3}{8}$	$\frac{1}{4}$	
Connecting Bar for 4-Point Switch	$1\frac{7}{8}$	$\frac{3}{8}$	$\frac{1}{4}$	
	Diameter of Heads.	Thickness of Head.	Diameter of Shanks.	Length of Shank.
Points	$\frac{3}{8}$	$\frac{1}{8}$ inch in center rounded to $\frac{1}{32}$ in circumference.	$\frac{3}{16}$	$\frac{1}{4}$ drilled and tapped.
	Diameter.	Diameter of Hole.	Thickness.	
Washers	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{8}$	
	Height.	Diameter.		
Thumb Screws	$\frac{5}{16}$	$\frac{3}{8}$	Milled heads, drilled and tapped base.	

For any of the intermediate and even the largest sized coils a double-throw double-pole knife switch shown in Fig. 89 is used; but as these can be purchased cheaper from supply dealers than they could possibly be made, a detailed description is not considered necessary. Suffice it to say that the contact blades are pivoted to the center posts and insulated from each other by a hard-rubber or fiber bar to which is attached a handle of the same material or of wood.

In Great Britain and on the Continent the reversing commutator devised by Ruhmkorff is used extensively on coils of every size from the smallest to the largest. It can be recommended for the 4-, 6-, and 8-inch coils as these are operated by interruptors working from the core of the coil. A commutator of the size given may be applied to any of the intermediate coils.

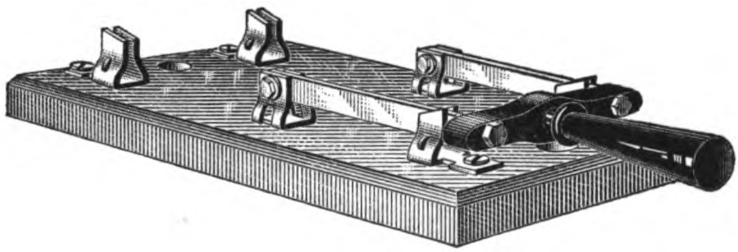


FIG. 89.—DOUBLE POLE DOUBLE THROW KNIFE SWITCH.

The device comprises a solid cylinder turned of hard rubber or wood, to which are screwed, in grooves cut on oppositely disposed sides, arcuated strips of brass. Each of the latter takes up about a quarter of the circumference

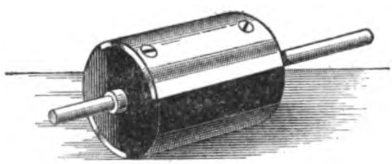


FIG. 90.—PERSPECTIVE VIEW OF REVOLVING ELEMENT.

of the cylinder, and they set in flush with its surface. On either end of the cylinder a short brass rod is screwed in forming a spindle, which in turn is supported by brass standards. To one of the ends of the spindle is attached a

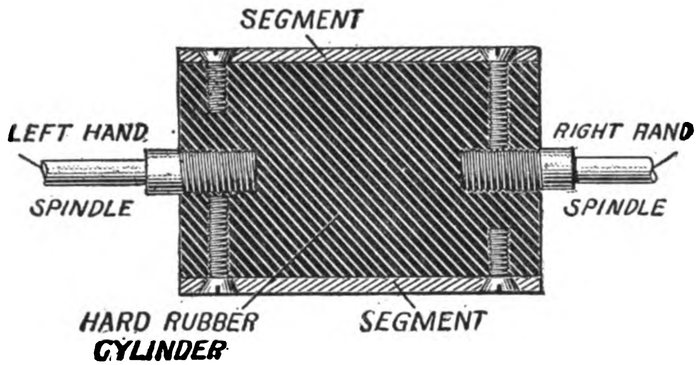


FIG. 90A.—CROSS SECTION OF COMMUTATOR.

handle, so that the cylinder can be rotated. On a line drawn at right angles to the axis of the cylinder are two spring brass brushes supported at the base by brass blocks, while the upper and free ends make contact with the arc-

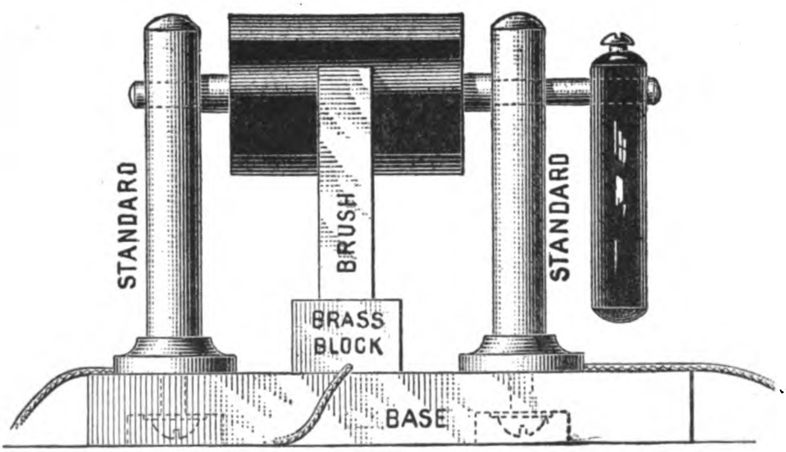


FIG. 91.—COMMUTATOR, FRONT ELEVATION.

uated brass strips or segments or with the surface of the cylinder as the case may be.

It will be observed by referring to the cross section, Fig. 90, that one of the brass strips is connected with one end

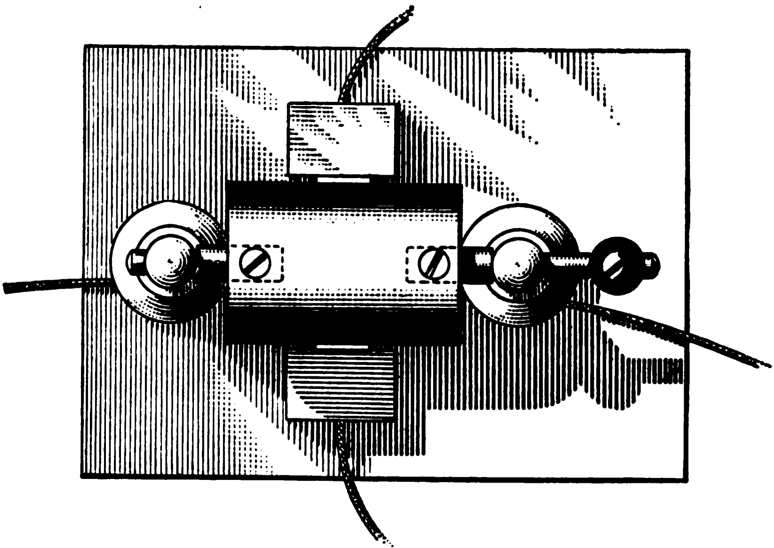


FIG. 92.—PLAN VIEW OF COMMUTATOR.

of the spindle, through one of the screws securing it to the rubber, while the opposite segment is likewise in connection with the opposite end of the spindle. The standards and the brass blocks may be secured directly to the bed of the coil or mounted on a hard-rubber base. A front elevation is shown in Fig. 91, a plan view in Fig. 92, and a perspective view in Fig. 93, while the dimensions may be ascertained from Table XXXI.

TABLE XXXI.

Sizes of Parts for Commutator.

	Length. Inches.	Diameter. Inches.		
Hard Rubber Cylinder.	$1\frac{5}{8}$	$1\frac{1}{8}$		$\frac{1}{4}$ inch holes drilled $\frac{3}{8}$ in. deep in both ends, and tapped.
Brass Commutator Segments (2)	Length. $1\frac{5}{8}$	Width. $\frac{7}{8}$	Thickness. $\frac{1}{16}$	Two $\frac{3}{32}$ in. holes drilled in ends.
Brass Spindle (right hand)........	Length. $1\frac{3}{4}$	Diameter. $\frac{1}{4}$	Length of Shank. $1\frac{1}{8}$	Diameter of Shank. $\frac{3}{16}$
Brass Spindle (left hand).....	$1\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{16}$
Brass Standards (2)....	Length. $2\frac{1}{2}$	Diameter. $\frac{3}{8}$		$\frac{3}{16}$ in. holes drilled $\frac{3}{16}$ in. from top. $\frac{1}{8}$ in. holes drilled and tapped in bottom.
Brass Blocks (2).......	Length. $\frac{3}{4}$	Width. $\frac{1}{2}$	Thickness. $\frac{1}{2}$	Two holes $\frac{3}{32}$ in. drilled and tapped in sides, and two $\frac{1}{8}$ in. holes in bottom.
Hard Rubber Handle..	Length. $1\frac{7}{8}$	Diameter. $\frac{3}{8}$		$\frac{3}{16}$ in. hole drilled through one end. Set screw in end.
Spring Brass Commutator Brushes (2).....	Length. $2\frac{1}{8}$	Width. $\frac{3}{8}$	$\frac{1}{16}$	Two holes $\frac{3}{32}$ in. drilled at one end for brass blocks.
Hard Rubber Base...	Length. $4\frac{1}{4}$	3	$\frac{1}{2}$	

For large coils employing an independent interruptor, an interlocking reversing switch, which is a refinement of the commutator just described, will prove more serviceable, for it prevents the current from flowing through the inductor until the make-and-break mechanism is in working order, and consequently eliminates the danger of short circuits and possible burn-outs.

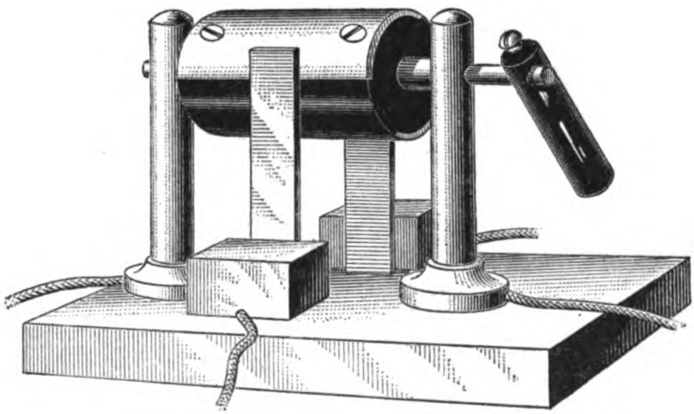


FIG. 93.—ROTATING COMMUTATOR COMPLETE.

This device consists of two rotating rods or spindles, each of which is provided with a crank handle formed of a bar of finished cast brass, drilled at its larger end to receive the rod and fitted with a set screw and drilled at the smaller end, through which a screw passes into a hard-rubber bar, rounded at the end, all of which is shown in Fig. 94. The right-hand spindle carries on its lower end a hard-rubber disk, Fig. 95, having four slots cut across its circumferential surface at equidistant points, as well as

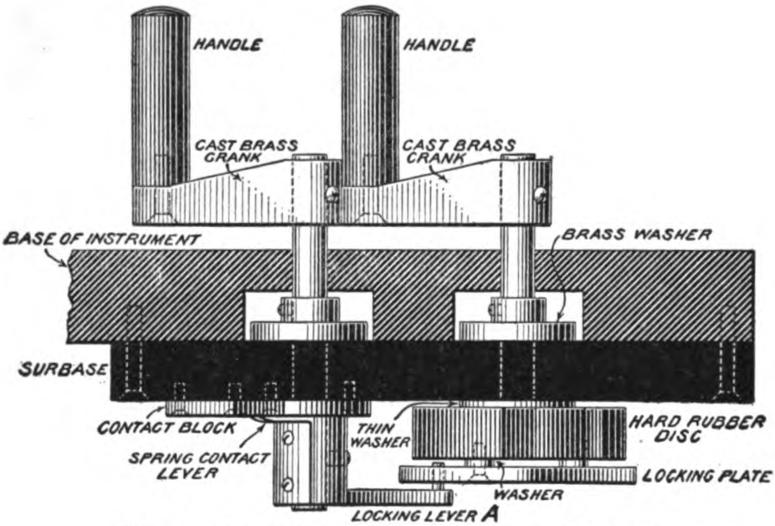


FIG. 94.—CROSS SECTION OF INTERLOCKING SWITCH.

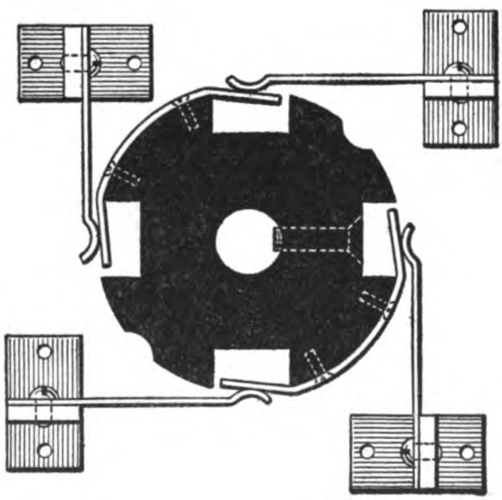


FIG. 95.—COMMUTATOR DISK AND BRUSHES.

two arcuated depressions diametrically opposed. Two strips of brass are then screwed to its periphery, and the ends bent over in the slots. Through the disk a hole is drilled from the surface of one of the slots to the aperture for the spindle, and tapped to receive a set screw. To the under surface of the disk a triangular interlocking plate, Fig. 96, is screwed, but is separated from

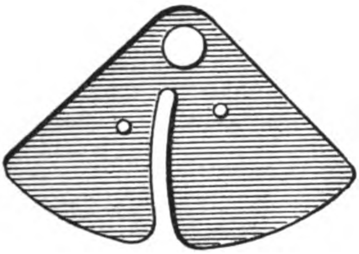


FIG. 96.—LOCKING PLATE.

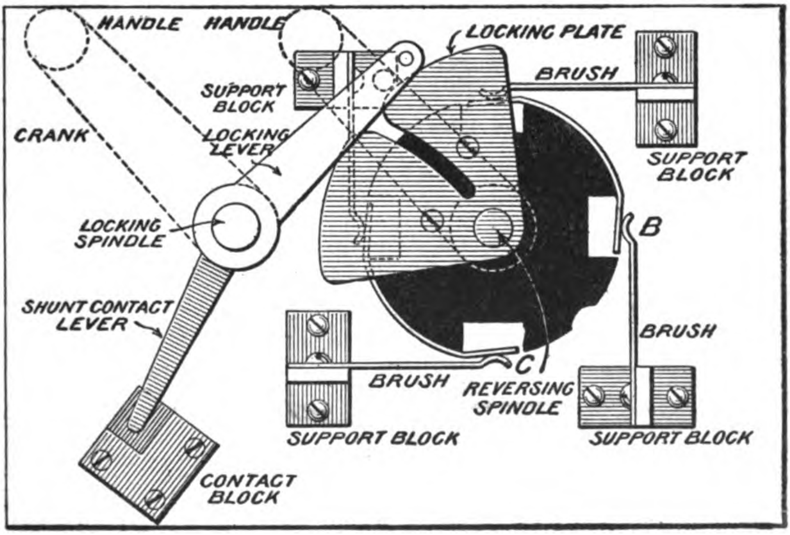


FIG. 97.—PLAN VIEW OF COMMUTATOR AND SWITCH.

it a distance of $\frac{1}{16}$ inch by brass washers, as will be seen in Fig. 94. This plate has a curved slot cut through it, and the open end should extend directly across the depression, as indicated in the plan, Fig. 97. Referring again to Fig. 94, between the handle and the disk a thin brass washer, a thick brass washer, and a collar having a set screw are slipped over the spindle, and when the switch is mounted these serve as bearings as well as to prevent any vertical play of the rod.

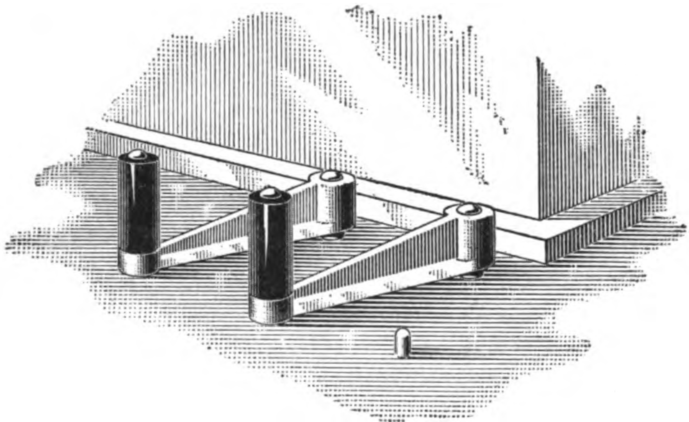


FIG. 98.—COMMUTATOR MOUNTED ON BASE OF COIL.

To the left-hand spindle, on the lower end, a cast-brass locking lever having a long shoulder is secured by a set screw, and screwed to this is a spring-brass shunt contact lever set at an angle of about 110 degrees to the crank lever, so that when the handle is thrown to the left the end of the contact lever slides on a beveled contact plate, as shown in Fig. 97. Between the locking lever and the handle a thick stationary washer, a thick bearing washer, and a collar are placed over the spindle to retain it in its proper position. Screwed to the bed of wood, which in turn is screwed to the under side of the bed of the coil, are four brass blocks, each of which has a projection at right angles to its base, thus ⊥. To each projection is screwed a brass spring or contact brush with a curved end, and these make a sliding connection with the brass strips on the hard-rubber disk, as shown in Fig. 95. The sizes of the different parts will be found tabulated below:

TABLE XXXII.

Sizes of Parts for Interlocking Switch.

	Length. Inches.	Diameter. Inches.		
Brass Spindle for Reversing Switch.	3¼	5/16		
Brass Spindle for Interlocking Switch..................	3¼	5/16		
Hard Rubber Handles (2)	1⅝	½		
Cast Brass Cranks (2)............	2⅝	Thickness at Spindle End. ⅝	Thickness at Handle End. ⅜	
Brass Collars with Set Screws (2)..	Thickness. ¼	Diameter. ½		
Brass Washers for Spindles (2) ...	⅛	1		
Brass Washers for Reversing Spindle...	1/16	1		
Hard Rubber Disk.........	½	2		
Brass Washers (2).	1/16	¼		
Brass Locking Plate	⅛	Length on straight Sides. 1½	Length on Arcuated Edge. 2½	
Cast Brass Locking Lever.........	Length. 2½	Thickness of Blade. ⅛	Shoulder Diameter. ⅝	Length. ⅝
Spring Brass Contact Lever.......	Length. 1½	Thickness. 1/16	Width. ¼ tapering to ⅛	
Spring Brass Brushes (4)..........	1¾	1/16	½	Height. ⅝
Brass Supporting Blocks (4).......	⅞	⅛	½	
Beveled Brass Contact Block.....	¾	⅛	¾	
Contact Strips for Hard Rubber Disk	2	1/16	½	
Surbase	Length. 6	Width. 4	Thickness. 9/16	

The operation of the reversing and locking levers is as follows: When the handles of both switches are parallel and at right angles to the side of the base of the instrument, the current is cut off in both the main and shunt circuits, for the upper and lower commutator brushes will rest in the arcuated depressions in the hard-rubber disk, and the contact lever will be thrown off the contact plate. Now, before the commutator can be moved, the locking switch must be thrown to the left, when the pin releases the angle plate, and the shunt circuit is completed through the movable contact and the contact plate. When in this position the commutator can be turned either to the right or left, by moving its handle, when the current will be reversed accordingly. Fig. 98 illustrates the handles of the interlocking switch mounted on the base board.

CHAPTER XIV.

SPARK-GAP TERMINALS AND OTHER FITTINGS.

Although an induction coil without spark-gap terminals is of little service to the experimentalist, yet curiously enough the small coils offered for sale by dealers in electrical supplies are without this very essential fitting. The makers of such coils evidently assume that pieces of wire inserted in the posts connected with the terminals of the secondary will suffice to form a spark gap, and this is in a measure true, but these are very inconvenient unless the experiments are to be confined to Geissler tubes and the like, but for disruptive discharges, such as are necessary to send wireless telegraph signals, the spark is most effective when it takes place between balls.

In the small-sized coils a binding post screwed into the periphery of each cheek will serve well enough to support the discharge terminals. For the ½-inch coil binding posts of the size shown at *A*, Fig. 99, may be used; for the 1-inch coil, the size indicated at *B;* while for the 2-inch coil a double binding post like that depicted at *C* will be found advantageous. In any case, stiff brass rod of the requisite length should be cut, and the ends that are to form the spark gap should be sharpened. Over the sharpened ends brass balls should be fitted, which may be done by simply drilling a hole in the ball to its center and

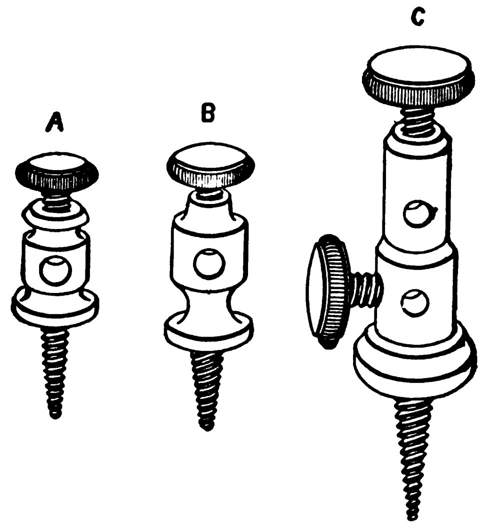


FIG. 99.—BINDING POSTS FOR SECONDARY TERMINALS.

slipping it over the sharpened point, or the wire may be threaded and the hole tapped out. The balls may be of any kind of metal, although zinc gives the best result, and further they may be either hollow or solid. The following table will show the size of the rods and the approximate diameter of the balls. In the 2-inch coils hard-rubber handles may be fitted to the outwardly projecting ends of the rods.

TABLE XXXIII.

Sizes of Spark Gap Fittings for Small Coils.

	Length of Rod.	Diameter of Rod.	Diameter of Balls.	Hard Rubber Handles.	
				Length.	Diameter.
$\frac{1}{2}$ in. Coil.	3 in.	$\frac{3}{16}$ in.	$\frac{3}{8}$ in.		
1 in. Coil.	4 in.	$\frac{1}{8}$ in.	$\frac{1}{2}$ in.		
2 in. Coil.	6 in.	$\frac{1}{8}$ in.	$\frac{3}{4}$ in.	2 in.	$\frac{3}{8}$ in.

While the sizes of the spark balls are specified in the preceding table, the actual diameter is of little consequence, but those cited will be more nearly in proportion

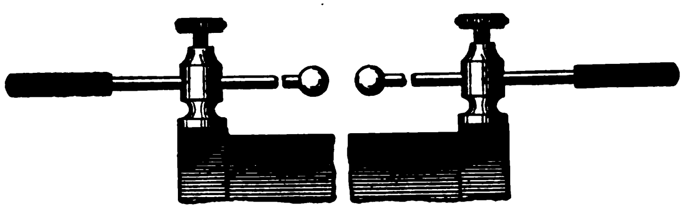


FIG. 100.—SPARK GAP TERMINAL FOR SMALL COILS.

to the size of the coil in so far as the design is concerned. The spark-gap terminals forming the oscillator for a small coil are shown in Fig. 100.

For the intermediate sizes of coils the standards through which the spark-gap electrodes slide may be made in three parts and then assembled, forming a neat and effective arrangement, and one which will keep the discharge terminals in alignment. Lengthwise through a cylindrical and tapering hard-rubber standard a small brass tube or sleeve having thin walls is tightly fitted. The lower end of the standard is turned down closely to the tube while in the surface of the shoulder two holes are drilled and tapped out; the shank is then inserted in a strip of wood, and screws are driven through it and into the base of the standard. Fig. 101 shows a cross section of the standard secured to the strip of wood, the latter being attached to the top of the cheek of the coil when the instrument is assembled. A set screw is provided midway between the top and the shoulder to connect in the terminal of the secondary coil.

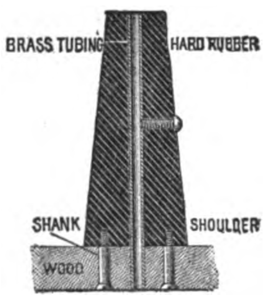


FIG. 101.—CROSS SECTION OF SPARK GAP STANDARD.

Diametrically through a brass ball a $\frac{5}{32}$-inch hole is drilled out, and a second hole $\frac{1}{8}$ inch is drilled through and tapped out at right angles to the first. A small binding post is screwed in on one side, and a brass rod threaded on one end and slotted longitudinally on the other, so that it will spring more or less, is screwed into the opposite side. Through and fitting snugly into the larger hole in the ball a spark-gap terminal, having a hard-rubber handle and a sharpened end, but threaded at a point where the rod assumes its normal diameter, is inserted. The dimensions of the different parts of the standards and the spark terminals are given in Table

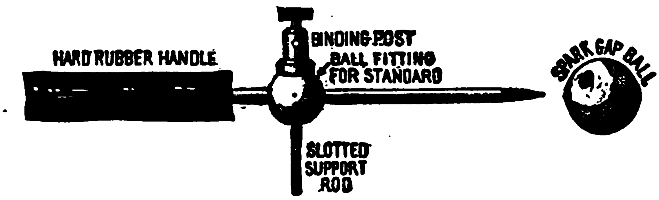


Fig. 102.—Spark Gap Terminal with Ball Detached.

XXXIV. One of the spark-gap terminals with the spark ball detached is illustrated in Fig. 102, while Fig. 103 shows one of the standards, its terminals and ball assembled.

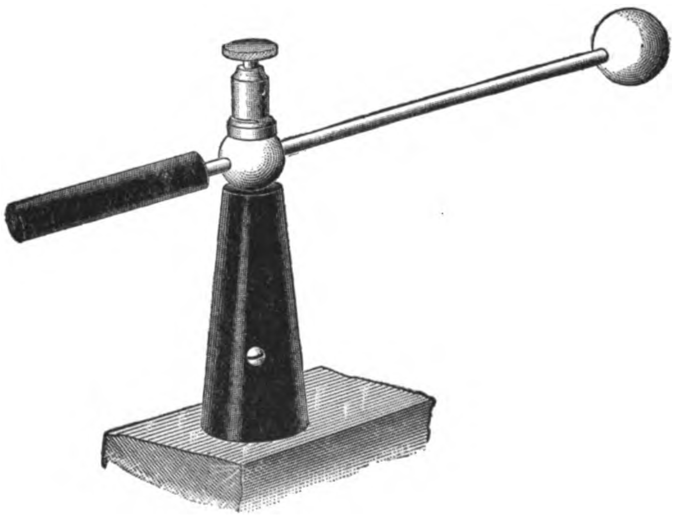


Fig. 103.—Spark Gap Terminal Assembled.

TABLE XXXIV.

Sizes of Spark Gap Terminals and Standards for Intermediate Sized Coils.

Tapering Hard Rubber Standard.	Length Over All. Inches.	Length of Shoulder. Inches.	Diameters of Shoulder. Inches.		Length of Shank. Inches.	Diameter of Shank. Inches.
			Base	Top.		
4 in. Coil.	2½	2	¾	⅝	½	⅜
6 in. Coil	3	2½	⅞	⅝	½	⅜
8 in. Coil	3½	3	1	⅝	½	⅜
Brass Tube.	**Length.**	**Outside Diameter.**	**Thickness.**			
4 in. Coil.	2½	3/16	1/64			
6 in. Coil.	3	3/16	1/64			
8 in. Coil	3½	3/16	1/64			
Brass Ball for Standard.		**Diameter.**				
4 in. Coil.		⅝				
6 in. Coil.		⅝				
8 in. Coil.		⅝				
Binding Post.	**Length.**	**Diameter.**				
4 in. Coil.	⅝	3/16				
6 in. Coil.	⅝	5/16				
8 in. Coil.	⅝	5/16				
Spark Terminal.	**Length.**	**Diameter.**				
4 in. Coil.	5	5/32				
6 in. Coil.	5½	5/32				
8 in. Coil	6	5/32				
Spark Gap Ball.		**Diameter.**				
4 in. Coil.		⅞				
6 in. Coil.		1				
8 in. Coil.		1⅛				
Hard Rubber Handle.	**Length.**	**Diameter.**				
4 in. Coil.	3	9/16				
6 in. Coil.	3	9/16				
8 in. Coil.	3	9/16				

If a larger coil is to be built and used for wireless telegraph work, the terminals of the secondary may be connected with standards as above, but the length should be increased to 4 inches for the 10-inch coil and to 4½ inches for the 12-inch coil, with proportionately longer bases; if, on the other hand, the coil is to be employed for energizing X-ray tubes, then a spark gap with adjustable

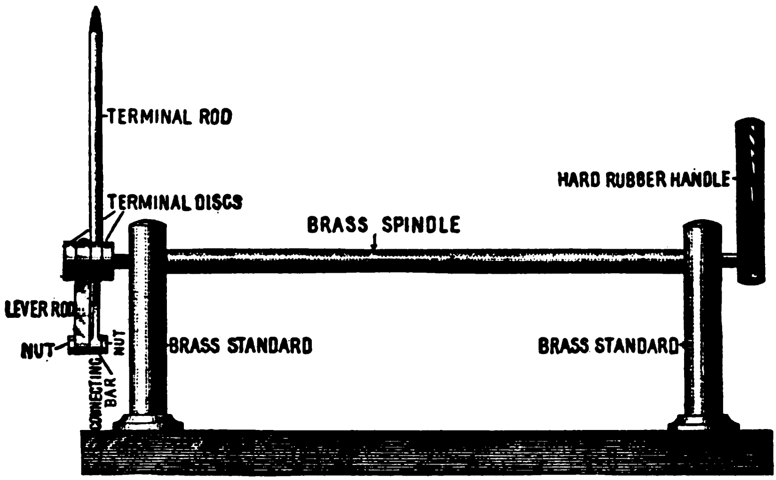


FIG. 104.—END ELEVATION OF SPARK GAP DEVICE.

terminals as shown in Figs. 104, 105, and 106 is more convenient.

This arrangement comprises a brass spindle with shanks turned on the ends, and this is supported by brass standards secured to a strip of hard rubber, which is in turn screwed to one of the cheeks of the coil. A hard-rubber handle is attached to one end of the spindle, while the opposite end carries a light brass rod pointed at the end. On this end of the spindle is likewise rigidly mounted, by means of a thumb nut, a hard-rubber bar or strip, preferably the former since it is stronger, that

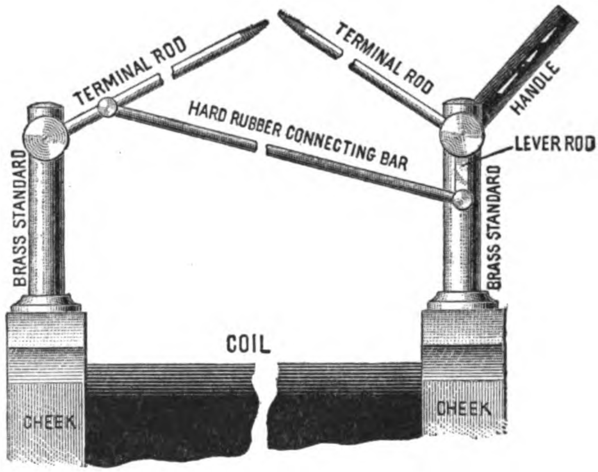


FIG. 105.—SIDE ELEVATION OF SPARK GAP DEVICE.

extends to the opposite cheek of the coil, on which is secured a complementary brass standard.

This latter standard carries a spindle to which is attached a second light brass pointed terminal rod oppositely disposed to the first and in alignment with it. The end of the hard-rubber bar is connected with the terminal rod at a point above the spindle and so that it can turn freely. It is obvious now in virtue of the mechanical movement employed, that if the handle turning the first

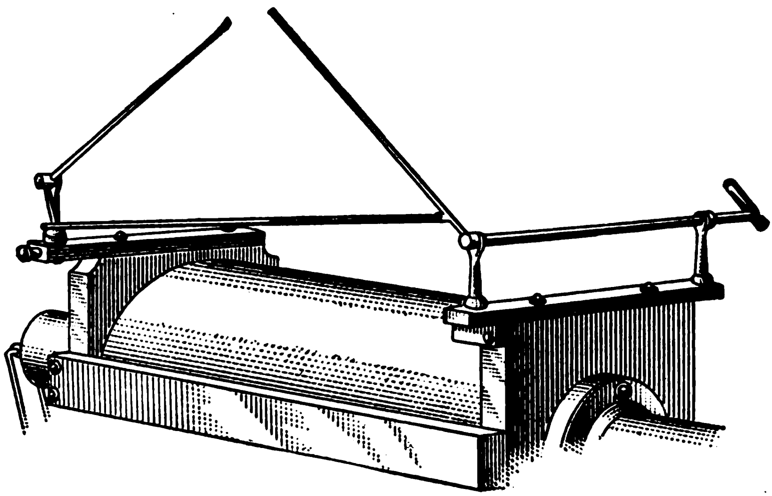


FIG. 106.—SPARK GAP TERMINAL COMPLETE.

terminal rod is moved to the right, the points forming the spark gap will recede from each other, or if turned to the left they will approach each other. Table XXXV gives the dimensions for the device for the 10- and 12-inch coils.

TABLE XXXV.

Sizes of Parts for Adjustable Spark-Gap Terminals.

	Length Over All. Inches.	Diameter. Inches.	Length of Shanks. Inches.		Diameter of Shank Ends. Inches.
			Handle End.	Terminal End.	
Brass Spindle.					
10 inch Coil......	13	5/16	1	1/4	1/4
12 inch Coil.....	15	5/16	1	1/4	1/4
	Length.				
Brass Spindle (Short)	1 1/2	5/16			
Brass Standards (3).	2 1/4	3/8			
Brass Terminal Rods					
10 inch Coil	6	3/8			
12 inch Coil.....	6 1/2	3/8			
			Thickness.		
Brass Terminal Disk		5/8	1/8		
		Width.			
Brass Lever Rod....	1	3/16	1/8		
Brass Lever Rod Nuts, Milled Heads		1/4	3/16		
		Length.	Diameter.		
Hard Rubber Connecting Bar.......	10 in. Coil	11 3/8	3/8		
	12 in. Coil	14 3/8	3/8		

An accessory of every large coil, especially if it is to be operated with a 110-volt current, is a safety-fuse block. This little device may be formed of a pair of brass standards which support flat blocks of brass terminating in hollow cylindrical ends. The upper surface of each block has a V groove cut longitudinally in it; the free ends are drilled through to receive screws that secure it to its respective standard. A piece of glass tubing is inserted in the cylindrical ends of the terminal blocks, and axially through the former a fuse wire is carried, the ends of the latter projecting through small holes and lying along

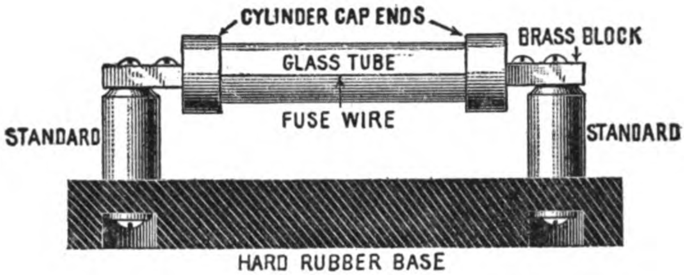


FIG. 107.—FUSE BLOCK.

the V grooves until the screws are reached, when it is given a turn around these, which are then screwed down. The sizes of the different parts for the fuse blocks will be found in Table XXXVI, and a side elevation is shown in Fig. 107.

TABLE XXXVI.

Sizes of Parts of Fuse Blocks.

	Length. Inches.	Diameter. Inches.	
Brass Standards (2)........	5/8	3/8	
		Width.	Thickness.
Brass End Blocks (2).........	5/8	3/8	3/16
		Outside Diameter.	Inside Diameter.
Brass Cap Ends (2)..........	5/16	1/2	3/8
Glass Tubing....	2	3/8	

For the smaller coils the binding posts can be purchased in the market more cheaply than they can be made; for the intermediate and larger sizes of coils the ordinary posts are not well adapted, and hence it is a good plan to make them. Plain binding posts present the best appearance for connecting the inductor with the source of electromotive force, and these may be made by cutting a rod of brass $\frac{3}{4}$ inch in diameter into $2\frac{1}{2}$-inch lengths and then turning a shank $1\frac{1}{2}$ inches in length and $\frac{1}{4}$ inch in diameter. This leaves the post proper 1 inch in height.

A hole $\frac{3}{16}$ inch in diameter should be bored diametrically through the post midway between the top and base, and a hole $\frac{1}{4}$ inch in diameter should be drilled and tapped axially from the top through to the hole for receiving the terminal of the power circuit. A screw with a milled head, the latter being $\frac{1}{8}$ inch thick and $\frac{7}{8}$ inch in diameter, is inserted in the top of the post. The brass work of all the different parts should be polished and lacquered in accordance with the instructions previously given.

CHAPTER XV.

THE BASE AND OTHER WOODWORK.

The coil and its subsidiary apparatus being completed, the next consideration is the base upon which the various devices are mounted. The base is made of hard wood, and mahogany, oak, and cherry are the kinds that have found most favor, the former having been almost exclusively adopted by the professional coil builder.

There are several kinds of mahogany, the choicest coming from Cuba and San Domingo, while the lower grades are much lighter and are imported from Honduras. Owing to its fine grain it is easily polished and extremely durable, except under lateral strain, and hence it is one of the most popular of all the woods with instrument makers. The wood of the American wild black cherry is the kind selected by cabinet makers, since it is harder and tougher and takes a higher polish than other woods of the same species.

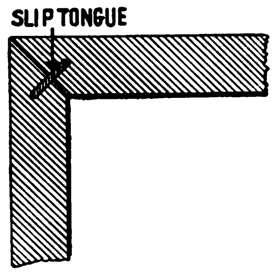


FIG. 108.—MITERED JOINT WITH SLIP TONGUE.

Oak is cheaper than mahogany or cherry, and is noted for its solidity, strength, and resistance to moisture. In virtue of its handsome graining and its ability to receive a polish, together with the good qualities previously cited, it is sometimes preferred for the bases of coils to other woods. There are two groups of oaks, the white and the black; the white is the more compact, though care must be taken in its selection, for the mossy cup, or burr oak, which resembles it in appearance, has a much coarser grain. When oak is used it should be quarter-sawed, that is to say, the log is cut lengthwise into quarters, so that these in turn can be cut into boards parallel to the radius of 45 degrees between these cuts; these sections will then be so nearly in the plane of the medullary rays that they

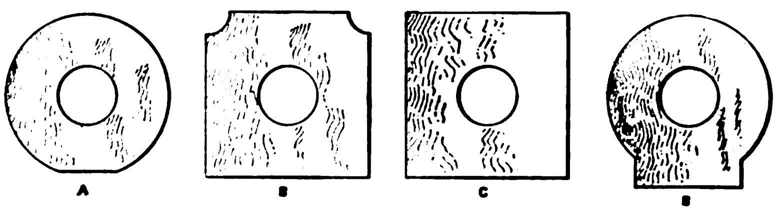


FIG. 109.—DESIGNS FOR COIL CHEEKS.

show the best grain, and boards cut in this manner are less likely to warp and less liable to shrinkage.

The method employed by the cabinet maker for joining the corners of the base of the coil, or box for the condenser, is to miter the joints, and after gluing secure them by means of a slip tongue, as shown in Fig. 108; but if the constructor desires to make this part of the instrument himself, and if he is not skilled in the art of joinery, he may miter the joints as before and brace them by gluing angular blocks inside the corners, which will greatly increase its strength.

The woodwork necessary for the small coils comprises a pair of cheeks, a base, and a set of four base blocks, the dimensions of these pieces being given in the succeeding table. The cheeks are usually circular, and planed flat, where they are to be screwed to the base, as shown in Fig. 109. These cheeks may be made of hard wood to match the base, or they may be made of soft wood and japanned to look like hard rubber.

A good japan may be made by melting 48 pounds of asphaltum in a pot, and when melted add 10 gallons of linseed oil; run in the pot 8 pounds of common gum animi and mix it with 2 gallons of oil; pour the mixture into the melted asphaltum, then run 10 pounds of common amber and mix with 2 gallons of oil. This running is also added to the set pot, the contents of which are boiled for three hours longer, during which time 7 pounds of red lead, 7 pounds of litharge, and 3 pounds of copperas are added and the boiling continued until the mass sets between the fingers into a hard mass. Allow it to cool, and then thin with 30 gallons of turpentine.

TABLE XXXVII.

Sizes of Bases and Cheeks for Small Coils.

Size of Coil.	Bases.				Rabbet.	
	Thickness of Wood. Inches.	Length of Base. (Outside Dimensions.) Inches.	Width. Inches.	Depth. Inches.	Width. Inches.	Depth. Inches.
½ inch.	½	9	4¼	1	3/16	3/16
1 inch.	9/16	11¾	5½	1¼	¼	3/16
2 inch.	⅝	15½	7¼	1½	¼	¼

Sizes of Bases and Cheeks for Small Coils (Continued).

Size of Coil.	Cheeks. Thickness. Inches.	Cheeks. Diameter. Inches.	Base Blocks. Length. Inches.	Base Blocks. Width. Inches.	Base Blocks. Thickness. Inches.	Base Blocks. Project Beyond Line of Base. Inches.
½ inch.	$\frac{7}{16}$	2⅞	1	¾	½	⅛
1 inch.	⅝	3¼	1¼	⅞	$\frac{3}{16}$	$\frac{3}{16}$
2 inch.	¾	4⅝			¼	¼

One edge of the sides and ends of the base are rabbeted, so that when it is completed a removable bottom, usually of some soft wood, may be set in flush and an interior space formed for the condenser between it and the top.

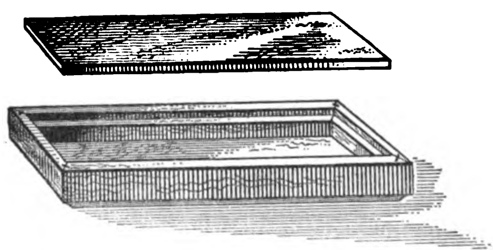


FIG. 110.—BASE OF SMALL COIL INVERTED.

The dimensions of the top are the same as those of the outside of the base, and if the edges of the first are molded so that it tapers down to $\frac{1}{16}$ or $\frac{1}{32}$ inch when it is glued on, there will be little of the cross section to show. To the removable bottom a block, of the same kind of wood as that of which the base is made, is secured to each corner, either with glue or screws or both, so that the edges of these may extend a little beyond the line of the base. This not only adds to the appearance of the coil, but serves to raise it slightly from the surface it sets on, a very good

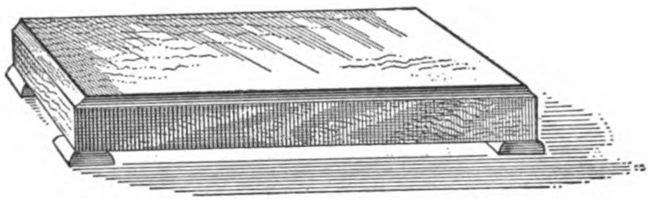


FIG. 111.—BASE OF SMALL COIL COMPLETE.

idea where the coil is used in connection with a plunge battery, the solution of which frequently spills. Fig. 110 shows the base of a small coil inverted ready for inserting the condenser, and Fig. 111 illustrates the base complete.

For coils of the intermediate sizes there are, other than the base, a base board to which the cheeks of the coil are screwed, strips of wood that are secured to the cheeks of the coil for bracing the former and protecting the latter; similar but shorter strips forming the bases for supporting the hard-rubber standards in which the spark-gap terminals are inserted, and finishing ends for the cheeks that slip over the inductor, as indicated in Fig. 112. As in the smaller coils, the base has mitered corners secured by slip tongues, and the middle of the ends and sides are

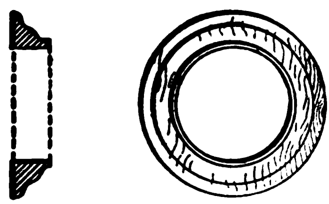


FIG. 112.—FINISHING ENDS FOR COIL CHEEKS.

cut away as illustrated in Fig. 113. The edges and corners of the base may be rounded.

The cheeks for these coils may be variously designed to suit the taste of the constructor. Fig. 109, *A, B, C,* and

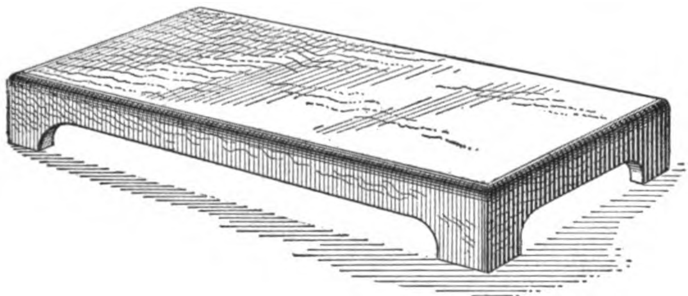


FIG. 113.—BASE FOR INTERMEDIATE AND LARGE COIL.

D, indicates some of the styles employed. These cheeks are sawed from a single piece of wood, and if it is well seasoned they will not warp. The finishing ends are sawed out and then molded on a machine, producing a cross section similar to that in Fig. 112. The strips that brace the cheeks and those that support the terminals forming the spark gap are made plain with smooth ends. The sizes of these parts are given below:

TABLE XXXVIII.

Sizes of Bases and Other Woodwork for Intermediate Coils.

Size of Coil.	Bases.			
	Length. Inches.	Width. Inches.	Height. Inches.	Thickness. Inches.
4 inch.	25½	20	3¾	¾
6 inch.	28	21	3¾	¾
8 inch.	31	22	3¾	¾

Sizes of Bases and Other Woodwork (Continued).

Size of Coil.	Cheeks.			Base Boards.		
	Height. Inches.	Width. Inches.	Thickness. Inches.	Length. Inches.	Width. Inches.	Thickness. Inches.
4 inch.	10	10	¾	11½	12	¾
6 inch.	11½	11½	⅞	13	13½	⅞
8 inch.	12	12	⅞	13½	14	⅞

Size of Coil.	Strips.			Finishing Ends.		
	Length. Inches.	Width. Inches.	Thickness. Inches.	Inside Diameter. Inches.	Outside Diameter. Inches.	Thickness. Inches.
4 inch.	11½	¾	7/16	2¾	4¾	¾
6 inch.	13	⅞	½	3¼	5½	⅞
8 inch.	13½	⅞	½	3¾	6¼	1

Size of Coil.	Terminal Strips.		
	Length. Inches.	Width. Inches.	Thickness. Inches.
4 inch.	10	¾	7/16
6 inch.	11½	⅞	½
8 inch.	12	⅞	½

The beds and cheeks of the 10- and 12-inch coils are patterned after the intermediate sizes. Some makers of induction coils use hard-rubber cheeks; and while this material certainly provides a better insulation for the ends of the coil than does wood, yet it adds considerably to the expense of construction, as a reference to the cost of materials will show. The strips supporting the spark-gap terminals may be of wood or hard rubber, the dimensions of course remaining the same. An additional piece of woodwork employed in the larger coils is a box for the condenser, which is mounted on top of the base. These

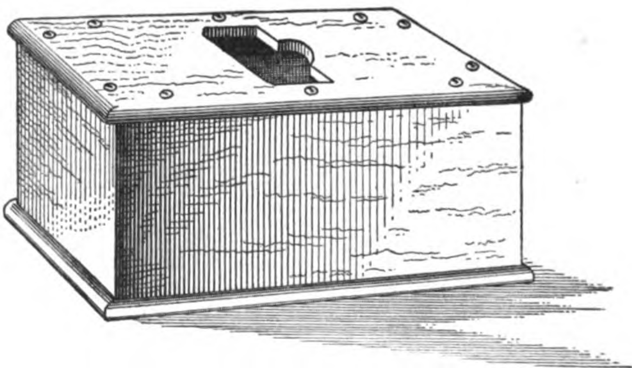


FIG. 114.—CONDENSER BOX.

boxes have tops and bottoms that project ¼ inch beyond the external measurements of the box proper, and their appearance may be further improved by slightly rounding off the edges of the top and half-rounding those of the bottom, leaving the corners sharp, as shown in Fig. 114. The bottom is glued to the box, and the top, after the condenser is placed inside and the revolving switch mounted on it, is screwed down. The dimensions of the bases and of the box for the condenser, which are the same in either case, will be found in Table XXXIX.

TABLE XXXIX.

Sizes of Bases, Condenser Boxes, Etc., for Large Coils.

Dimensions in Inches.

Size of Coil.	Bases.				Condenser Boxes.			
	Length	Width.	Thickness of Wood.	Height.	Length	Width.	Height.	Thickness of Wood.
10 inch.	31	19	1	4	10	6	6	5/16
12 inch.	33½	20½	1	4	10	6	6	5/16

Size of Coil.	Cheeks.			Base Boards.			Bracing Strips.		
	Height.	Width.	Thickness.	Length	Width.	Thickness.	Length	Width.	Thickness.
10 inch.	11¾	11¾	1	15	14	1	12½	1¾	½
12 inch.	13¼	13¼	1	16	15	1	14¼	2	½

Size of Coil.	Terminal Strips.			Finishing Ends.		
	Length	Width	Thickness.	Inside Diam.	Outside Diam.	Thickness.
10 inch.	11¾	1	½	4¼	6¾	1
12 inch.	13¼	1	½	4⅞	7¾	1

The bed and other woodwork is completed by rubbing the exposed surfaces down with the finest sandpaper until they are very smooth, when they may be varnished, or if a higher finish is desired they must be polished. A

French polish is not difficult to obtain after a little experience, and a satisfactory polish will be produced if the following method is adhered to: After the surfaces have been rubbed smooth with sandpaper, French polish, which can be bought already prepared or made by dissolving about 6 ounces of bleached shellac in a pint of methylated spirit, is then applied to a pad or rubber, formed of cotton wadding wrapped in a piece of linen, and this is rubbed over the surface of the wood until a good body is produced, when a circular movement is given the pad until it is dry.

As the rubber begins to get dry it will become more sticky, but this may be counteracted by applying a few drops of raw linseed oil to lubricate it, though care must be taken not to use too much. If the polish is too thick, then more of the methylated spirit must be added to it, or if too thin more shellac. The first bodying in, as it is termed, will not give a polish, as the process is just begun. It must, on the other hand, be sandpapered down a little before commencing the next rubbing, but the paper must be used lightly or it will rub through to the wood.

The work must be gone over several times with the rubber, which should be used slowly and evenly, and the pressure should not be too hard. The finishing process is called spiriting off, which means that instead of applying polish to the rubber the last time, methylated spirit alone is used. This kills the oil that has been rubbed on with the polish, and at the same time it gives the surface a bright gloss.

CHAPTER XVI.

WIRING DIAGRAMS FOR INDUCTION COILS.

After the coil and its subsidiary appliances are mounted on the bed, the instrument is completed by connecting the various parts together. The wiring is done under the bed of the coil, which effectually conceals all of the rough connections, leaving the top free except for the devices and the terminal binding posts.

In the smaller coils the connections may be made by looping the ends of the wires around the screws with a washer under and another over the loop, but in the intermediate and larger-sized coils the terminals of the connecting wires should be soldered to the screws or if it is desired to take the coil apart for demonstration purposes the wires may be soldered to the washers. The size of the wire used for these connections should be the same as that employed for the primary winding, or it may be larger but never smaller and it should be double cotton covered and well shellacked. Wherever the wires cross each other the parts must be well protected by short lengths of flexible rubber tubing, or in lieu of this it may be wrapped with adhesive tape, though the first method will make the neatest looking job.

The following wiring diagrams show all the various connections for the different sizes and types of coils. As there is very little or no wiring necessary for the secondary coil, the diagrams show only the primary, and the latter is drawn as a single layer of wire in order to make the connections as clear as possible. This method of graphically illustrating, however, has the disadvantage of bringing the terminals of the primary out at the opposite ends of the inductor, whereas in reality the terminals project from the same end. By placing the devices on the bed as indicated in the succeeding chapter, and connecting

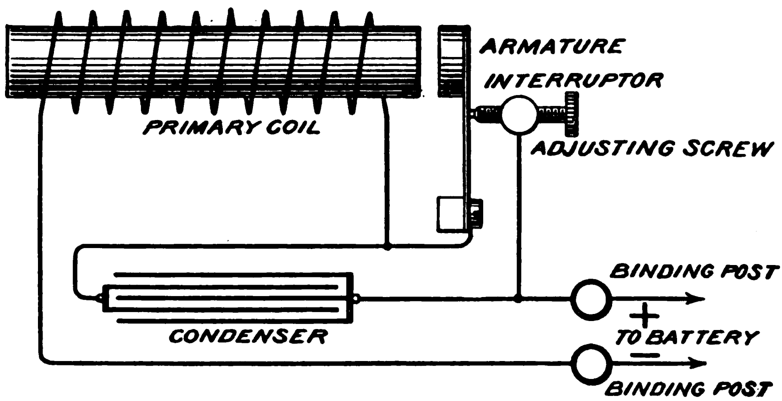


FIG. 115.—WIRING DIAGRAM FOR SIMPLE INDUCTION COIL.

them as shown in the succeeding diagrams, there will be no difficulty encountered in properly wiring the coil.

In the small coils, where there is no reversing switch employed, the wiring takes on the very simple form indicated in Fig. 115; from one of the binding posts a wire leads to the standard carrying the adjusting screw of the interruptor. The complementary standard carrying the spring leads to one terminal of the primary coil while the opposite terminal is connected to a second binding post.

The condenser is bridged across the interruptor contacts by connecting one side to the standard carrying the adjusting screw and the other and opposite side to the standard supporting the vibrating spring.

Where the coil is fitted with a three-point reversing

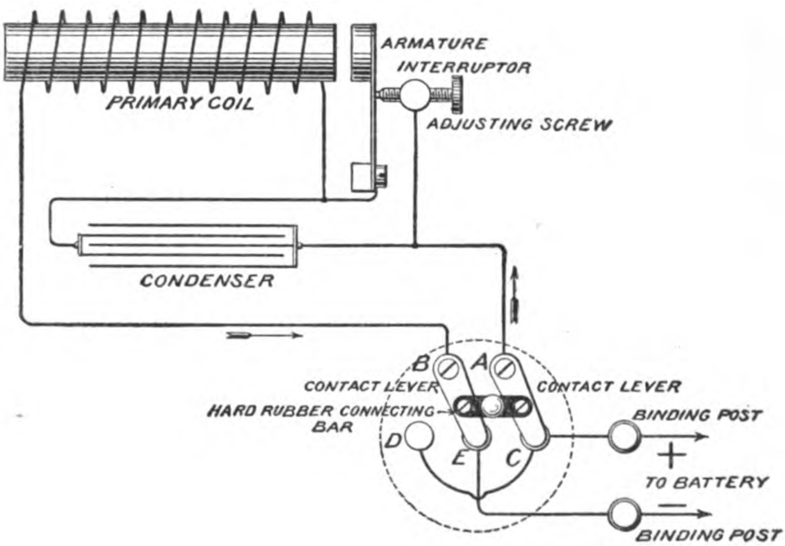


FIG. 116.—WIRING DIAGRAM FOR INDUCTION COIL WITH THREE-POINT SWITCH.

switch the connections are made as shown in the diagram, Fig. 116. The switch is included within the dotted circle, and a reference to it will not only illustrate the method of wiring but will serve to render clear its mode of operation. The rear post A is connected to one terminal of the primary coil through the interruptor, while the point B is connected with the opposite terminal of the primary. The points *A* and *B* serve as pivots upon which the parallel

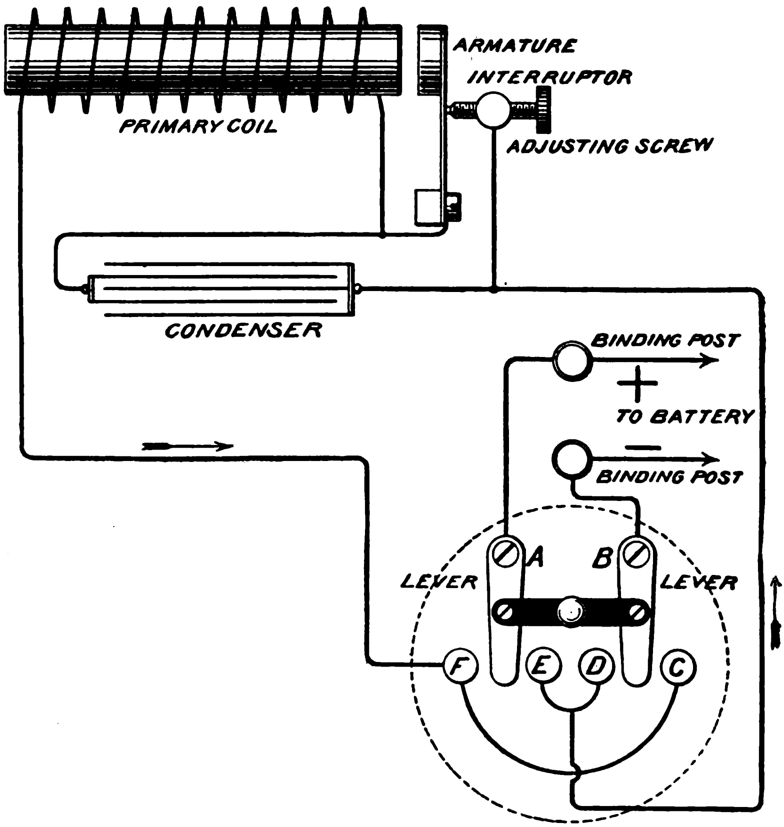


FIG. 117.—WIRING DIAGRAM FOR INDUCTION COIL WITH FOUR-POINT SWITCH.

contact levers—insulated from each other—may be moved to the right or left. The point *C* is joined to one of the binding posts leading to the battery, and *C* and *D* are connected together. The middle point *E* leads to the other binding post, to which the negative side of the battery is attached. When the contact levers are in the position shown in the diagram, the current passes through the circuit in the direction indicated by the arrows; but when

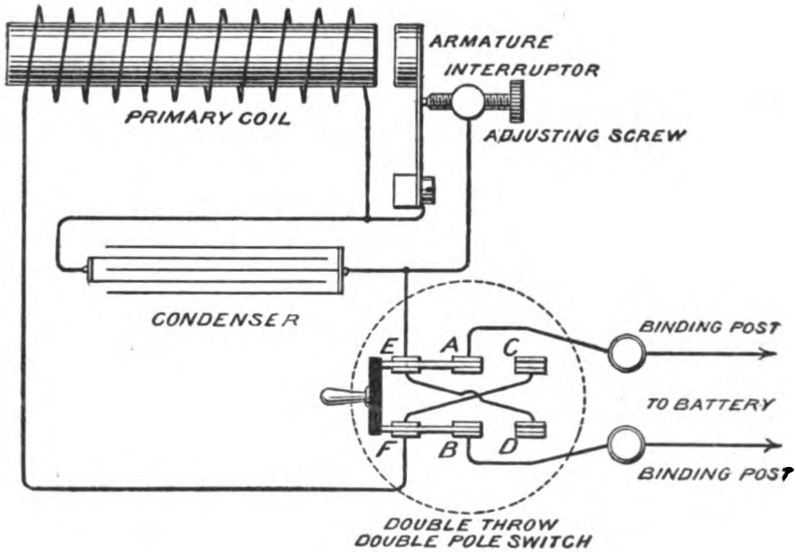


FIG. 118.—WIRING DIAGRAM FOR INDUCTION COIL WITH DOUBLE POLE DOUBLE THROW SWITCH.

the levers are moved to the left, *C* becomes the *nil* point and *D* the active point, consequently the direction of the current is reversed.

Where a four-point switch is used, the connections are made as shown in the diagram, Fig. 117. From one of the battery binding posts on the bed of the coil a wire leads to the point *A*, while the opposite post connects with the point *B*. A pair of parallel levers, insulated from each other, are arranged to make contact with *C* and *E* and *D* and *F*. *C* and *F* are connected together, and are joined to one of the terminals of the primary coil; *D* and *E* are likewise connected together and lead to the opposite terminal of the coil through the interruptor contacts. When

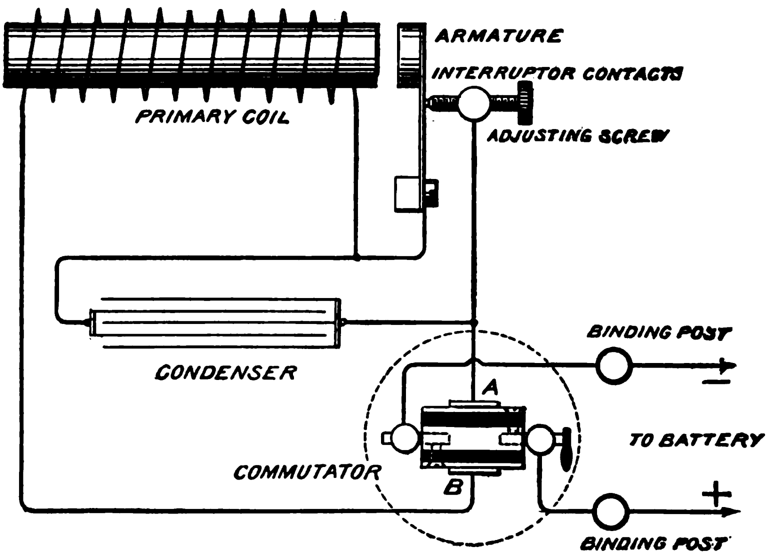


FIG. 119.—WIRING DIAGRAM FOR INDUCTION COIL WITH RUHMKORFF COMMUTATOR.

the levers are in the position shown in the diagram, the circuit is of course broken and no current can flow. If the levers are thrown to the points *C* and *E*, the current takes the direction of the arrows, but if they are to the left, making contact with the points *D* and *F*, the current will traverse the circuit in the opposite direction.

If a double-pole, double-throw switch is employed, the connections are virtually the same as where a four-point switch is used; but as the contact posts and blades of the former occupy relatively different positions from the points and levers of the latter, the diagram, Fig. 118, is given.

The method of connecting in a Ruhmkorff commutator

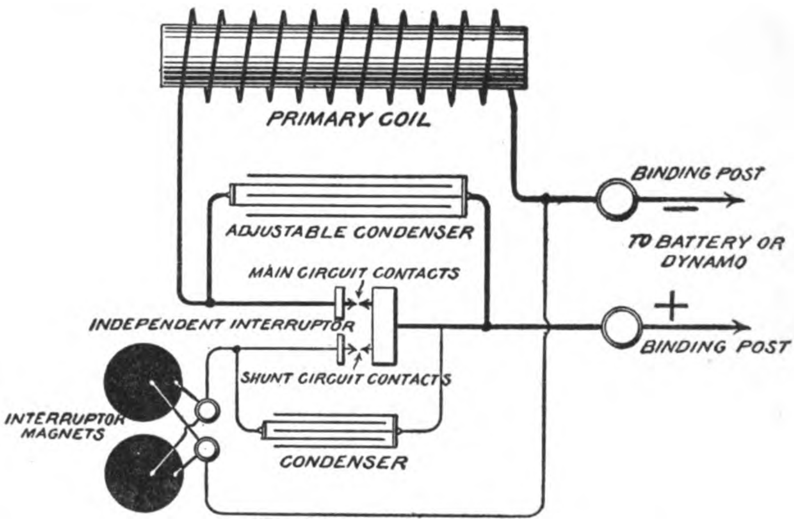


FIG. 120.—WIRING DIAGRAM FOR INDUCTION COIL WITH INDEPENDENT INTERRUPTOR.

is shown in Fig. 119. The + binding post is connected with one of the standards of the commutator, and the — binding post with the other standard. From the standard of the interruptor carrying the adjusting screw a connecting wire leads to one of the commutator brushes, while the free end of the primary is connected to the second commutator brush.

It is now apparent that when the connections are made as set forth in the diagram, the circuit will be completed so that the current will pass from the + terminal up one of the standards of the commutator, thence through the

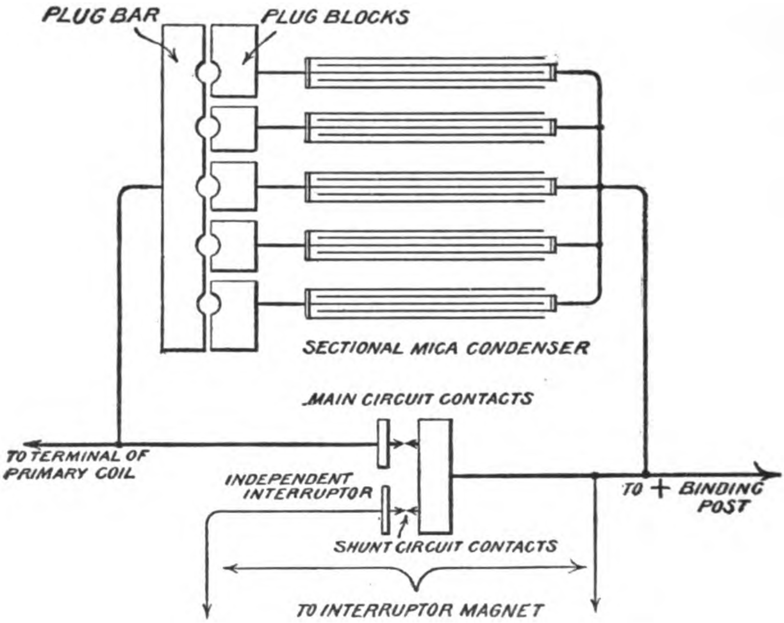


FIG. 121.—WIRING DIAGRAM FOR BLOCK AND PLUG ADJUSTABLE CONDENSER AND INDEPENDENT INTERRUPTOR.

spindle to the segment and the brush *A* through the interruptor contacts and to the primary coil. After energizing the latter the current returns through the brush *B* of the commutator, the segment, spindle, and standard, and thence to the binding post to which the — pole of the battery is attached. If now the handle is turned a half revolution, the position of the brushes will be reversed in their relation to the segment, and the current will flow through *B* and return *via A*, thus reversing the current through the inductor.

The interlocking reversing switch is employed to advantage only where an independent interruptor is used; and in order to present a complete wiring diagram of the first, an elementary diagram of the second will be necessary. By referring to Fig. 120, it will be seen that one terminal of the + binding post is connected to the stationary contact of the standard carrying the adjusting screws for both the main and shunt circuits, namely, the primary coil and the interruptor magnets. From the spring contact block in the main circuit a wire leads to the primary coil and thence to the opposite binding post. A shunt circuit, indicated by the light lines, is formed by the contact block, to which the spring carrying the armature is attached, the magnet coils, and back to the — binding post.

The connections for an adjustable condenser of the plug and block type are shown in the diagrammatic sketch, Fig. 76, while the method of connecting it across the interruptor contacts is shown in Fig. 121. In the adjustable mica condenser operated with a revolving switch the terminals of all the sections are connected together, and lead direct to the standard of the interruptor carrying the adjusting screws for the main and shunt circuits. The opposite side of each section is soldered to its respective spring pins underneath the hard-rubber block. From the angle plate, which is attached to the spindle carrying the brass semicircular contact and hard-rubber handle, the flexible conductor leads to the brass blocks supporting the main contact spring of the interruptor, all of which is clearly brought out in the diagram, Fig. 122.

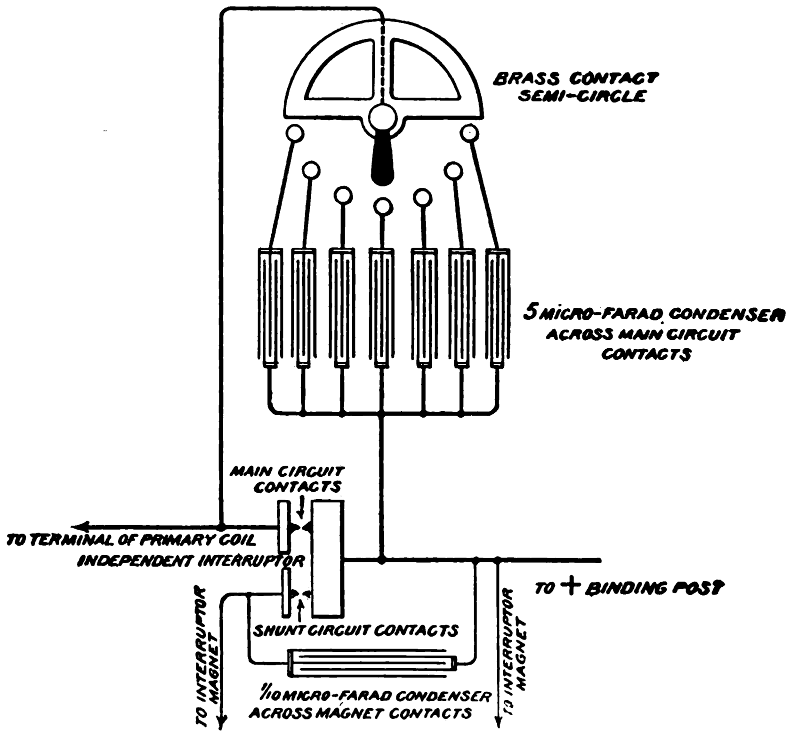


FIG. 122.—WIRING DIAGRAM FOR REVOLVING SWITCH CONDENSER AND INDEPENDENT INTERRUPTOR.

The interlocking switch connections are shown diagrammatically in Fig. 123, and its relation and control of the main and shunt circuits are also made apparent. From the + binding post a connection is made with the stationary contacts of the interruptor as previously described; but instead of the primary being connected directly with the spring contact block in the main circuit of the interruptor, it leads to the commutator brush marked *A*. When the handle of the reversing commutator is turned to the

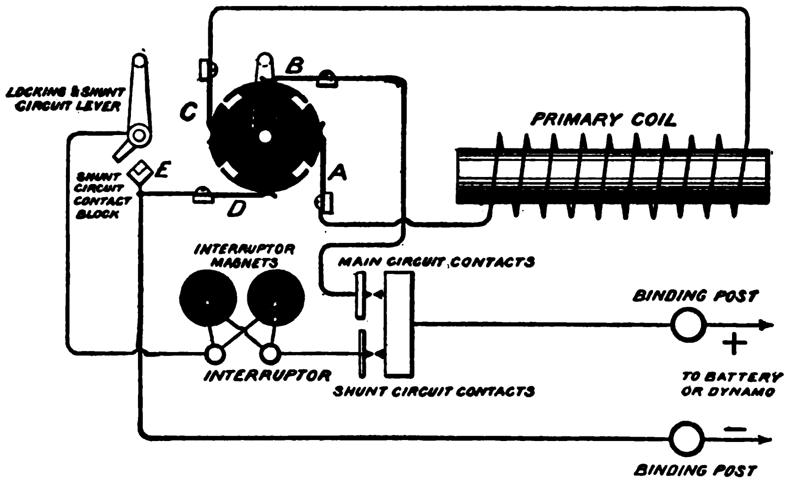


FIG. 123.—WIRING DIAGRAM OF INDEPENDENT INTERRUPTOR AND INTERLOCKING REVERSING SWITCH.

right, the brushes *A* and *B* are connected through the segment on the hard-rubber disk, and the circuit is then completed through the primary coil, the opposite terminal being connected with the brush *C*, and the continuity of the circuit is preserved on through to the — binding post by means of the brushes *C* and *D*, which now rest on the same segment. The shunt circuit is derived by connecting the contact block supporting the spring carrying the

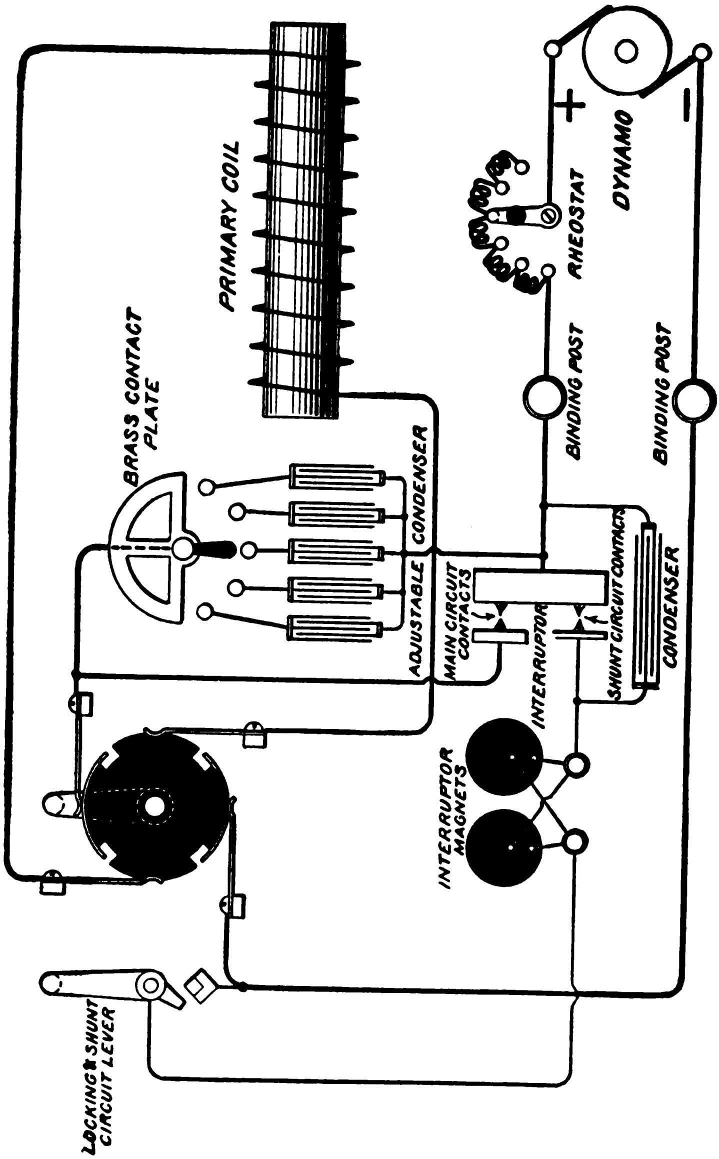


FIG. 124.—COMPLETE WIRING DIAGRAM OF A COLLINS INDUCTION COIL.

armature to one of the terminals of the magnet coils, and the other terminal of the latter on to the shunt-circuit lever. The shunt-circuit contact block *E* is connected with the main line leading to the — binding post as shown.

If now the handle of the reversing commutator is turned to the left, it is obvious that *A* and *D* will rest on one of the segments, and *B* and *C* on the oppositely-disposed one. Under these conditions the current will pass through the inductor in the reverse direction, since it will flow from *B* and *C* to the inductor instead of from *B* and *A*, as it does when the handle is turned to the right. If the handle of the lever is in a neutral position, the brushes *A* and *C* will rest on the arcuated depressions in the surface of the hard-rubber disk, and hence the main circuit will be broken. When the handle of the locking switch is turned back to its neutral position, its contact lever will be thrown off the block *E*, and the pin engaging the slot of the plate will lock the reversing lever. A complete wiring diagram of the foregoing devices is given in Fig. 124.

CHAPTER XVII.

ASSEMBLING THE COIL.

To assemble a small coil is a simple matter, and one that would seem to require no instruction, but I have had oc-

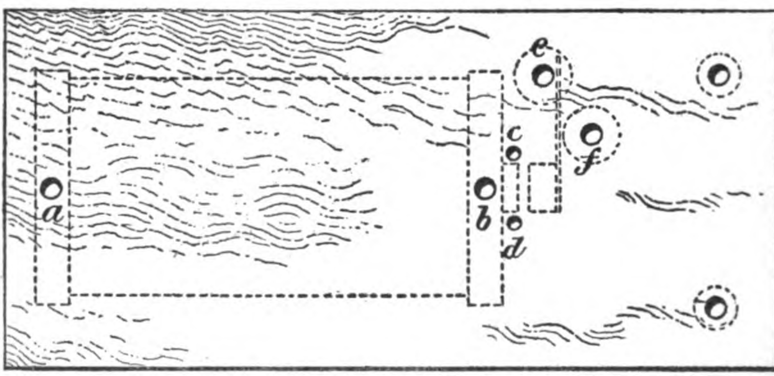


FIG. 125.—PLAN VIEW OF ½-INCH INDUCTION COIL.

casion to observe that in this as in many other things there are two ways to proceed, and the right one will be found the easiest and best.

To begin with, all the parts, together with the necessary wood and machine screws, connecting wire, rubber insulating tube, etc., are laid out on a table or bench. Through the top of the base, holes must be bored for the screws that are to sustain the cheeks of the coil, the interruptor standards, reversing switch, if one is to be used, and the binding posts. Plans for these bases, which include the ½, 1, and 2-inch sizes of coils, are given in Figs. 125, 126, and 127. The first two are drawn to a scale of ½ inch to

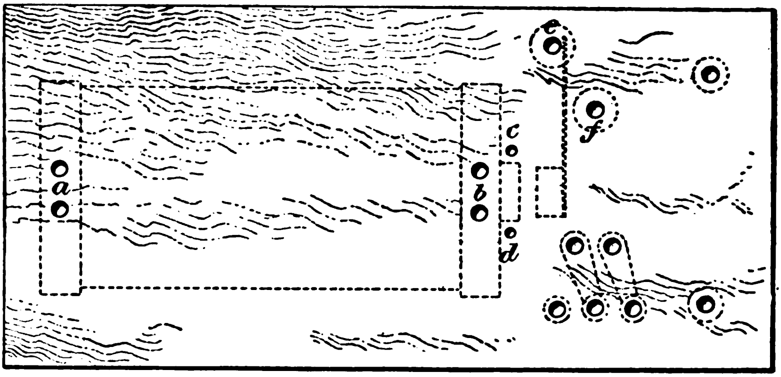


FIG. 126.—PLAN VIEW OF ONE-INCH INDUCTION COIL.

the inch, and the third to ¼ inch to the inch, and a glance will suffice to show the relative positions of the holes, while the distances between them may be ascertained with an ordinary rule. The holes for the screws are indicated by heavy black shaded circles, while the light and dotted lines show the arrangement of the different parts on the base.

The base having thus been prepared, all the metal parts are secured to its top by inserting machine screws and tightening them up. The shank of each screw should be provided with two washers, so that the connecting wire may be looped around it and a good contact made between them. When the interruptor, reversing switch, and binding posts have been set in their proper positions, they should be connected up in so far as possible before the coil is screwed to the base.

This done, the secondary of the coil may be finished off

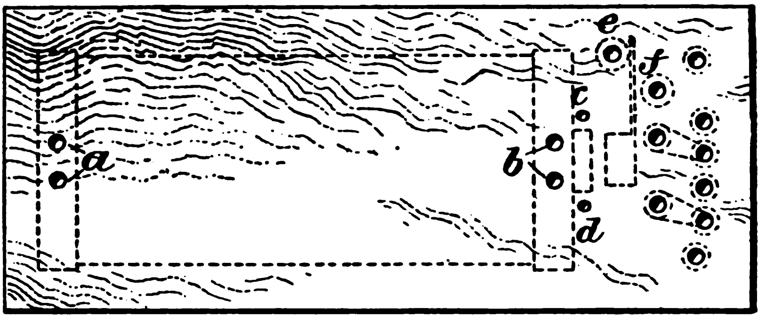


FIG. 127.—PLAN VIEW OF TWO-INCH COIL.

with black bookbinder's cloth, cut so that the ends will overlap ¼ inch and glued together, or a neater appearance may be given the coil by covering it with a thin sheet of hard rubber, and this not only looks better, but prevents the moisture from reaching the paper insulation of the secondary. In this case the ends of the hard-rubber sheet should just meet, and the length, width, and thickness of the sheets required to cover the different sized coils are given in the following table:

TABLE XL.

Sizes of Hard Rubber Sheets for Covering Induction Coils.

Sizes of Coils.	Length of Coil. Inches.	Width of Coil. Inches.	Thickness. Inches.
½ inch.	8⅝		$\frac{1}{32}$
1 inch.	9½		$\frac{1}{32}$
2 inch.	18⅝		$\frac{1}{32}$
4 inch.			$\frac{1}{16}$
6 inch.			$\frac{1}{16}$
8 inch.			$\frac{1}{16}$
10 inch.			$\frac{3}{32}$
12 inch.			$\frac{3}{32}$

Through the sheet of hard rubber oppositely disposed holes are drilled ¼ inch from the edge and ½ inch apart, as shown in Fig. 128, and when this is done it should be immersed in hot water, when it may be easily bent around the coil and laced up with waxed shoemaker's thread; it will then assume the form of a perfect cylinder. The laced juncture is of course placed underneath, and as it sets very closely to the base, it cannot easily be seen. The secondary terminals that have been previously brought through the radial holes in the cheeks are connected to their respective binding posts, which are screwed into the former.

The coil is then screwed to the base with wood screws at *a* and *b*, Figs. 125, 126, and 127, and the primary terminals with their coverings of soft-rubber tubing are brought through the holes *c* and *d* to the under part of the base, where one leads to the standard carrying the vibrating spring and the other to one of the binding posts, as shown in the wiring diagram, Fig. 105, provided no reversing switch is used, or if a three or four-point switch is employed, then the connections must conform to the diagrams, Figs. 106 and 107.

FIG. 128.—HARD RUBBER COVERING.

Before the condenser is set in the interior of the base, terminals should be formed of sheets of tinfoil folded over several times, and the ends of these are twisted around the shanks of the screws *e* and *f* between the washers, so that a good contact may be formed. The condenser may now be laid in and the tinfoil terminals connected to the opposite ends by bending or rolling them up together. The wiring must be scrutinized, to see that it does not touch at any point where it would cause a short circuit; and if there are places where it has a tendency to do so, it should be insulated with paper, mica, or other material. If the condenser does not completely fill the length or depth of the base, then folded papers should be placed around and on it until it cannot be deranged by any subsequent ordinary usage it may get. If the coil is to be carried around or shipped about, it is a good scheme to fill the space in the base not otherwise taken up by the condenser with paraffin, as this will effectually prevent it from shifting. In assembling the 1 and 2-inch coils the method of procedure is exactly the same as that described, but the connections are of course arranged to suit the exigencies of the case. Fig. 129 shows a small coil completely assembled.

Preparatory to assembling an intermediate sized coil, a sheet of hard rubber prepared as described in connection with the small coils is laced tightly around the secondary with the seam on the opposite side from the terminals. The cheeks of the coil are slipped over the protruding ends of the hard-rubber insulating tube that separates the secondary from inductor. The terminals of the secondary should be soldered to flexible silk-covered conductors, 6 or 7 inches in length, formed of several strands of fine wire and inclosed in a good quality of soft-rubber tubing. The terminals thus prepared are drawn through the holes in the cheeks, leaving the free ends exposed above the upper surface. These are cut off about 2 inches above the tops of the cheeks, and the insulation, both rubber and silk, taken off nearly flush with it, so that the bare ends can pass into the brass tubes in the hard-rubber supports for the spark-gap terminals, the purpose of which will soon be apparent.

The cheeks are now secured to the base board by means of four 1½-inch flat-headed wood screws put through the board from the bottom and screwed into each cheek. Next the brace strips are screwed into place on the side, and then the cross strips supporting the hard-rubber standards

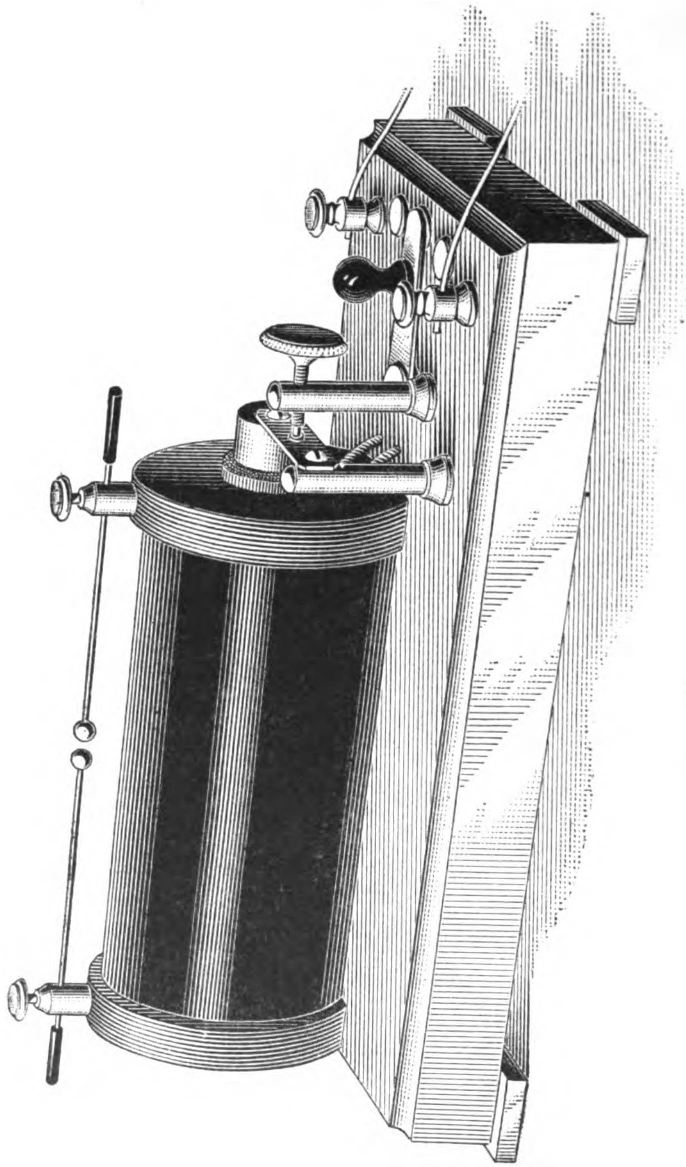


Fig. 129.—Small Coil Complete.

are attached to the upper surface of the cheeks; before these are screwed down, however, the bared terminals of the secondary coil are pushed in the tubes of the standards, where they are retained in good electrical contact with them by the set screws. The inductor is now slipped into the hard-rubber tube, the hard-rubber caps are fitted in its ends, a brass finishing washer and hexagonal nut is put

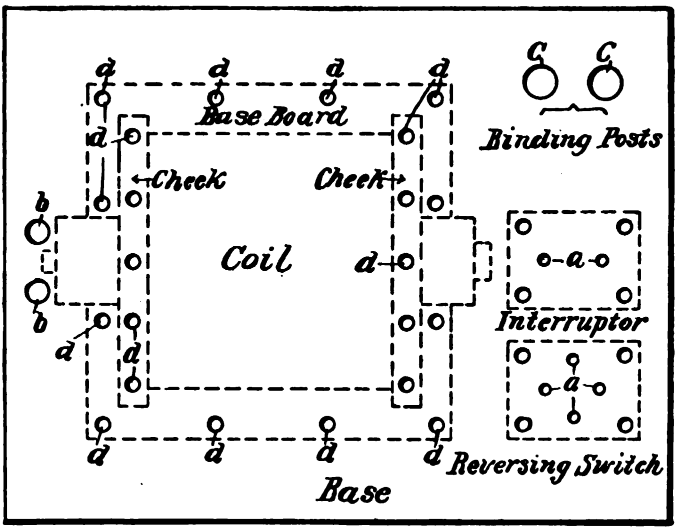


FIG. 130.—PLAN VIEW OF FOUR-INCH COIL.

on the end where the terminals of the primary are joined to the connectors, and a polar projection is screwed on the opposite end of the bar. The wood finishing ends are slipped over the hard-rubber tube and screwed to the outside surfaces of the cheeks.

At the points indicated in Figs. 130, 131, and 132, the smallest circles *a, a, a, a, a, a,* represent 1/8-inch holes bored through the base; the next larger circles, *b, b,* are 1/4-inch holes for the connectors for the primary coil, and the largest circles, *c, c,* are 3/8-inch holes for the large binding posts. One-eighth-inch holes are bored in the base board at the *d* points, but as wood screws are to be used to

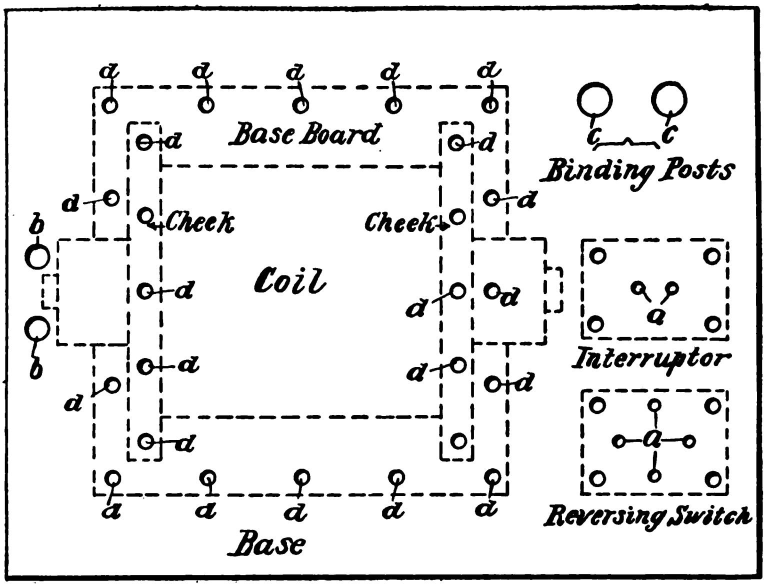


FIG. 131.—PLAN VIEW OF SIX-INCH COIL.

secure the base board to the base proper, the latter need not be bored out.

The coil having been assembled on the base board, attention may now be given to the base proper. Double cotton-covered insulated wire cut off in 8-inch lengths, the ends of which have been scraped, are soldered to the screws holding the interruptor standard and spring to its hard-rubber base, and the standards and brushes of the commutator to its base; round-headed screws may be used for this purpose, as the bases of both these devices are recessed, so that the heads set below the surface and will not therefore come in contact with the top of the base of the coil. The wires from the interruptor and the commutator

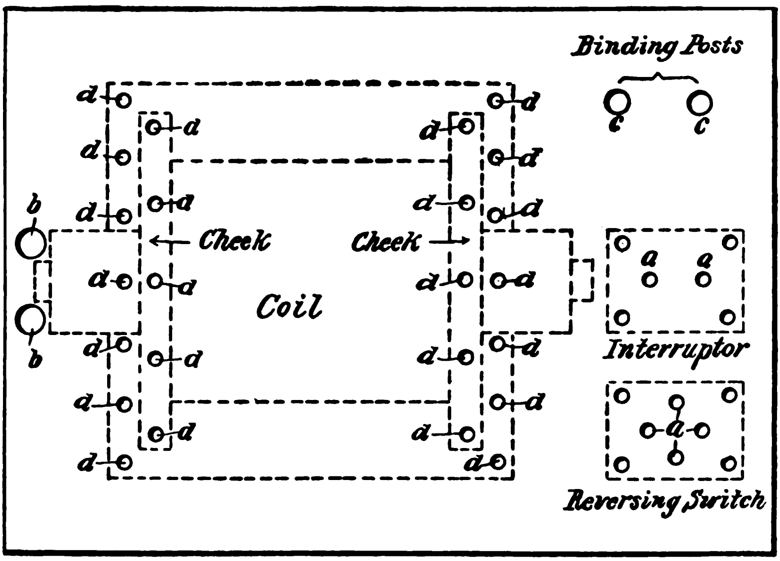


FIG. 132.—PLAN VIEW OF EIGHT-INCH COIL.

are thrust through the holes in the base, and their own bases screwed down with round-headed wood screws. The connections for the primary coil and the leading-in binding posts are put into position and secured down with nuts on the under side of the base. To these wires are likewise soldered.

The beeswax and resin condensers previously suggested for the intermediate sized coils are now selected, and the requisite number taken to give the proper value. These may be inclosed in a shallow soft-wood box with insulated terminals leading out of the ends; the box may be filled with the melted insulating compound and the top put on, when it is ready to be screwed to the under side of the base. The wiring is then proceeded with in accordance with the diagram, Fig. 108 or 109, depending on the type of reversing switch used.

When these connections have been made, the base board carrying the coil is set in position on the base and screwed down; all that now remains to be done is to join the connections on the end of the inductor with the connectors immediately under them, a No. 10 wire being suitable for the purpose, insert the split brass supports carrying the spark-gap terminals into the brass tube of the hard-rubber standard, when the coil will be finished and present an external appearance as illustrated in Fig. 133.

In assembling the 10 and 12-inch coils, a similar method of procedure is followed, since the diagram is virtually the same, this being preferred for the reason that the coil is mounted separately from the subsidiary devices, yet brought into a unit by simply screwing the base board down to the base. The arrangement of the parts is hardly more difficult than that of the intermediate sizes, though the assembling and wiring are considerably more complicated.

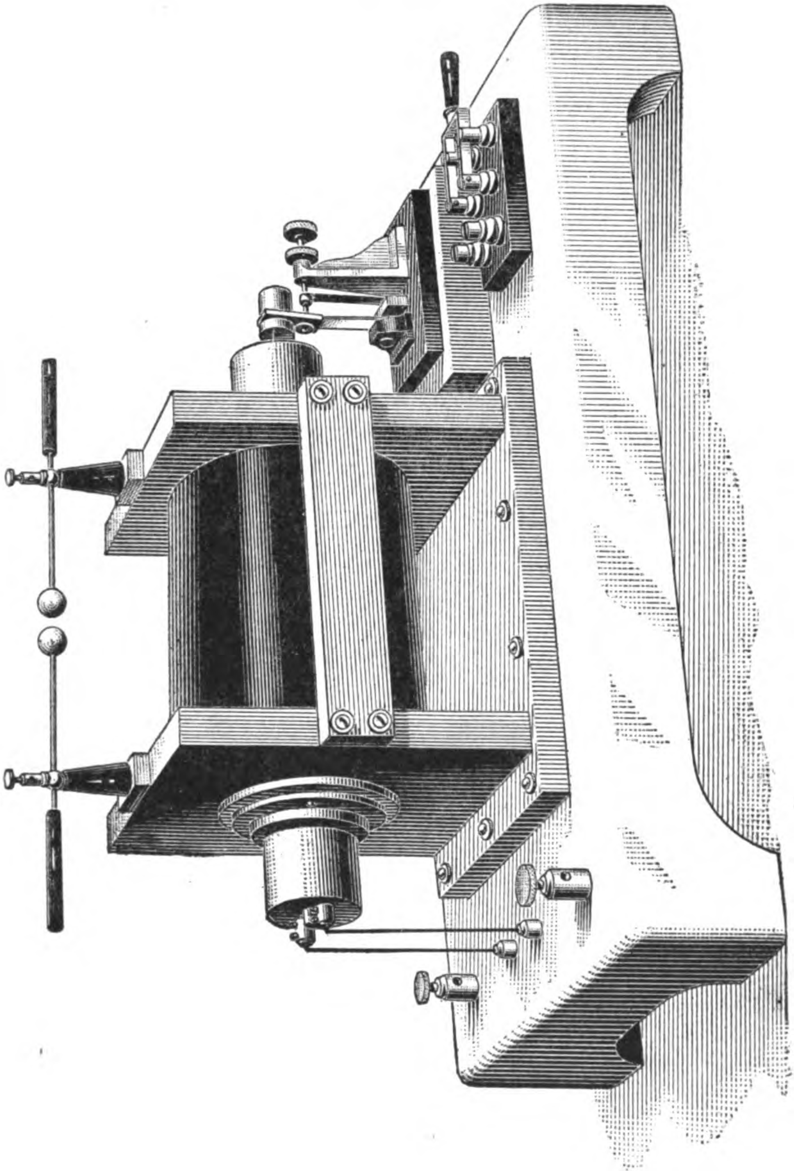


Fig. 133.—Intermediate Coil Complete.

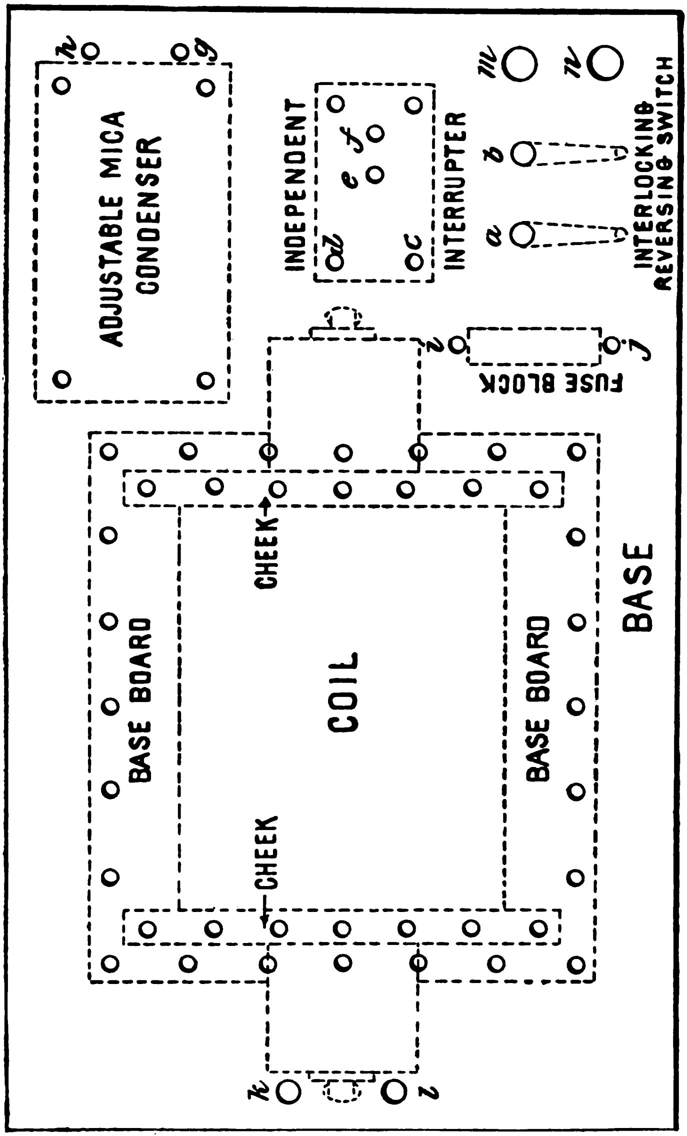


Fig. 134.—Plan View of Ten-Inch Coil.

The usual arrangement adopted by makers where the different subsidiary parts are combined on a single base, is to place the condenser box between the interruptor and the reversing switch. This makes the various adjustments rather awkward, for the interruptor needs looking after more frequently than the condenser; and as the switch handles are low compared with the height of the box, it becomes necessary to reach over the latter, no matter on which side of the coil the operator stands. The disposition of the parts shown in Figs. 134 and 135 obviates this undesirable feature, the condenser box being placed in the rear, the interruptor in the middle, and the locking and reversing handles in front.

In assembling the large coils the terminals of the secondary should be led up through the cheeks in hard-rubber tubes having walls at least 1/8 inch thick, and all possible precautions taken to prevent the high-potential currents from coming in contact with any of the woodwork. Hard-rubber cheeks circumvent this danger, and if expense can be made a secondary consideration, they should by all means be used. The rubber strips on which the adjustable spark-gap terminals have been previously mounted are drilled longitudinally through their centers to the points where the secondary terminals emerge from the tops of the cheeks and the wires—in this case it is better to use bare wire—are led through the hole, to the points where they make contact with the standards supporting the spindle shanks. The inductor is now pushed through the hard-rubber insulating tube, the hard-rubber caps are placed in the ends, finishing washers are put on

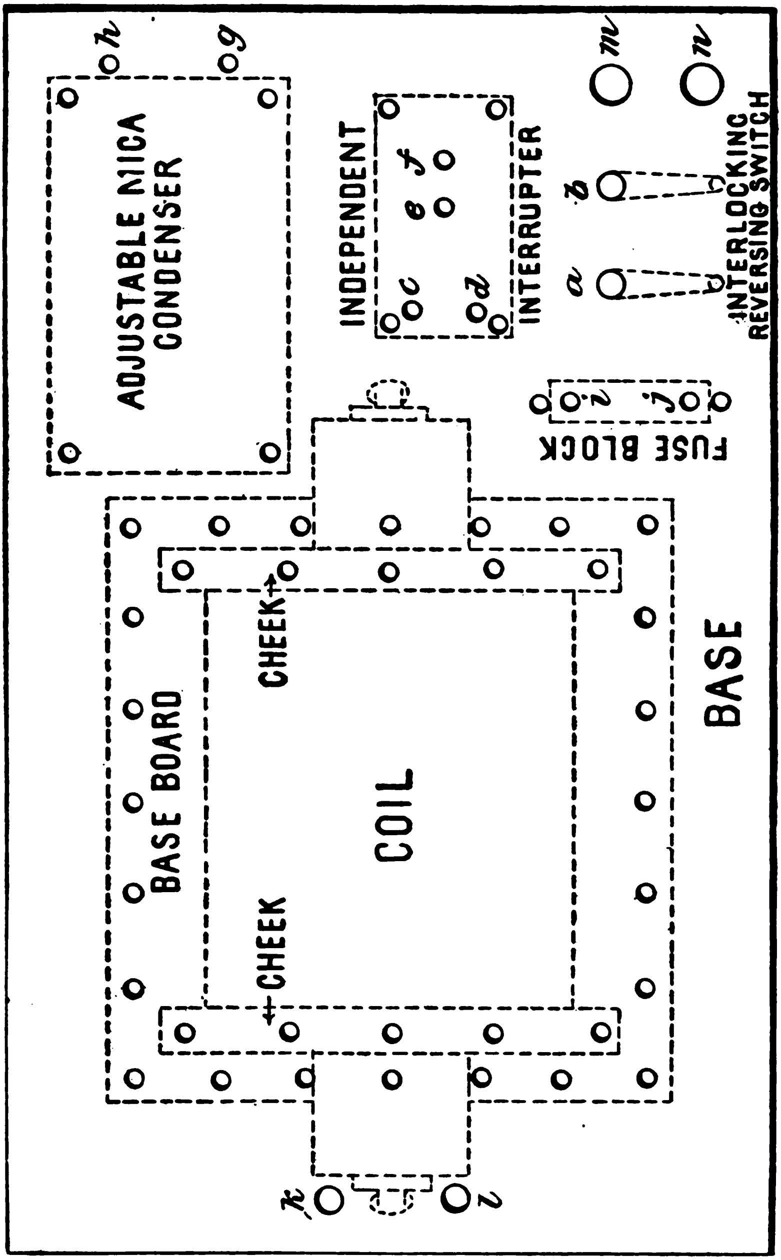


FIG. 135.—PLAN VIEW OF TWELVE-INCH COIL.

next to these, and the whole sustained in position by hexagonal nuts or brass screw caps.

Having mounted the coil on the base board, the subsidiary apparatus may now be secured to the base and the wiring done. It is easiest to mount the interlocking reversing switch first, the interruptor next, and the condenser last. By referring to Fig. 94, it will be observed that two holes are bored half way through the under side of the base board; these holes are $1\frac{1}{4}$ inches in diameter, and are cut out of the base at the points indicated by *a* and *b*, Figs. 134 and 135. The reversing and interlocking spindles carrying the commutator and locking devices are already mounted on a surbase of wood 6 x 4 x $\frac{9}{16}$ inches, as described in Chapter XIII; the upper and free ends of the spindles are inserted through the holes *a* and *b*, and the surbase screwed to the under part of the base proper. The brass collars screwed to the spindles in the recessed holes of the base prevent the spindles from moving downward, while the commutator on the first spindle and the cast-brass locking lever on the second spindle oppose any upward motion. The assembling of the switch is completed by securing the handles to the upper ends of the spindles.

The interruptor has its own binding posts, see Fig. 71, and the insulated wires previously attached to these are inclosed in thin rubber tubing and the ends brought down through the holes *c* and *d*, Figs. 134 and 135, while the terminals from the main-current and shunt-circuit blocks are brought through the holes *e* and *f* when the hard-rubber block of the interruptor is screwed down to the base.

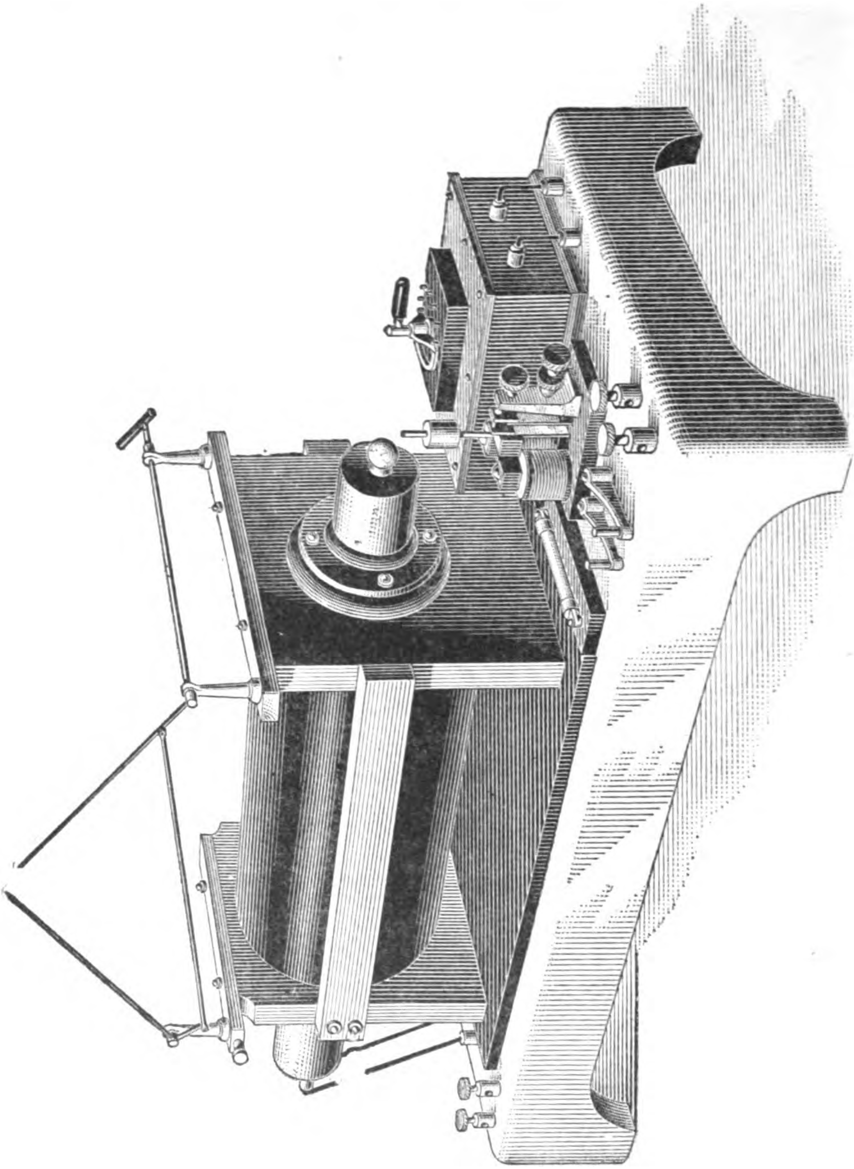


FIG. 136.—LARGE COLLINS COIL COMPLETE.

Projecting from one end of the condenser box is a pair of connectors; the angle plate of the spindle carrying the handle being connected to one of these, and the ends of the condenser sections joined in parallel to the other. Immediately under these connectors, when the box is secured in position on the base, are two binding posts, *g* and *h*; each of the connectors of the condenser is coupled to its binding posts by short lengths of bare copper wire.

The fuse block is also provided with terminals of insulated wire, and these are led through the holes *i* and *j* and the block screwed to the base. Small binding posts are set in the base at *k* and *l*, where they will come immediately under the connectors in the end of the inductor, and the large binding posts with the knurled heads are secured in the corners of the base at *m* and *n*. To the ends of these posts are soldered insulated wires. The instrument is now ready for wiring, all of which is done before the base board supporting the coil is screwed to the base. When this is finished and the coil and base are formed into a unit, the connectors of the inductor are coupled to the posts *k* and *l* by short lengths of heavy bare copper wire. This completes the coil, and when finished it presents the appearance shown in Fig. 136.

The design of the coils may be changed if the basic principle of coil making, high insulation, is adhered to, and the larger the coil, the more care must be exercised in the elimination of air in the secondary, which disrupts it by overheating, and the prevention of short circuits in the primary by the use of heavily-covered wire and mica where the wires cross each other.

CHAPTER XVIII.

SOURCES OF ELECTROMOTIVE FORCE.

For the operation of induction coils where vibrating-spring interruptors, such as those described in the preceding chapters, are employed, it is necessary to use a direct current. The reason alternating currents cannot be used to energize a coil equipped with these make-and-break devices is that the time required for the reversals is too great to give effective spark lengths without excessive heating.

Direct current suitable for energizing induction coils may be obtained from primary or storage batteries or from 110-volt lighting circuits. Where primary batteries are utilized, especially for the intermediate and larger sized coils, a considerable excess of current must be provided or the resulting sparks will lack power, and the coil, however well designed and constructed, will not be effective.

For a ½-inch coil a battery of dry cells will serve to develop enough current to energize it, provided it is used intermittently, as for instance in sending wireless telegraph signals, but dry batteries are by no means recommended even for this purpose, for they quickly drop in both voltage and current. Dry cells are not really dry, but are very convenient to handle, since they do not contain any free liquid to run out. The elements are of zinc and carbon, and the space between them is filled with a paste that acts as a depolarizer. Various compositions are used for the paste by different makers, but the following formula gives excellent results: Charcoal, 3 parts; graphite, 1 part; peroxide of manganese, 3 parts; slaked lime, 1 part; white arsenic, 1 part; and a mixture of starch and glucose, 1 part. These are thoroughly mixed while dry and are then worked into a smooth paste with equal parts of a saturated solution of sal ammoniac and a similar solution of common salt to which a $\frac{1}{10}$ (by

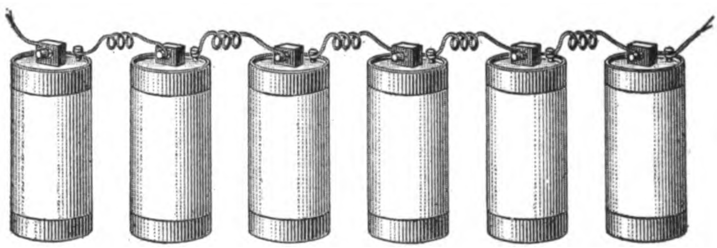


FIG. 137.—DRY CELLS IN SERIES.

volume) saturated solution of corrosive sublimate and $\frac{1}{10}$—also by volume—of hydrochloric acid have been added.

The minimum number of dry cells that should be used with a ½-inch coil are four, but six or eight will give a heavier discharge. Where four cells are used, they should be coupled together in series, namely, each zinc terminal should be connected to the next carbon terminal, as shown in Fig. 137. Where six or more cells make up the battery, they may be connected in series parallel, as illustrated in the diagram, Fig. 138. Each cell will give at the beginning at least 1.5 volts, and 8 volts and 1 or

2 amperes will suffice to give fairly good results. If the illumination of Geissler tubes and other experiments are to be preferred, where a continuous current, though its duration may be but a few moments, is required, it is strongly advised to use a fluid battery.

For the operation of coils larger than the ½-inch size, dry batteries are simply out of the question. Where the

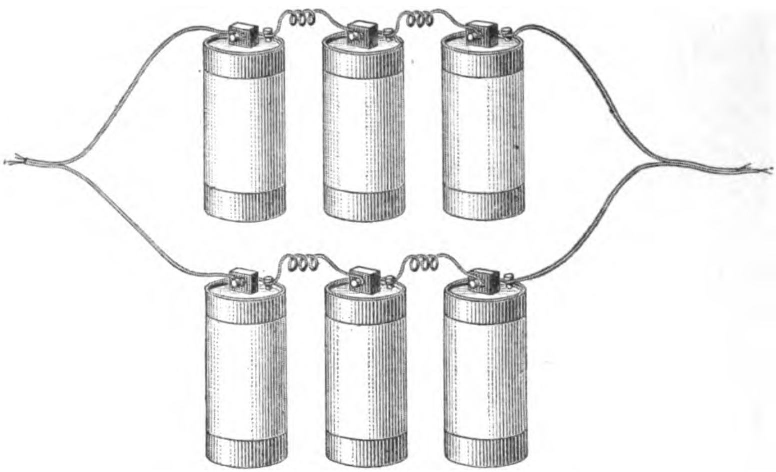


FIG. 138.—DRY CELLS IN SERIES-PARALLEL.

smaller coils are used for periodic experimental work, a plunge battery will be found convenient and satisfactory. The cells of this type of battery comprise a zinc plate hung between, but insulated from, two carbon plates. These elements are immersed in a solution composed of 1 pound of powdered bichromate of potash dissolved in 1 gallon of hot water. When this is cold, from ½ to 1 pint of commercial sulphuric acid is added, according to the action desired.

When impure zinc is used for the positive element, miniature closed circuits are set up between the particles of foreign matter and those of the zinc, and this local action, as it is termed, quickly destroys the zinc plate and weakens the current output. Chemically-pure zinc would prevent this outward action, but it is too expensive for

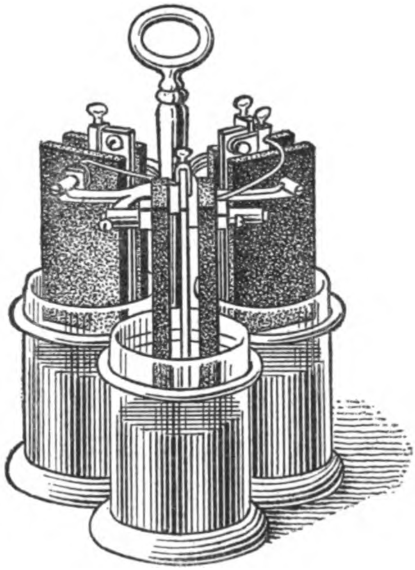


Fig. 139.—Small Plunge Battery.

general use. Ordinary commercial zinc contains many impurities, but the waste of zinc and decrease of current may be prevented by amalgamating the zincs. This may be done by cleaning the zincs with hot water to which a small quantity of sulphuric acid has been added. A little mercury is then poured on the surface of the zincs and rubbed in with a cloth dampened in the acidulated water.

In the plunge battery a number of bichromate of potash cells are arranged in a metal or wood frame so equipped that the elements of each cell can be raised or lowered simultaneously from the solution. Various devices are utilized to accomplish this movement. Fig. 139 shows a small plunge battery mounted on an iron stand and which is well adapted to operate a ½-inch coil. Fig. 140 illus-

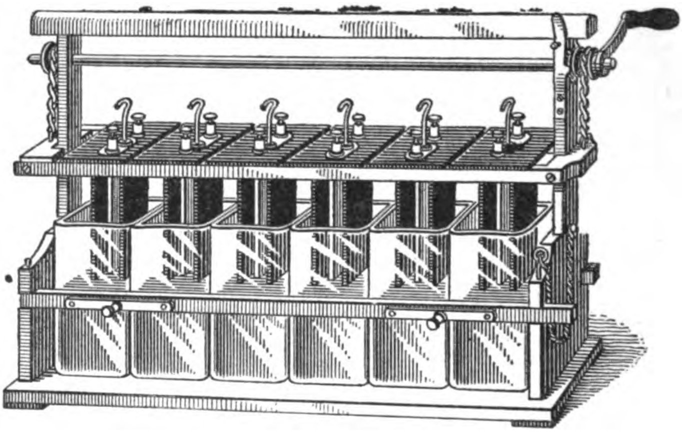


FIG. 140.—LARGE PLUNGE BATTERY.

trates a much more powerful battery suitable for the 1 and 2-inch coils, having six cells and arranged with a rack and pinion movement, or a chain and pulley to which is attached a crank, so that the elements may be raised and lowered in the solution. For the 1 and 2-inch coils, if these are to be used continuously for given periods, a primary battery of from six to twelve cells of the Edison type, or a storage battery of two to four cells, will be required.

Likewise for the intermediate-sized coils, a battery of these primary cells may be used or a storage battery or a direct current from a 110-volt circuit employed. Where the Edison battery is to supply the current, type "S," having a capacity of 300 ampere hours without renewal, is most suitable. Each cell has an initial electromotive force of 0.95 volt, which drops to 0.7 when the circuit is closed. Batteries made up of the cells differ from all primary batteries in that they require no attention until the charge is completely exhausted; as there is no local action, it does not deteriorate when not in use. Further, this battery has a very low internal resistance, and delivers a heavy current that is constant. The general appearance of the cell is shown in Fig. 141. The following table shows the minimum number of cells required to operate the different-sized coils:

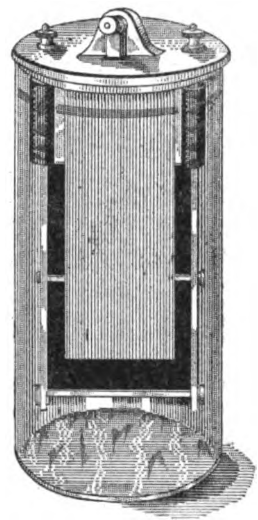


FIG. 141.—EDISON PRIMARY CELL.

TABLE XLI.

Number of Edison Primary Cells Required for Coils.

Spark Length of Coil, inches.	Number of Cells, minimum.
1	5
2	7
4	9
6	12
8	15
10	18
12	21

Storage batteries are to be preferred to primary batteries, as they require practically no attention, are less liable to breakage, and occupy less space. The storage battery known under the trade name of the *chloride accumulator* is one of the best on the market. It is made in portable sizes, gives off no fumes, and has no glass jars to break. Two tables of sizes are given below, and are designated as *preferred* and *non-preferred* batteries. The preferred sizes have a larger capacity, and are better adapted for heavy service in wireless telegraph stations and hospitals, where they will develop energy for transmitters or X-ray tubes for a month or six weeks without recharging. The non-preferred sizes are exactly the same as the preferred sizes in every respect, except that they have a smaller ampere-hour or total current capacity.

TABLE XLII.

Preferred Sizes of Portable Storage Batteries.

Spark Length of Coil, inches.	Number of Cells.	Weight of Battery, pounds.
4	2	58
6	3	83
8	4	108
10	5	133
12	6	158

Each individual cell in the above group of batteries has a total capacity of 7½ amperes for eight hours, and will run a correspondingly longer time with a current of proportionately lesser value.

TABLE XLIII.

Non-Preferred Sizes of Portable Storage Batteries.

Spark Length of Coil, inches.	Number of Cells.	Weight of Battery, pounds.
4	2	43
6	3	62
8	4	81
10	5	100
12	6	123

In the above group each individual cell has a total

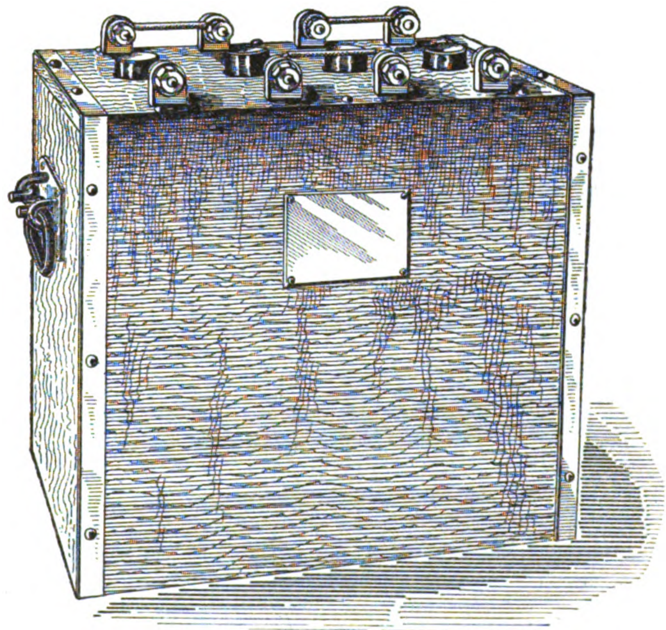


FIG. 142.—STORAGE BATTERY.

capacity about two-thirds that of the preferred sizes. For wireless telegraph field work and for the occasional use of physicians, this size will be found large enough. The chloride accumulator is shown in Fig. 142.

Where possible it is preferable to operate 6-inch and larger coils on 110-volt circuits, as the increased energy gives a much heavier spark. In order to utilize a 110-volt current with coils, it is necessary to include in the primary circuit a suitable resistance or rheostat, connected as shown in Fig. 124. When a coil is operated on a battery circuit in connection with an independent interruptor, it will break the circuit from 200 to 400 times per minute, while on a 110-volt circuit it will break it nearly 800 times per minute.

It is not advisable to operate a coil on a 220-volt circuit, since the reactive kick on the primary becomes so great that it is a source of danger to both operator and coil. Where a 220 or 500-volt direct current only is available, a small motor generator should be installed. A motor generator has two windings on its armature; the current entering one drives it as a motor, while the other serves to generate current. Motor generators designed for use with induction coils deliver a current of 15 amperes at 20 volts, an output equal to the voltage of ten storage battery cells giving 15 amperes, or about thirty Edison cells. It is obviously better to reduce a 110 or 220-volt current with a motor generator than to interpose a rheostat, since with the former there is little loss of energy, while with the latter to take up the excess there is a large percentage wasted. Fig. 143 shows a motor generator designed to convert 110, 220, or 500 volts direct current to 20 volts direct current.

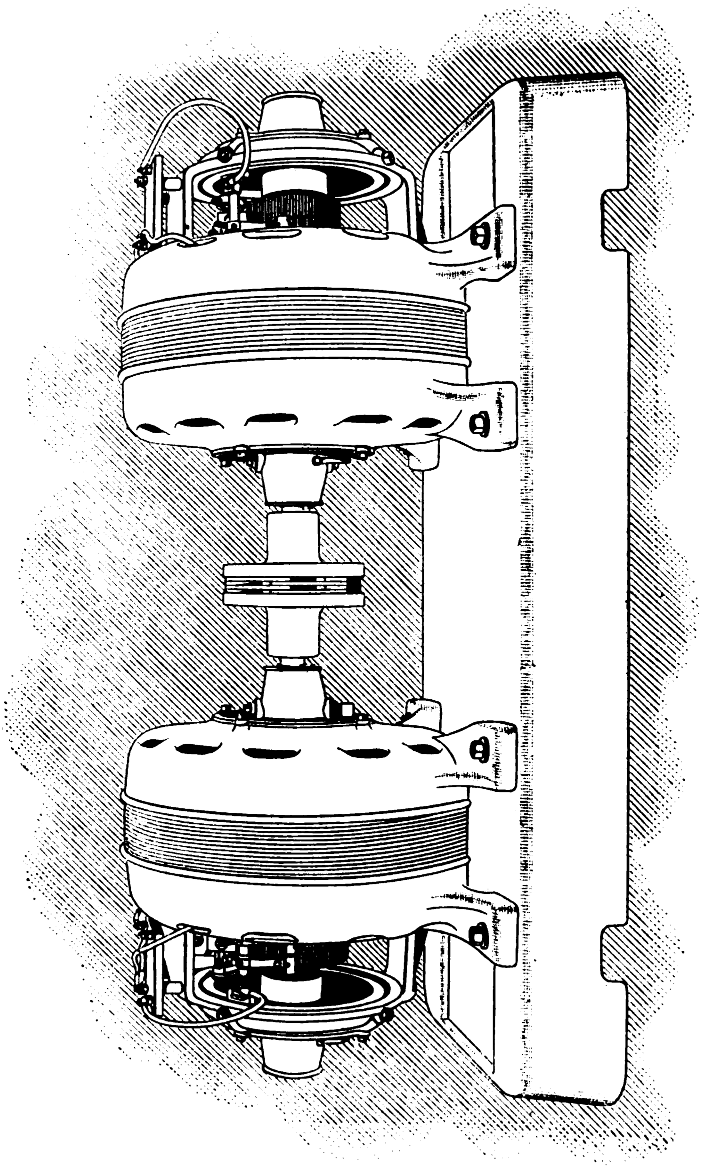


Fig. 143.—Direct Current Motor Generator Set.

An alternating current, as previously stated, cannot be employed to operate an induction coil where the latter is equipped with a mechanical spring interruptor, but where alternating currents only are available, an electrolytic interruptor or a mercury turbine interruptor can be inserted in the circuit instead of the vibrating-spring make-and-break device, though such arrangements are far from economical.

When an alternating current is used in connection with an electrolytic interruptor, the positive impulses only will generate gas bubbles on the platinum point, for the upper half of the current wave is always in the same direction, the negative impulses do not exhibit any appreciable effect, since these are not capable of electrolyzing the solution.

Even when a direct current is used the electrolytic interruptor is very wasteful of current, and under these conditions, with an alternating current this loss is accentuated, for only one-half of the current is serviceable, and moreover the platinum point rapidly deteriorates, both of which are costly features.

The mercury turbine interruptor is likewise expensive when operated with an alternating current; where it is thus used, it should be driven by a synchronous motor, when the revolving segment of the device will shear off the crest of each current wave, and the interrupted current will flow into the primary coil unidirectionally. Instead of using these interruptors interposed in an alternating-current circuit, it is better to utilize a rotary converter or alternating-current motor generator. This machine comprises an alternating-current motor the armature of

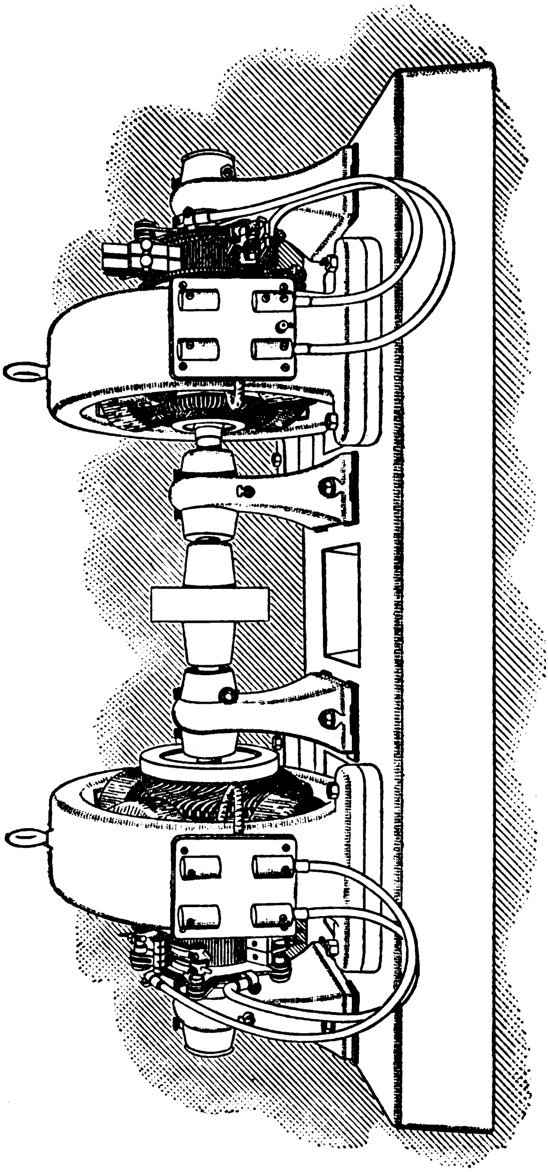


Fig. 144.—Alternating Current Motor Generator Set.

which is coupled to the shaft, carrying at its opposite end the armature of a direct-current dynamo, as shown in Fig. 144; the former operating on single, two, or three phase 110, 220, or 500-volt currents, while the latter delivers a direct current of 10 amperes and 20 volts, suitable for the induction coil.

CHAPTER XIX.

THE COST AND PURCHASE OF MATERIALS.

It would be exceedingly difficult to state definitely the cost of the materials required to construct any of the coils herein enumerated, for nearly all the supplies used are subject to the fluctuations of the market. The following price lists will nevertheless serve to give the intending purchaser a very good idea of how the materials are sold at the prices quoted, and are believed to be fairly accurate at the present writing.

To further facilitate the buying of such stocks as may be necessary, the names of the manufacturers and dealers can be obtained from the author.

In some instances the makers sell only in large quantities, and to differentiate from dealers where small parcels may be purchased, the former are marked thus: (wholesale).

TABLE XLIV.

Price List of Annealed Iron Wire for Cores.

Numbers	18	19	20	21	22
Cents per pound	8	9½	10	10½	11

TABLE XLV.

Price List of Magnet Wire for Primary Coils.

Double Cotton-Covered.

Number of Wire B. & S. Gage.	Cents per Pound.
16	$0.28
14	.27
13	.26½
12	.26
10	.25

TABLE XLVI.

Price List of Bare Copper Wire for Small Secondary Coils.

Number of Wire, B. & S. Gage.	Cents per Pound.
38	$0.38
40	.66½

TABLE XLVII.

Price List of Cotton and Silk Covered Magnet Wire for Secondary Coils (Wholesale).

Number.	Price per Pound.			
B. & S. Gage.	Cotton Covered.		Silk Covered.	
	Single.	Double.	Single.	Double.
17			$0.41	$0.47
18			.42	.48
19			.43	.49
20	$0.29	$0.32	.44	.50
21	.30	.35	.45	.51
22	.31	.37	.46	.53
23	.32½	.38	.48	.56
24	.34	.42	.51	.61
25	.36½	.46	.55	.68
26	.40	.50	.60	.75
27	.43	.55	.65	.83
28	.46	.60	.69	.87
29	.48	.65	.74	.92
30	.51	.71	.80	1.06
31	.56	.77	.88	1.28
32	.62	.82	.99	1.54
33	.72	.94	1.12	1.70
34	.82	1.10	1.27	2.00
35	.93	1.25	1.44	2.30
36	1.06	1.50	1.70	2.50
37	1.35	2.15	2.10	3.30
38	1.80	2.85	2.45	3.70
39	2.35	3.60	3.10	4.50
40	3.00	4.50	4.00	5.40

The prices quoted are for lots of 20 pounds or more of wire from No. 10 to No. 16, and 10 pounds or more for lots from No. 16 to No. 40.

TABLE XLVIII.

Price List of Magnet Wire in One-Pound Lots or More.

Size by B. & S. Gage.	Single Covered.		Double Covered.		Size by B. & S. Gage.	Single Covered.		Double Covered.	
	Cotton.	Silk.	Cotton.	Silk.		Cotton.	Silk.	Cotton.	Silk.
10	$0.28	..	$0.30	..	26	$0.88	$1.68	$1.12	$2.32
11	.30	..	.32	..	27	1.00	1.80	1.26	2.46
12	.30	..	.32	..	28	1.08	1.92	1.36	2.60
13	.32	..	.36	..	29	1.20	2.20	1.52	3.02
14	.32	..	.36	..	30	1.32	2.36	1.66	3.22
15	.37	..	.41	..	31	1.44	2.60	1.80	3.52
16	.37	$0.90	.41	$1.24	32	1.95	3.45	2.28	4.53
17	.39	.90	.45	1.24	33	2.40	3.90	2.85	5.10
18	.39	.92	.45	1.26	34	2.85	4.10	3.42	5.30
19	.43	.92	.49	1.26	35	3.25	5.85	3.88	7.78
20	.48	.94	.60	1.28	36	4.37	7.00	4.93	8.88
21	.56	.96	.70	1.32	37	6.75	11.00	7.25	13.63
22	.62	1.04	.76	1.42	38	9.00	13.00	9.50	14.50
23	.66	1.14	.84	1.56	39	11.00	15.00	12.00	18.00
24	.72	1.26	.92	1.72	40	13.00	20.00	15.00	23.00
25	.80	1.44	1.02	2.00					

TABLE XLIX.

Price List of Magnet Wire on One-Pound Spools or Less.

Size by B. & S. Gage.	Single Cotton Covered.				Size by B. & S. Gage.	Double Cotton Covered.			
	1 ounce Spool.	2 ounce Spool.	¼ lb. Spool.	1 lb. Spool.		1 ounce Spool.	2 ounce Spool.	¼ lb. Spool.	1 lb. Spool.
16	..	..	$0.20	$0.37	16	..	..	$0.23	$0.41
18	..		.22	.39	18	..	..	.25	.45
20	.	$0.10	.26	.48	20	..	$0.12	.33	.60
22	$0.08	.12	.34	.62	22	$0.10	.15	.42	.76
24	.08	.15	.45	.72	24	.10	.17	.51	.92
26	.10	.15	.48	.88	26	.12	.20	.62	1.12
28	.12	.20	.59	1.08	28	.15	.25	.75	1.36
30	.12	.24	.73	1.32	30	.15	.26	.91	1.66
32	.16	.32	1.07	1.95	32	.18	.35	1.25	2.28
34	.25	.50	1.57	2.85	34	.27	.54	1.88	3.42
36	..		2.40	4.37	36	..	..	2.71	4.93

TABLE L.

Price List of 18 Per Cent German Silver Resistance Wire.

No. B. & S.	Ohms. 1000 Ft.	Bare per Pound.	Cotton Covered.		Silk Covered.	
			Single.	Double.	Single.	Double.
0	1.7	$0.78	....	....	....	....
1	2.2	.78	....	....	....	....
2	2.8	.78	...	....	....	....
3	3.6	.78	....	....	....	....
4	4.5	.78	....	....	....	....
5	5.7	.78	....	...	....	....
6	7.2	.78	....	....	....	....
7	9.1	.78	...	....	....	....
8	11.5	.78	....	.	....	....
9	14.5	.78	....	....	...	....
10	18.1	.78	....	....	....	....
11	22.8	.78	....	....	....	....
12	28.8	.78	...	....	....	....
13	36.5	.78	....	....	....	....
14	46.1	.78	....	....	....	...
15	58.2	.78	....	....	....	....
16	72.7	.78	$1.40	$1.70	$1.85	$2.38
17	93.4	.80	1.40	1.70	1.85	2.38
18	118.	.80	1.40	1.70	1.85	2.38
19	146.	.83	1.40	1.70	1.85	2.38
20	184.	.83	1.42	1.74	1.88	2.43
21	234.	.95	1.44	1.75	1.93	2.48
22	295.	.98	1.52	1.83	2.06	2.64
23	370.	1.03	1.62	1.98	2.21	2.87
24	468.	1.08	1.71	2.09	2.37	3.08
25	590.	1.08	1.84	2.26	2.65	3.48
26	749.	1.14	2.05	2.48	3.02	3.93
27	936.	1.25	2.25	2.73	3.23	4.20
28	1,192.	1.40	2.45	2.98	3.42	4.43
29	1,480.	1.55	2.60	3.13	3.85	5.00
30	1,890.	1.75	2.84	3.38	4.14	5.33
31	2,386.	1.95	3.09	3.66	4.52	5.81
32	2,950.	2.35	3.59	4.21	4.94	6.23
33	3,740.	2.60	3.96	5.61	5.46	6.89
34	4,760.	2.95	4.61	5.44	5.84	7.29
35	6,020.	3.65	5.01	5.69	7.52	9.45
36	7,560.	6.50	8.09	8.88	10.00	11.75
37	9,550.	11.50	13.00	13.75	18.50	22.00
38	12,038.	18.00	24.00	27.00	28.00	33.00
39	15,240.	22.00	33.00	36.00	38.00	40.00
40	19.285.	30.00	40.00	42.00	45.00	48.00

TABLE LI.

Price List of German Silver Wire.

Single Silk Insulation on One Ounce Spools.

Numbers	20	22	26	28	32
Price, per ounce	35 cts.	35 cts.	40 cts.	50 cts.	60 cts.

NOTE.—In ordering wire to be sent by mail, postage must be added.

TABLE LII.

Price List of "Advance" Resistance Wire.

No. B. & S.	Ohms, per 1,000 Ft.	Bare, per Pound.	Cotton Covered.		Silk Covered.	
			Single.	Double.	Single.	Double.
10	29.	$1.50	$2.20	$2.50	$3.00	$4.40
11	36.3	1.50	2.20	2.50	3.00	4.40
12	46.	1.50	2.20	2.50	3.00	4.40
13	58.	1.55	2.20	2.50	3.00	4.40
14	73.5	1.55	2.20	2.50	3.00	4.40
15	92.5	1.55	2.20	2.50	3.00	4 40
16	117.	1.60	2.20	2.50	3.00	4.40
17	147.	1.60	2.20	2.50	3.00	4.40
18	186.	1.60	2.20	2.50	3.00	4.40
19	234.	1.65	2.20	2.50	3.00	4.40
20	296.	1.70	2.20	2.50	3.00	4.40
21	374.	1.75	2.40	2.70	3.20	4.60
22	470.	1.80	2.60	2.90	3.30	4.70
23	597.	1.80	2.80	3.10	3.40	4.80
24	748.	1.86	3.00	3.30	3.50	5.00
25	946.	1.94	3.20	3.50	3.80	5.40
26	1193.	1.98	3.40	3.70	4.20	5.80
27	1498.	2.05	3.60	3.90	4.60	6.40
28	1890.	2.10	3.80	4.40	4.90	7.00
29	2408.	2.25	4.00	4.70	5.50	7.60
30	3005.	2.40	4.50	5.50	6.00	8.20
31	3789.	2.55	4.80	5.60	6 60	9.00
32	4779.	2.75	5.20	6.00	7.40	9.80
33	6025.	3.00	5.70	6.50	8.00	11.00
34	7600.	3.30	6.60	7.40	9.00	12.00
35	9583.	3.70	7.00	8.00	10.60	13.20
36	12081.	4.50	10.00	11.60	13.00	16.50
37	15229.	7.80	13.00	14.40	19.00	24.00
38	19213.	12.00	16.00	18.00	24.00	33.00
39	24218.	15.50	20.00	22.00	30.00	39.00
40	30570.	20.00	24.00	27.00	36.00	45.00

TABLE LIII.

Price List of "Climax" Resistance Wire.

No. B. & S.	Bare, per Pound.	Cotton Covered.		Silk Covered.	
		Single.	Double.	Single.	Double.
8 and heavier.	$1.10	$2.40	$3.10	....	....
9	1.10	2.40	3.10	....	....
10	1.15	2.40	3.10	....	....
11	1.15	2.40	3.10	....	....
12	1.15	2.40	3.10	....	....
13	1.20	2.65	3.35	....	....
14	1.20	2.65	3.35	....	....
15	1.20	2.65	3.35	....	....
16	1.25	2.65	3.35	....	....
17	1.25	2.65	3.35	...	...
18	1.30	2.93	3.56	$3.90	$4.70
19	1.30	2.93	3.56	3.90	4.70
20	1.30	2.98	3.63	4.05	4.80
21	1.35	3.03	3.66	4.05	4.80
22	1.35	3.19	3.83	4.24	4.94
23	1.35	3.40	4.16	4.60	5.46
24	1.40	3.60	4.40	4.90	5.74
25	1.40	3.86	4.78	5.30	5.76
26	1.40	4.30	5.20	5.80	6.10
27	1.50	4.73	5.73	6.10	6.14
28	1.60	5.13	6.26	6.60	7.75
29	1.70	5.46	6.56	6.94	8.50
30	1.85	5.96	7.10	7.40	8.98
31	2.00	6.50	7.70	7.90	10.00
32	2.25	7.53	8.83	9.20	10.40
33	2.50	8.30	9.73	10.10	11.50
34	3.25	9.66	11.43	11.84	13.40
35	4.00	10.53	11.93	12.30	13.90
36	5.00	17.00	18.63	19.20	21.00
37	6.25	20.00	22.00	24.00	26.00
38	9.00	24.00	24.00	27.00	29.00
39	12.00	30.00	32.00	31.00	34.00
40	15.00	33.00	36.00	35.00	39.00

TABLE LIV.

Price List of Insulating Materials.

	Price per Pound.
Paraffin, pure, hardest	$0.15
Resin, white (in 5-pound lots 6 cts.)	.10
Beeswax, good quality	.65
Sealing wax	.15
Gum shellac, orange or amber	.60
	Price per Gallon.
Alcohol, wood (methylic)	$0.70

TABLE LV.

List of Insulating Varnishes and Impregnating Compounds.

Insulating varnish.
Quick-drying insulating varnish.
Special cloth varnish.
Voltalac insulating compound.
Baking voltalac.
H. R. voltalac.
Black finishing varnish.
Flexible mica sticking varnish.

TABLE LVI.

Price List of Selected Mica.

Size.	Price per Pound.
1½ x 3	$1.50
1¾ x 3	1.80
2 x 2	1.75
2¼ x 2¼	2.00
2½ x 2½	2.55
2¾ x 2¾	3.00
3 x 3	5.00
3¼ x 3¼	5.25
3½ x 3½	6.00
4 x 4	7.50
4½ x 4½	8.25
5 x 5	9.00
5½ x 5½	10.00
6 x 6	11.00
7 x 7	15.00
8 x 8	16.50
8 x 10	17.50

(30 per cent discount from listed price.)

TABLE LVII.

Price List of Tinfoil.

	Per Pound.
Plain composition foil, in 50-lb. lots	$0.25
Plain composition foil, in 5-lb. lots	.50
Yields about 5,500 square inches per pound.	
"Extra light" foil, in 50-lb. lots	.52
"Extra light" foil, in 5-lb. lots	1.10
Yields about 13,000 square inches per pound.	

TABLE LVIII.

Price List of Hard-Rubber Insulating Tubes.

Length.	Inside Diam.	Outside Diam.	Thickness of wall.	Price.
12 1/2" long	2 1/2" i.d. x	2 3/4" o.d.	1/8 " wall	$2.25 each
14 1/2" long	2 7/8" i.d. x	3 1/4" o.d.	3/16" wall	2.75 each
18 5/8" long	3 1/4" i.d. x	3 3/4" o.d.	1/4 " wall	3.50 each
22 7/8" long	3 5/8" i.d. x	4 1/4" o.d.	5/16" wall	6.25 each

TABLE LIX.

Price List of Hard-Rubber Sheets.

Sheet hard rubber in the regular size sheets, 20" x 48", 20" x 24" and 20" x 12" from 1/8" to 1" inclusive, in thickness, 75c. per lb.

TABLE LX.

Price List of Hard-Rubber Rods.

Hard rubber rods from 1/4" to 2" diam., in the rough, that is unfinished, and in the regular 24" lengths, 75c. per lb. These prices are for a medium quality of this material which is carried in stock.

TABLE LXI.

Price List of Binding Posts and Connectors.

Number.	Price Each.	Number.	Price Each.
1	$0.03	8	$0.20
2	.04	9	.10
3	.05	10	.12
4	.07	11	.14
5	.10	12	.35
6	.10	13	.40
7	.09	14	.12
		15	.15

A discount of from 25 to 50 per cent is usually allowed where posts are purchased in lots of 100.

TABLE LXII.

Price List of Brass Rods.

	Per Pound.
Round brass rod, hard drawn, ⅛ to 3 inches in diameter	$0.35
Hexagonal brass rod, ⅛ to 2 inches in diameter	.40
Square brass rod, 3/16 to 1 inch in diameter	.40
Half-round brass rod, ⅜ to 1 inch in diameter	.40

These brass rods are made from selected copper and spelter, are straight and true, and especially adapted for free turning.

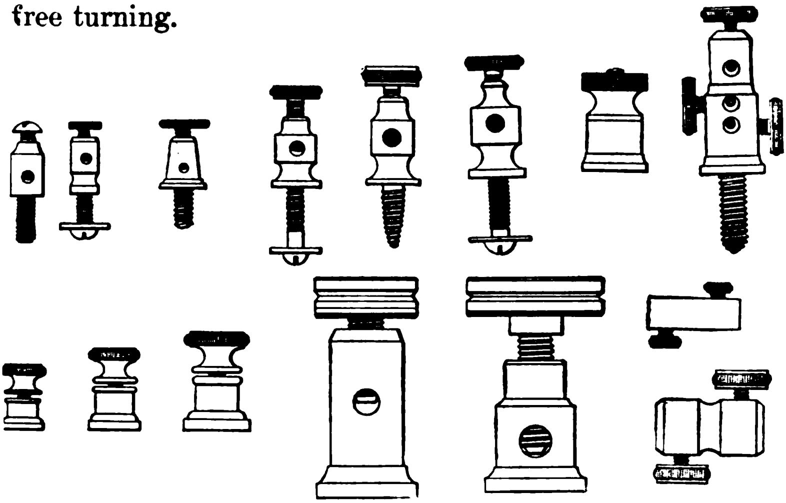


FIG. 145.—FORMS OF BINDING POSTS AND CONNECTORS.

TABLE LXIII.

Price List of Machine-Made Brass Hexagonal Nuts.

Diameter.	Thick.	Threads.			Price per 100.
3/16	3/32	2/56	3/48		$0.45
1/4	3/32	4/36	4/40		.45
5/16	1/8	6/32	8/32		.52
3/8	1/8	10/32	10/24	12/24	.65
7/16	5/32	14/20	14/24	¼/20	.95
1/2	3/16	¼/20	16/20	16/18	1.35
9/16	3/16	5-16/18	18/18	⅜/16	1.75
5/8	3/16	24/16		7-16/14	2.10
11/16	1/4	½/12		½/13	3.15
3/4	1/4	½/12		½/13	3.75

TABLE LXIV.

Price List of Simple Spring Interruptors.

For ½-inch coil	$1.00
For 1-inch coil	1.50
For 2-inch coil	2.00

TABLE LXV.

Price of Platinum.

Platinum wire or sheet can be had in any size down to 0.007 inch at $35 per Troy ounce net cash.

TABLE LXVI.

Price of Vacuum Drying and Impregnating Apparatus.

The smallest size made has an impregnating chamber 13 inches in diameter and 13 inches deep. The complete apparatus includes the impregnating chamber, condenser, and air pump, which can also be used as an air compressor. Price, $300.

TABLE LXVII.

Price List of Vulcanized Fiber.

Vulcanized fiber is made in sheets about 44 inches wide by about 66 inches long and from 0.005 to 2 inches thick. It can be procured in

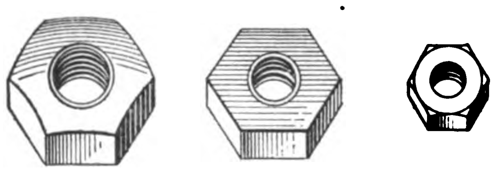


FIG. 146.—SIZES OF HEXAGONAL NUTS.

tubes from ⅛ inch to 6 inches inside diameter. This material can be worked in a lathe, drilled, sawed, and punched, and can be fitted with sharp strong screw threads and takes a fine polish.

Price List of Vulcanized Fiber (Continued).

Below 1/16 inch in thickness........................45 cents per pound
From 1/16 to 1/2 inch in thickness................40 cents per pound
Above 1/2 inch in thickness........................45 cents per pound

Prices of fiber rods, tubing, etc., will be quoted on application.

TABLE LXVIII.

Price List of Balls for Spark-Gap Terminals.

Brass Balls, accurately turned, polished, and lacquered.

Diameter—	½ inch	¾ inch	1 inch	1½ inches	2 inches
Price each—	$0.30	$0.75	$0.90	$1.20	$1.75

Cast-iron Balls, not turned, but with holes drilled.

Diameter—	¾ inch	1 inch	1½ inches	2 inches	3 inches
Price each—	$0.08	$0.11	$0.23	$0.33	$0.53

Cast-steel Balls, accurate and hardened.

Diameter—								
⅛ inch	¼ inch	⅜ inch	½ inch	⅝ inch	¾ inch	1 inch	1¼ inch	1½ inch
Price each—								
$0.03	$0.05	$0.08	$0.12	$0.15	$0.20	$0.30	$0.50	$0.70

TABLE LXIX.

Price List of Glass Tubing for Fuse Blocks, Etc.

	Per Pound
Glass tubing, best quality of German glass........................	$0.60
Assorted sizes, see Nos. 1 to 15.	
Glass tubing, capillary, sizes 19 to 23...........................	1.20
Glass rods, German glass	.70

TABLE LXX.

Price List of Soft-Rubber Tubing.

⅛ inch.	No. 20, B. & S. G., Ins.	100, per lb..................	$1.35
3/16 inch.	No. 14, B. & S. G., Ins.	50, per lb..................	.85
¼ inch.	No. 10, B. & S. G., Ins.	20, per lb..................	.85
5/16 inch.	No. 6, B. & S. G., Ins.	15, per lb..................	.85
⅜ inch.	No. 4, B. & S. G., Ins.	12, per lb..................	.85
½ inch.	No. 0, B. & S. G., Ins.	9, per lb..................	.85

TABLE LXXI.

Price List of Fuse Wire.

	Per Foot.	Per Pound.
1 to 5 amperes	$0.02	$0.50
5 to 10 amperes	0.03	0.48
10 to 30 amperes	0.03	0.45

TABLE LXXII.

Price of Book Binders Cloth.

This material retails at about 25 cents per yard.

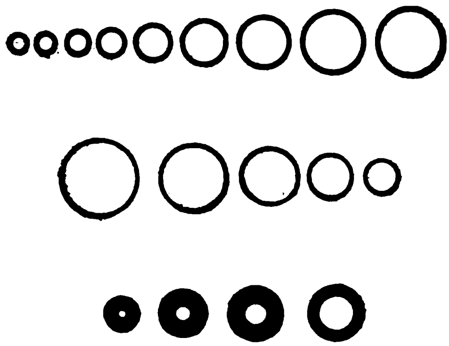


FIG. 147.—GLASS TUBING.

TABLE LXXIII.

Price List of Adhesive Insulating Tapes.

Standard tape, black or white, width ¾ inch, per lb...	$0.70
Grimshaw, white, per pound	1.30
Grimshaw, black, per pound	1.40
Okonite, per pound	1.50
Manson, per pound	1.10
Kerite, per pound	1.60
Paragon, per pound	.50

These tapes are sold by all dealers in electrical supplies.

FIG. 148.—RUBBER TUBING.

TABLE LXXIV.

Prices of Wire Solder.

Wire solder, per pound	$0.25
Wire solder, small coil	.05
Allen soldering stick	.15

TABLE LXXV.

Hard Woods.

Hard woods are obtainable at nearly all lumber yards. Addresses of New York dealers furnished on application.

TABLE LXXVI.

Price List of Dry Cells.

Mesco	$0.15
Columbia, 2½ x 6 inches	.25
Columbia, 3 x 7 inches	.65
Columbia, 3½ x 8 inches	.75

TABLE LXXVII.

Price List of Gem Plunge Batteries.

The 1 Cell Student's Plunge Battery, will run an Electro-Medical Machine, Electric Bell or Signal	$1.35
The 2 Cell Student's Plunge Battery, will run a Ruhmkorff Coil, Geissler Tube Rotator or a 1 candle power lamp	2.80
The 3 Cell Student's Plunge Battery, will run a Gem Motor or any other similar Motor or a 2 candle power lamp	4.00
The 4 Cell Student's Plunge Battery, will run all above with increased force or a 3 candle power lamp	4.80

Extra Zincs, each, 30 cents.

TABLE LXXVIII.

Price List of Large Plunge Batteries.

A simple dip battery of four cells, in case	$7.50
Plunge battery, four cells, zincs and carbons, 4 x 6 x 5/16	21.00
Plunge battery, six cells, zincs and carbons, 4 x 6 x 5/16	30.00

TABLE LXXIX.

Price List of Chemicals for Plunge Batteries.

	Per Pound.
Bichromate of potash, pulverized	$0.30
Sulphuric acid, commercial	0.10
Mercury for amalgamating zincs	0.80

TABLE LXXX.

Price List of Edison Primary Battery and Parts.

Type "S," per cell	$2.85
Renewal parts required for each recharge:	
Two zinc plates	.42
Two copper oxide plates	.50
Can with two sticks of potash	.28
Bottle of heavy paraffin oil	.05

Three of these cells in parallel give an output of energy equivalent to one cell of the non-preferred storage battery.

TABLE LXXXI.

Price List of Portable Storage Batteries.

Preferred Sizes.

Total Capacity, Eight Hours at 7½ Amperes.

For 4-inch coil, 2 cells	$22.00
For 6-inch coil, 3 cells	30.00
For 8-inch coil, 4 cells	40.00
For 10-inch coil, 5 cells	50.00
For 12-inch coil, 6 cells	60.00

TABLE LXXXII.

Non-Preferred Sizes.

Total Capacity, Two-thirds of the Preferred Sizes.

For 4-inch coil, 2 cells	$18.00
For 6-inch coil, 3 cells	26.00
For 8-inch coil, 4 cells	32.00
For 10-inch coil, 5 cells	38.00
For 12-inch coil, 6 cells	46.00

Unless otherwise ordered, portable storage batteries are usually shipped filled with acid and charged ready for service. These are shipped by express, but where this method is too expensive, the shipment can be made by freight and the acid sent separately in another vessel.

TABLE LXXXIII.

Price List of Direct-Current Motor Generator Sets.

To operate on	Output.	
110-volt d. c.,	10 amperes at 20 volts	$125.00
220-volt d. c.,	10 amperes at 20 volts	132.00
500-volt d. c.,	10 amperes at 20 volts	140.00

TABLE LXXXIV.

Price List of Alternating-Current Motor Generator Sets.

To operate on.	Secondary voltage.	Output in Volts.	
110 volt a. c.	20	175	$225.00
220 volt a. c.	20	175	240.00
110 volt a. c.	20	275	260.00
220 volt a. c.	20	275	275.00

In ordering an alternating-current motor generator, it is necessary to specify the voltage and frequency of the alternating current to be used.

Price of regulating rheostat for 110-volt direct-current or battery circuit and suitable for use with coils ranging from 4 inches to 12 inches. All other information relating to induction-coil construction can be obtained by addressing the author who will also furnish list of dealers.

CHAPTER XX.

USEFUL TABLES, FORMULAS, SYMBOLS, AND OTHER DATA.

TABLE LXXXV.

Simple Mathematical Formulas.

$\pi = 3.14159$.
D = diameter.
R = radius.
Circumference of a circle $= \pi D$.
Area of a circle $= \pi R^2$.
Surface of a sphere $= 4 \pi R^2 = \pi D^2$.
Volume of a sphere $= 4/3 \pi R^3 = 1/6 \pi D^3$.

Definitions of Electrical Terms.

Electromotive force is usually indicated by the letters *E.M.F.*, or by simply *E*. It is frequently called *pressure* or *voltage*, and sometimes *difference of potential*, though the latter is not strictly correct, for it is the difference of potential that gives rise to the electromotive force.

Current is often designated by the letter *C*, but as the International Electrical Congress in 1893 recommended that the letter *I* should be used instead, it is more frequently found in current literature. A current can only flow when there is an electromotive force sufficient to overcome the resistance of the circuit.

Resistance has for its symbol the letter *R*. It may be conveniently regarded as that property which opposes the passage of the current.

The *Volt* is the practical unit of the *E.M.F.*, or *E*.

The *Ampere* is the practical unit of I.

The *Ohm* is the practical unit of R.

Ohm's Law.—The following important formula is known as Ohm's law:

(*a*) $\frac{\text{Volts}}{\text{Ohms}} = \text{amperes}$, or $\frac{E}{R} = I$, from which we obtain

(*b*) $\frac{\text{Volts}}{\text{Amperes}} = \text{ohms}$, or $\frac{E}{I} = R$, hence

(*c*) Ohms $\times$ amperes = volts, or $RI = E$.

Calculation of Resistivity.—The resistance of a conductor varies directly as its length, inversely as its cross-section, and depends upon the specific resistance of its composition. It may be expressed by the formula:

(*d*) $R = s\frac{L}{A}$

where R is the resistance, L the length of the conductor, A the area of its cross section, and s the resistivity of the material of which it is formed.

TABLE LXXXVI.

Symbols of Physical Quantities.

Recommended by the Committee on Notation of the Chamber of Delegates of the International Electrical Congress of 1893.

With the names added in italics of the practical magnetic units provisionally adopted by the American Institute of Electrical Engineers.

Physical Quantities.	Symbols.	Defining Equations.	Dimensions of the Physical Quantities.	Names of the C. G. S. Units.	Practical Units.
Fundamental.					
Length	L, l	....	L	Centimeter.	Meter.
Mass.	M	....	M	Mass of one gramme.	Mass of a kilogramme.
Time	T, t	....	T	Second.	Minute; hour.
Geometric.					
Surface	S, s	$S=L.L$	L^2	Square centimeter.	Square meter.
Volume	V	$V=L\,L.L$	L^3	Cubic centimeter.	Cubic meter.
Angle	α, β	$\alpha=\frac{\text{arc}}{\text{radius}}$	A number.	Radian.	Degree; minute; second; grade.
Mechanical.					
Velocity	v	$v=\frac{L}{T}$	LT^{-1}	Centimeter per second.	Meter per second.
Angular velocity	ω	$\omega=\frac{v}{L}$	T^{-1}	Radian per second.	Revolutions (turns) per minute.
Acceleration	a	$a=\frac{v}{T}$	LT^{-2}	Centimeter per second per second.	Meter per second per second.
Force	F, f	$F=Ma$	LMT^{-2}	Dyne.	Gramme; kilogramme.
Work	W	$W=FL$	L^2MT^{-2}	Erg.	Kilogrammeter.
Power	P	$P=\frac{W}{T}$	L^2MT^{-3}	Erg per second.	Kilogrammeter per second.
Pressure	p	$p=\frac{F}{S}$	$L^{-1}MT^{-2}$	Dyne per square centimeter.	Kilogramme per square centimeter.
Moment of inertia	K	$K=ML^2$	L^2M	Gramme-mass-centimeter-squared.	
Magnetic.					
Strength of pole	m	$F=\frac{m^2}{L^2}$	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-1}$		
Magnetic moment	$\mathfrak{M}$	$\mathfrak{M}=ml$	$L^{\frac{5}{2}}M^{\frac{1}{2}}T^{-1}$		
Intensity of magnetization	$\mathfrak{J}$	$\mathfrak{J}=\frac{\mathfrak{M}}{V}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}T^{-1}$		

Field intensity	$\mathfrak{H}$	$\mathfrak{H}=\frac{F}{m}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}T^{-1}$	*Gauss.*	*Gauss.*
Flux of (magnetic) force	Φ	$\Phi=\mathfrak{B}S$	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-1}$	*Weber.*	*Weber.*
Magnetic induction	$\mathfrak{B}$	$\mathfrak{B}=\mu\mathfrak{H}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}T^{-1}$	*Gauss.*	*Gauss.*
Magnetizing force‡	$\mathfrak{H}$	$\mathfrak{H}=\frac{4\pi NI}{L}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}T^{-1}$	*Gauss.*	*Gauss.*
Magnetomotive force	$\mathfrak{F}$	$\mathfrak{F}=4\pi NI$	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-1}$	*Gilbert.*	*Gilbert*; 1 *Gilbert*=0.7958 ampere-turns (a-t).
Reluctance (magnetic resistance)	$\mathfrak{R}$	$\mathfrak{R}=\nu\frac{L}{S}$	L^{-1}	*Oersted.*	*Oersted.*
Magnetic permeability	μ	$\mu=\frac{\mathfrak{B}}{\mathfrak{H}}$	A number.		
(Magnetic) susceptibility	$\varkappa$	$\varkappa=\frac{\mathfrak{I}}{\mathfrak{H}}$	A number.		
Reluctivity (specific magnetic resistance)	ν	$\nu=\frac{1}{\mu}$	A number.		
Electromagnetic.					
Resistance	R, r	$R=\frac{E}{I}$	LT^{-1}	....	Ohm.
Electromotive force	E, e	$E=RI$	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-2}$	....	Volt.
Difference of potential	U, u	$U=RI$	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-2}$	....	Volt.
Intensity of current	I, i	$I=\frac{E}{R}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-1}$	....	Ampere.
Quantity of electricity	Q, q	$Q=IT$	$L^{\frac{1}{2}}M^{\frac{1}{2}}$	....	Coulomb; ampere-hour.
Capacity	C, c	$C=\frac{Q}{E}$	$L^{-1}T^{2}$	....	Farad.
Electric energy	W	$W=EIT$	$L^{2}MT^{-2}$	....	Joule; watt-hour.
Electric power	P	$P=EI$	$L^{2}MT^{-3}$	....	Watt; kilowatt.
Resistivity (specific resistance)	ρ	$\rho=\frac{RS}{L}$	$L^{2}T^{-1}$	....	Ohm-centimeter.
Conductance	G, g	$G=\frac{1}{R}$	$L^{-1}T$	....	Mho.
Conductivity (specific conductance)	γ	$\gamma=\frac{1}{\rho}$	$L^{-2}T$		
Coefficient of induction (inductance)	L, l	$L=\frac{\Phi}{I}$	L	....	Henry.

‡ N is the number of windings, and L the length of the solenoid generating the magnetizing force.

TABLE LXXXVII.

Reciprocals of Numerals up to 100.

The reciprocal of any number is the quotient arising from dividing unity by that number; thus as an example, the reciprocal of 4 is ¼ or 0.250. The conducting property of circuit is equal to the reciprocal of its resistance, or in other words, the conducting property is inversely proportional to its resistance.

No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.
2	.5000	22	.0455	42	.0338	62	.0161	82	.0122
3	.3333	23	.0435	43	.0233	63	.0159	83	.0120
4	.2500	24	.0417	44	.0227	64	.0156	84	.0119
5	.2000	25	.0400	45	.0222	65	.0154	85	.0118
6	.1667	26	.0385	46	.0217	66	.0152	86	.0116
7	.1429	27	.0370	47	.0213	67	.0149	87	.0115
8	.1250	28	.0357	48	.0208	68	.0147	88	.0114
9	.1111	29	.0345	49	.0204	69	.0145	89	.0112
10	.1000	30	.0333	50	.0200	70	.0143	90	.0111
11	.0909	31	.0323	51	.0196	71	.0141	91	.0110
12	.0833	32	.0313	52	.0192	72	.0139	92	.0109
13	.0769	33	.0303	53	.0189	73	.0137	93	.0108
14	.0714	34	.0294	54	.0185	74	.0135	94	.0106
15	.0667	35	.0286	55	.0182	75	.0133	95	.0105
16	.0625	36	.0278	56	.0179	76	.0132	96	.0104
17	.0588	37	.0270	57	.0175	77	.0130	97	.0103
18	.0556	38	.0263	58	.0172	78	.0128	98	.0102
19	.0526	39	.0256	59	.0169	79	.0127	99	.0101
20	.0500	40	.0250	60	.9167	80	.0125	100	.0100
21	.0476	41	.0244	61	.0164	81	.0123		

(*Clark & Sabine.*)

TABLE LXXXVIII.

Comparative Resistance of Various Conductors, Taking Copper as Unity.

Copper	1
Norway iron	6
Soft steel	8
German silver, 18 per cent	17
German silver, 30 per cent	28
"Advance" copper-nickel alloy	30
"Climax" resistance wire	48
Nichrome	60

The composition known as *German silver* usually contains about 18 per cent of nickel. Its resistance varies with different makes, and depends somewhat on its temper. The harder it is, the higher its resistance. The *copper-nickel* alloy contains no zinc, and has a temperature coefficient that is practically *nil.* It is sold under the trade name of "Advance" resistance wire. The "Climax" resistance wire has, as the table shows, a high specific resistance, and possesses strength and toughness far in excess of the ordinary wires used for resistance work. Its low temperature coefficient fits it for any use to which German silver can be applied, while its mechanical properties make it especially serviceable for rheostats, where German silver wire is speedily rendered brittle by repeated heating and cooling.

TABLE LXXXIX.

Number, Length, Diameter, Weight, and Resistance of Pure Copper Wire.

Gage, B. & S. No.	Diameter in 1000ths.	Sectional Area in Circular Mils.	Capacity in Amperes.	Ohms. Per 1,000 Feet.	Ohms. Per Mile.	Ohms. Per Pound.	Feet. Per Pound.	Feet. Per Ohm.	Pounds. Per 1,000 Feet.	Pounds. Per Ohm.
0000	.460	211600.	312.	.0490	.2590	.00007	1.5612	20497.7	640.59	12987.
000	.40964	167805.	262.	.0618	.3266	.00012	1.9687	16255.27	507.85	8333.
00	.3648	133079.	220.	.0780	.4118	.00019	2.4824	12891.37	402.83	5263.
0	.32486	105534.	185.	.0983	.5190	.00031	3.1303	10223.08	319.45	3225.
1	.2893	83694.	156.	.1240	.6549	.00049	3.9471	8107.49	253.34	2041.
2	.25763	66373.	131.	.1564	.8258	.00078	4.9772	6429.58	200.91	1228.
3	.22942	52634.	110.	.1972	1.0414	.00125	6.2765	5098.61	159.32	800.
4	.20431	41473.	92.3	.2486	1.313	.00198	7.9141	4043.6	126.35	505.
5	.18194	33102.	77.6	.3136	1.655	.00314	9.9798	3206.61	100.20	318.
6	.16202	26251.	65.2	.3954	2.088	.00499	12.5847	2542.89	79.462	200.
7	.14428	20817.	54.8	.4987	2.633	.00792	15.8696	2015.51	63.013	126.
8	.12849	16510.	46.1	.6529	3.3	.0125	20.0097	1599.3	49.976	80.
9	.11443	13094.	38.7	.7892	4.1	.0197	25.229	1268.44	39.636	50.
10	.10189	10382.	32.5	.8441	4.4	.0270	31.8212	1055.66	31.426	37.
11	.09074	8234.	27.3	1.254	6.4	.0501	40.1202	797.649	24.924	20.
12	.08080	6530.	23.	1 580	8.3	.079	50.5906	632.555	19.766	12.65
13	.07196	5178.	19.3	1 995	10.4	.127	63.7948	501.63	15.674	7.87
14	.06408	4107.	16.2	2.504	13.2	.200	80.4415	397.822	12.435	5.00
15	.05706	3257.	13.6	3.172	16.7	.320	101.4365	315.482	9.859	3.12
16	.05082	2583.	11.5	4 001	23.	.512	127.12	250.184	7.819	1.95
17	.04525	2048.	9.6	5 04	26.	.811	161.29	198.409	6.199	1.23
18	.04030	1624.	8.1	6.36	33.	1.29	203.374	157.35	4.916	.775
19	.03589	1288.	.....	8.25	43.	2.11	256.468	124.777	3.899	.473
20	.03196	1021.	....	10.12	53.	3.27	323.399	98.9533	3.094	.305
21	.02846	810.	.....	12.76	68.	5.20	407.815	78.473	2.452	.192
22	.02534	642.	.....	16.25	85.	8.35	514.193	62.236	1.945	.119
23	.02257	509.	.....	20 30	108.	13.3	648.452	49.3504	1.542	.075
24	.0201	404.	.....	25 60	135.	20.9	817.688	39.1365	1.223	.047
25	.0179	320.	.....	32.2	170.	32.2	1031.038	31.0381	.9699	.030
26	.01594	254.	....	40.7	214.	52.9	1300.180	24.6131	.7692	.0187
27	.01419	201.	.....	51 3	270.	84.2	1639.49	19.5191	.6099	.0118
28	.01264	159.8	.... .	64 8	343.	134.	2067.364	15.4793	.4807	.0074
29	.01125	126.7	.....	81 6	432.	213.	2606.959	12.2854	.3835	.0047
30	.01002	100.5	.....	103.	538.	338.	3287.084	9.7355	.3002	.0029
31	.00892	79.7	....	130.	685.	539.	4414.49	7.7214	.2413	.0018
32	.00795	63.	.....	164.	865.	856.	5226.915	6.1224	.1913	.0011
33	.00708	50.1	.....	206.	1033.	1357.	6590.41	4.8557	.1517	.00076
34	.00630	39.74	.....	260.	1389.	2166.	8312.8	3.8496	.1204	.00046
35	.00561	31.5	.....	328.	1820.	3521.	10481.77	3.0530	.0956	.00028
36	.005	25.	.....	414.	2200.	5469.	13214.16	2.4217	.0757	.00018
37	.00445	19.8	.....	523.	2765.	8742.	16659.97	1.9208	.0600	.00011
38	.00396	15.72	.....	660.	3486.	13722.	21013.25	1.5229	.0475	.00007
39	.00353	12.47	.....	832.	4395.	21896.	26496.237	1.2077	.0375	.00004
40	.00314	9.88	.....	1049.	5542.	34823.	33420.63	0.9798	.0299	.00002

TABLE XC.

Resistances and Feet Per Pound of German Silver Wire.

Brown & Sharpe Gage.	Diameter.	Feet per Pound.	German Silver. Approximate. Ohms per 1,000 Feet.
8	.1285	20	11.77
9	.1144	25	11.83
10	.1019	32	18.72
11	.09074	40	29.59
12	.08081	51	29.75
13	.07196	64	37.51
14	.06408	81	47.30
15	.05707	102	59.65
16	.05082	129	75.22
17	.04525	162	94.84
18	.0403	204	119.61
19	.03539	264	155.10
20	.03196	325	190.18
21	.02846	409	239.81
22	.02535	517	302.38
23	.02257	660	381.33
24	.0201	823	480.83
25	.0179	1039	606.31
26	.01594	1310	764.59
27	.01419	1650	964.13
28	.01264	2082	1215.76
29	.01126	2623	1533.06
30	.01002	3311	1933.03
31	.00893	4165	2437.23
32	.00795	5263	3073.77
33	.00708	6636	3875.61
34	.0063	8381	4888.49
35	.00561	10560	6163.97
36	.005	13306	7770.81

TABLE XCI.

Resistance and Conductivity of Pure Copper at Different Temperatures.

(*a*) The resistance of metallic conductors increases as the temperature rises. (*b*) The resistance of electrolytes decreases as the temperature rises. (*c*) The resistance of dielectrics and non-conductors decreases as the tempera- ture rises.

Centigrade Temperature. Degrees.	Resistance.	Conductivity.	Centigrade Temperature. Degrees.	Resistance.	Conductivity.
0	1.00000	1.00000	16	1.06168	.94190
1	1.00381	.99624	17	1.06563	.93841
2	1.00756	.99250	18	1.06959	.93494
3	1.01135	.98878	19	1.07356	.93148
4	1.01515	.98508	20	1.07742	.92814
5	1.01896	.98139	21	1.08164	.92452
6	1.02280	.97771	22	1.08553	.92121
7	1.02663	.97406	23	1.08954	.91782
8	1.03048	.97042	24	1.09365	.91455
9	1.03435	.96679	25	1.09763	.91110
10	1.03822	.96319	26	1.10161	.90776
11	1.04199	.95970	27	1.10567	.90443
12	1.04599	.95603	28	1.11972	.90113
13	1.04990	.95247	29	1.11382	.89784
14	1.05406	.94893	30	1.11782	.89457
15	1.05774	.94541			

TABLE XCII.

Comparison of Thermometrical Scales.

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
125	257.0	93	199.4	61	141.8	29	84.2
124	255.2	92	197.6	60	140.0	28	82.4
123	253.4	91	195.8	59	138.2	27	80.6
122	251.6	90	194.0	58	136.4	26	78.8
121	249.8	89	192.2	57	134.6	25	77.0
120	248.0	88	190.4	56	132.8	24	75.2
119	246.2	87	188.6	55	131.0	23	73.4
118	244.4	86	186.8	54	129.2	22	71.6
117	242.6	85	185.0	53	127.4	21	69.8
116	240.8	84	183.2	52	125.6	20	68.0
115	239.0	83	181.4	51	123.8	19	66.2
114	237.2	82	179.6	50	122.0	18	64.4
113	235.4	81	177.8	49	120.2	17	62.6
112	233.6	80	176.0	48	118.4	16	60.8
111	231.8	79	174.2	47	116.6	15	59.0
110	230.0	78	172.4	46	114.8	14	57.2
109	228.2	77	170.6	45	113.0	13	55.4
108	226.4	76	168.8	44	111.2	12	53.6
107	224.6	75	167.0	43	109.4	11	51.8
106	222.8	74	165.2	42	107.6	10	50.0
105	221.0	73	163.4	41	105.8	9	48.2
104	219.2	72	161.6	40	104.0	8	46.4
103	217.4	71	159.8	39	102.2	7	44.6
102	215.6	70	158.0	38	100.4	6	42.8
101	213.8	69	156.2	37	98.6	5	41.0
100	212.0	68	154.4	36	96.8	4	39.2
99	210.2	67	152.6	35	95.0	3	37.4
98	208.4	66	150.8	34	93.2	2	35.6
97	206.6	65	149.0	33	91.4	1	33.8
96	204.8	64	147.2	32	89.6	0	32.0
95	203.0	63	145.4	31	87.8		
94	201.2	62	143.6	30	86.0		

TABLE XCIII.

Conversion of Thermometrical Scales.

To convert degrees *Centigrade or Reaumur* into degrees *Fahrenheit* or *vice versa*, use one of the following formulas:

To convert degrees Centigrade into degrees Fahrenheit:

$$F = \frac{9C}{5} + 32.$$

To convert degrees Fahrenheit into degrees Centigrade:

$$C = \frac{5(F - 32)}{9}.$$

To convert degrees Reaumur into degrees Fahrenheit:

$$F = \frac{9R}{4} + 32.$$

To convert degrees Fahrenheit into degrees Reaumur:

$$R = \frac{4(F - 32)}{9}.$$

To convert Centigrade and Reaumur into Fahrenheit:

$$F = C + R + 32.$$

Freezing point = 32 deg. F. = 0 deg. C. = 0 deg. R.
Boiling point = 212 deg. F. = 100 deg. C. = 80 deg. R.

TABLE XCIV.

Safe Carrying Capacity of Wires.

Brown & Sharpe Gage.	Diameter in Mils.	Area in Circular Mils.	Number of Amperes, Exposed Work.	Number of Amperes, Confined Spaces.	Ohms per 1,000 Feet.	Pounds per 1,000 Feet, Bare.	Pounds per 1,000 Feet, Insulated.
18	40	1.624	5	3	6.3880	4.92	18
17	45	2.048	6	4	5.0660	6.20	21
16	51	2.583	8	6	4.0176	7.82	25
15	57	3.257	10	8	3.1860	9.86	31
14	64	4.106	16	12	2.5266	12.44	38
13	72	5.178	19	14	2.0037	15.68	43
12	81	6.530	23	17	1.5890	19.77	48
11	91	8.234	27	21	1.2602	24.93	64
10	102	10.380	32	25	.99948	31.44	80
9	114	13.090	39	29	.79242	39.65	97
8	128	16.510	46	33	.62849	49.99	116
7	144	20.820	56	39	.49845	63.03	118
6	162	26.250	65	45	.39528	79.49	166
5	182	33.100	77	53	.31346	100.23	196
4	204	41.740	92	63	.24858	126.40	228
3	229	52.630	110	75	.19714	159.38	265
2	258	66.370	131	88	.15633	200.98	296
1	289	83.690	156	105	.12398	253.43	329
0	325	105.500	185	125	.09827	319.74	421
00	365	133.100	220	150	.07797	402.97	528

TABLE XCV.

Number of Turns of Wire that Can be Wound in a Given Space.

No. B. & S. or American Gage.	COTTON.				SILK.			
	Single.		Double.		Single.		Double.	
	Per Square Inch.	Per Square Qu. Inch.	Per Square Inch.	Per Square Qu. Inch.	Per Square Inch.	Per Square Qu. Inch.	Per Square Inch.	Per Square Qu. Inch.
20	676	42	576	36	841	52	676	42
21	842	53	625	39	961	60	842	53
22	1.024	64	729	45	1.225	76	1.024	64
23	1.296	81	900	56	1.521	95	1.296	81
24	1.600	100	1.089	68	1.936	121	1.600	100
25	1.849	115	1.296	81	2.304	144	1.849	115
26	2.209	138	1.440	90	2.916	182	2.209	138
27	2.500	156	1.600	100	3.249	206	2.500	156
28	3.025	189	1.849	115	4.096	254	3.025	189
29	3.481	218	2.025	126	4.761	297	3.481	218
30	4.356	272	2.500	156	6.400	400	4.356	272
31	5.001	315	2.704	169	7.769	485	5.041	315
32	5.929	370	3.025	189	9.025	564	5.929	370
33	7.089	443	3.481	218	11.025	689	7.089	443
34	7.769	485	3.600	225	12.321	770	7.769	485
35	8.100	506	3.844	240	13.689	855	8.100	506
36	10.000	625	4.356	272	17.689	1.105	10.000	625
37	11.025	689	4.761	297	20.164	1.240	11.025	689
38	12.321	770	5.041	315	23.716	1.482	12.321	770
39	13.689	855	5.476	342	27.556	1.722	13.689	855
40	15.625	976	5.929	370	32.761	2.047	15.625	976

(*W. J. Clarke.*)

TABLE XCVI.

Puncture Test of Insulating Materials.

Material.	Grade.	Thickness in Mils.	Puncture Test in Volts.	Guaranteed Resistance to Puncture.
Linen	A	6— 7	5,000— 9,000	.
Linen	B	8— 9	13,000—15,000	10,000
Linen	C	11—12	18,000—23,000	15,000
Insulated Canvas	....	10—11	5,000— 9,000	....
Paper	A	5— 6	8,000—10,000	...
Paper	B	8— 9	14,000—16,000	10,000
Paper	C	11—12	20,000—25,000	15,000
Bond Paper	A	4— 5	5,000— 9,000	...
Fiber Paper	A	5— 6	8,000—10,000	...
Red Rope Paper	A	8— 9	9,000—11,000	....

TABLE XCVII.

Carrying Capacity, Diameter, Etc., of Fuse Wire.

Safe Carrying Capacity. Amperes.	Best length for use and fusing currents for such lengths.		Length. Per Pound Feet.	Mils. Diameter.
	Inches.	Amperes.		
½	1	1½	.....	10
¾	1	2¼	.....	13
1	1¼	3	1,025	16
2	1½	5	680	25
3	1½	7	445	31
4	1¾	9	290	35
5	1¾	10	168	39
6	2	12	145	42
7	2	13	122	46
8	2	15	105	49
9	2	16	92	52
10	2¼	17	82	55
12	2¼	20	66	61
14	2¼	23	56	66
15	2¼	24	53	68
16	2½	25	47½	72
18	2½	28	42	77
20	2½	30	37⅓	82
25	2¾	37	28⅓	94
30	2¾	43	23⅔	103
35	3	49	19 10-12	113
40	3	56	17	122
45	3	62	15	129
50	3	69	13 7-12	137
60	3¼	81	10½	158
70	3¼	93	9	170
75	3½	99	7 10-12	182
80	3½	106	7⅛	189
90	3½	118	6	212
100	4	129	5	226

TABLE XCVIII.

Cross-Sectional Circular Units.

A *mil* is $\frac{1}{1000}$ inch. It is a unit of length used in measuring the diameter of wires. A circular mil is a unit of area used in measuring the cross sections of wires.

1 circular mil	.... = 0.78540 square mil.
1 circular mil	.... = 0.00064514 circular millimeter.
1 circular mil	.... = 0.00050669 square millimeter.
1 square mil	.... = 1.2732 circular mils.
1 square mil	.... = 0.00082141 circular millimeter.
1 circular millimeter	.... = 1550.1 circular mils.
1 circular millimeter	.... = 1217.4 square mils.
1 circular millimeter	.... = 0.78540 square millimeter.
1 square millimeter	.... = 1973.6 circular mils.
1 square millimeter	.... = 1.2732 circular millimeters.

If d is the diameter of a circle, the area in other units is:

If d is in mils, the area in square millimeters....... $= d^2 \times 0.00050669$.
d in millimeters, area in square mils............. $= d^2 \times 1217.4$.
d in centimeters, area in square inches........... $= d^2 \times 12174$.
d in inches, area in square centimeters........... $= d^2 \times 5.0669$.

—(*Hering.*)

TABLE XCIX.

Decimal Equivalents of Fractions of an Inch.

1/64 =	.015625	17/64 =	.265625	33/64 =	.515625	49/64 =	.765625
1/32 =	.03125	9/32 =	.28125	17/32 =	.53125	25/32 =	.78125
3/64 =	.046875	19/64 =	.296875	35/64 =	.546875	51/64 =	.796875
1/16 =	.0625	5/16 =	.3125	9/16 =	.5625	13/16 =	.8125
5/64 =	.078125	21/64 =	.328125	37/64 =	.578125	53/64 =	.828125
3/32 =	.09375	11/32 =	.34375	19/32 =	.59375	27/32 =	.84375
7/64 =	.109375	23/64 =	.359375	39/64 =	.609375	55/64 =	.859379
1/8 =	.125	3/8 =	.375	5/8 =	.625	7/8 =	.875
9/64 =	.140625	25/64 =	.390625	41/64 =	.640625	57/64 =	.890625
5/32 =	.15625	13/32 =	.40625	21/32 =	.65625	29/32 =	.90625
11/64 =	.171875	27/64 =	.421875	43/64 =	.671875	59/64 =	.921875
3/16 =	.1875	7/16 =	.4375	11/16 =	.6875	15/16 =	.9375
13/64 =	.203125	29/64 =	.453125	45/64 =	.703125	61/64 =	.953125
7/32 =	.21875	15/32 =	.46875	23/32 =	.71875	31/32 =	.96875
15/64 =	.234375	31/64 =	.484375	47/64 =	.734375	63/64 =	.984375
1/4 =	.25	1/2 =	.5	3/4 =	.75	1 =	1

Different Wire Gages.

TABLE C.

There are several kinds of wire gages in use throughout the world, but the American standard, as the Brown & Sharpe gage is sometimes termed, is the principal one in the United States, although for determining the size of iron wire the Birmingham or Stubs gage is generally employed. The following table lists most of them:

(a) American Standard, or Brown & Sharpe.
(b) Birmingham, or Stubs (English).
(c) Washburn & Moen Manufacturing Company (Worcester, Mass.).
(d) Trenton Iron Company (Trenton, N. J.).
(e) Old English Brass Manufacturing List (English).
(f) New Legal Standard (English).

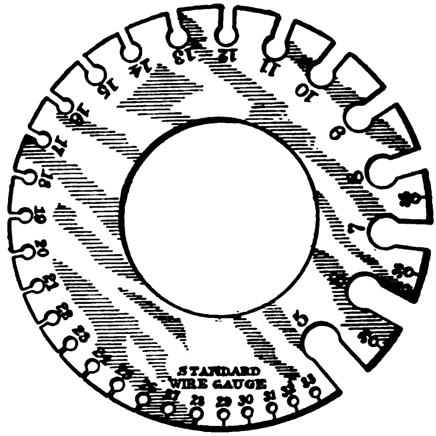


FIG. 149.—BROWN & SHARPE WIRE GAGE.

FIG. 150.—STUBS ENGLISH WIRE GAGE.

TABLE CI.

Difference Between Wire Gages in Decimal Parts of an Inch.

No. of Wire Gage.	American or Brown & Sharpe.	Birmingham or Stubs.	Washburn & Moen Mfg. Co., Worcester Mass.	Trenton Iron Co., Trenton, N. J.	New British.	Old English from Brass Mfrs. List.	No. of Wire.
000000	....	....	.46	....	....	...	000000
00000	....	.	.43	.45	....	....	00000
0000	.46	.454	.393	.4	.4	....	0000
000	.40964	.425	.362	.36	.372	....	000
00	.3648	.38	.331	.33	.348	....	00
0	.32495	.34	.307	.305	.324	....	0
1	.2893	.3	.283	.285	.3	....	1
2	.25763	.284	.263	.265	.276	....	2
3	.22942	.250	.244	.245	.252	....	3
4	.20431	.238	.225	.225	.232	....	4
5	.18194	.22	.207	.205	.212	....	5
6	.16202	.203	.192	.19	.192	....	6
7	.14428	.18	.177	.175	.176	....	7
8	.12849	.165	.162	.16	.16	....	8
9	.11443	.148	.148	.145	.144	....	9
10	.10189	.134	.135	.13	.128	....	10
11	.090742	.12	.12	.1175	.116	....	11
12	.080808	.109	.105	.105	.104	....	12
13	.071961	.095	.092	.0925	.092	...	13
14	.064084	.083	.08	.08	.08	.083	14
15	.057068	.072	.072	.07	.072	.072	15
16	.05082	.065	.063	.061	.064	.065	16
17	.045257	.058	.054	.0525	.056	.058	17
18	.040303	.049	.047	.045	.048	.049	18
19	.03589	.042	.041	.039	.04	.04	19
20	.031961	.035	.035	.034	.036	.035	20
21	.028462	.032	.032	.03	.032	.0315	21
22	.025347	.028	.028	.027	.028	.0295	22
23	.022571	.025	.025	.024	.024	.027	23
24	.0201	.022	.023	.0215	.022	.025	24
25	.0179	.02	.02	.019	.02	.023	25
26	.01594	.018	.018	.018	.018	.0205	26
27	.014195	.016	.017	.017	.0164	.01875	27
28	.012641	.014	.016	.016	.0148	.0165	28
29	.011257	.013	.015	.015	.0136	.0155	29
30	.010025	.012	.014	.014	.0124	.01375	30
31	.008928	.01	.0135	.013	.0116	.01225	31
32	.00795	.009	.013	.012	.0108	.01125	32
33	.00708	.008	.011	.011	.01	.01025	33
34	.006304	.007	.01	.01	.0092	.0095	34
35	.005614	.005	.0095	.009	.0084	.009	35
36	.005	.004	.009	.008	.0076	.0075	36
37	.004453	...	.0085	.00725	.0068	.0065	37
38	.003965	....	.008	.0065	.006	.00575	38
39	.003531	....	.0075	.00575	.0052	.005	39
40	.003144	..	.007	.005	.0048	.0045	40

TABLE CII.

THE MICROMETER.

This device will accurately measure from $\frac{1}{1000}$ inch up to 1 inch, reading in the thousandths of an inch. The spindle *C* is attached to the thimble *E* at the point *H*. The part of the spindle which is concealed within the sleeve and thimble is threaded to fit a nut in the frame *A*. The frame being held stationary, the thimble *E* is revolved by the thumb and finger, and the spindle *C* being attached to the thimble revolves with it, and moves through the nut

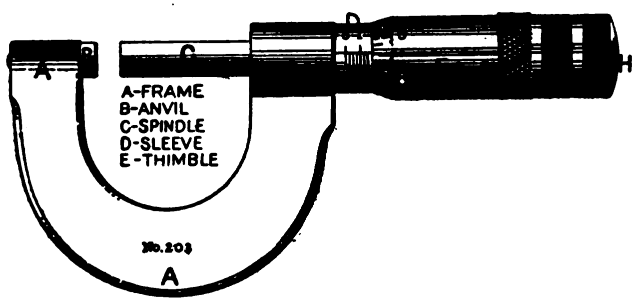


FIG. 151.—MICROMETER WIRE GAGE.

in the frame approaching or receding from the spindle *C*. The measurement of the opening between the anvil and the spindle is shown by the lines and figures on the sleeve *D* and the thimble *E*, Fig. 151.

The pitch of the screw threads on the concealed part of the spindle is 40 to an inch. One complete revolution of the spindle therefore moves it longitudinally one-fortieth (or twenty-five thousandths) of an inch. The sleeve *D* is marked with 40 lines to the inch, corresponding to the number of threads on the spindle. When the micrometer is closed, the beveled edge of the thimble coincides with the line marked 0 on the sleeve, and the 0 line on the thimble agrees with the horizontal line on the sleeve. Open the micrometer by revolving the thimble one full revolution, or until the 0 line on the thimble again coincides with the horizontal line on the sleeve; the distance between the anvil *B* and the spindle *C* is then $\frac{1}{40}$ (or 0.025) of an inch, and the beveled edge of the thimble will coincide with the second vertical line on the sleeve. Each vertical line on the sleeve indicates a distance of $\frac{1}{40}$ of an inch. Every fourth line is made longer than the others, and is numbered 0, 1, 2, 3, etc. Each numbered line indicates a distance of four times $\frac{1}{40}$ of an inch, or one-tenth.

The beveled edge of the thimble is marked in twenty-five divisions, and every fifth line is numbered from 0 to 25. Rotating the thimble from one of these marks to the next moves the spindle longitudinally $\frac{1}{25}$ of twenty-five thousandths, or one thousandth of an inch. Rotating it two divisions indicates two thousandths, etc. Twenty-five divisions will indicate a complete revolution—0.025 or $\frac{1}{40}$ of an inch.

To read the micrometer, therefore, multiply the number of vertical divisions visible on the sleeve by 25, and add the number of divisions on the bevel of the thimble from 0 to the line which coincides with the horizontal line on the sleeve. For example, as the tool is represented in the engraving, there are seven divisions visible on the sleeve. Multiply this number by 25, and add the number of divisions shown on the bevel of the thimble 3. The wire or sheet of metal between the anvil *B* and the end of the spindle C is one hundred and seventy-eight thousandths ($7 \times 25 = 175 + 3 = 178$).

TABLE CIII.

How to Read a Ten-Thousandths Micrometer.

Readings in ten-thousandths of an inch are obtained by the use of a vernier, so named from Pierre Vernier, who invented the device in 1631. As applied to a micrometer, Fig. 152, this consists of ten divisions on the adjustable, which occupy the same space as nine divisions on the

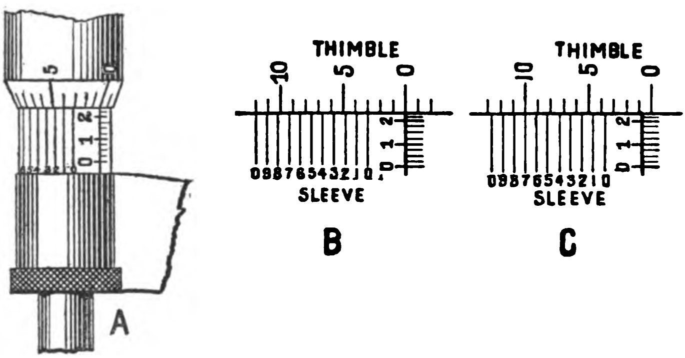


FIG. 152.—VERNIER MICROMETER READING TO TEN-THOUSANDTHS.

thimble. The difference between the width of one of the ten spaces on the sleeve and one of the nine spaces on the thimble is therefore one-tenth of a space on the thimble. In the above figure represented by *B*, the third line from 0 on the thimble coincides with the first line on the sleeve; the next two lines on the thimble and sleeve do not coincide by one-tenth of a space on the thimble, the next two, marked 5 and 2, are two-tenths apart, and so on. In opening the tool, by turning the thimble to the left, each space on the thimble represents an opening of one-thousandth of an inch. If, therefore, the thimble is turned so that the lines marked 5 and 2 coincide, the caliper will be opened two-tenths of one-thousandth, or two ten-thousandths. Turning the thimble farther, until the line 10 coincides with the line 7 on the sleeve, as in the engraving *C*, the caliper has been opened seven ten-thousandths, and the reading of the micrometer is 0.2257. To read a ten-thousandths micrometer, first note the thousandths as in the ordinary micrometer, then observe the line on the sleeve which coincides with the line on the thimble. If it is in the second line, marked 1, add one ten-thousandth; if it is in the third, marked 2, add two ten-thousandths, etc.

TABLE CIV.

Letter Sizes of Drills.

Diameter. Inch.	Decimals of 1 Inch.	Diameter. Inch.	Decimals of 1 Inch.
A $\frac{15}{64}$	.234	N	.302
B	.238	O $\frac{5}{16}$	.316
C	.242	P $\frac{21}{64}$	.323
D	.246	Q	.332
E $\frac{1}{4}$	.250	R $\frac{11}{32}$	.339
F	.257	S	.348
G	.261	T $\frac{23}{64}$	.358
H $\frac{17}{64}$	.266	U	.368
I	.272	V $\frac{3}{8}$	.377
J	.277	W $\frac{25}{64}$	.386
K $\frac{9}{32}$	.281	X	.397
L	.290	Y $\frac{13}{32}$	.404
M $\frac{19}{64}$	.295	Z	.413

TABLE CV.

Sizes of Tap Drills.

Tap Diameter.	Threads Per Inch.	Drill for V Thread.	Drill for U. S. Standard.	Drill for Whitworth.
1/4	16, 18, 20	5/32 5/32 11/64	3/16	3/16
9/32	16, 18, 20	3/16 13/64 13/64		
5/16	16, 18	7/32 15/64	1/4	15/64
11/32	16, 18	1/4 17/64		
3/8	14, 16, 18	1/4 9/32 9/32	9/32	9/32
13/32	14, 16, 18	19/64 21/64 21/64		
7/16	14, 16	21/64 11/32	11/32	11/32
15/32	14, 16	23/64 3/8		
1/2	12, 13, 14	3/8 25/64 25/64	13/32	3/8
9/16	12, 14	7/16 29/64	7/16	
5/8	10, 11, 12	15/32 1/2 1/2	1/2	1/2
11/16	11, 12	9/16 9/16		
3/4	10, 11, 12	19/32 5/8 5/8	5/8	5/8
13/16	10	21/32		
7/8	9, 10	45/64 23/32	23/32	23/32
15/16	9	49/64		
1	8	13/16	27/32	27/32

TABLE CVI.

Forms of Screw Threads.

(*a*) *The V Thread.*—The sharp V thread is a thread having its sides at an angle of 60 deg. to each other and perfectly sharp, top and bottom, as in Fig. 153.

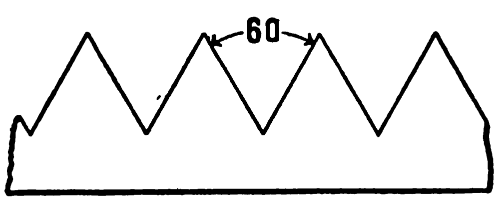


FIG. 153.—THE V THREAD.

(*b*) *The U. S. Standard Thread.*—The U. S. standard thread has its sides cut at an angle of 60 deg. to each other, but has its top cut off to the extent of one-eighth of its pitch and the same quantity filled in at its bottom, as in the cut.

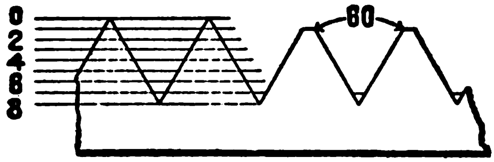


FIG. 154.—THE U. S. STANDARD THREAD.

TABLE CVII.

Screw Pitch Gage.

The gage shown in Fig. 155 has twenty-two pitches,

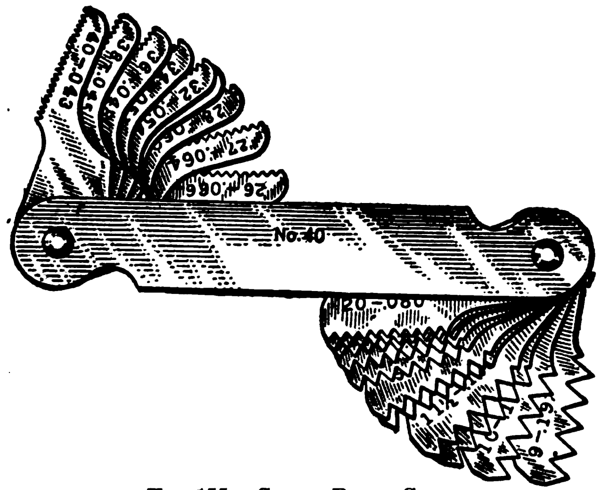


FIG. 155.—SCREW PITCH GAGE.

namely, 9, 10, 11, 11½, 12, 13, 14, 15, 16, 18, 20, 22, 24, 26, 27, 28, 30, 32, 34, 36, 38, 40. It can be used inside a nut as well as outside of a screw. On each leaf are stamped decimals showing the double depth of thread, and this of course equals the depth of threads on the two sides of a tap having the same pitch, and helps materially in determining the size of drill needed to drill the hole the right size to leave a full V thread for a tap having same pitch. To do this it is necessary to caliper with a micrometer over the threads of the tap, and from its size in thousandths shown, deduct the decimals given on the pitch gage leaf, agreeing with the pitch of the tap. The result will show in thousandths the size of the drill needed for a full thread. An allowance must be made for the extent to which it is desired the thread should be flattened.

TABLE CVIII.

Formula for Depth of V Threads.

$$d = D - \frac{1.733}{M}.$$

Formula for Depth of U. S. Standard Threads.

$$d = D - \frac{1.299}{M}.$$

D = outside diameter of tap.

d = bottom diameter of tap.

M = number of threads per inch.

TABLE CIX.

Double Depth of V and U. S. Standard Threads.

Threads Per Inch.	U. S. Standard DD.	V Thread DD.	Threads Per Inch.	U. S. Standard DD.	V Thread DD.
64	.02029	.02706	16	.08118	.10825
60	.02165	.02887	14	.09278	.12357
56	.02319	.03093	13	.09992	.13323
50	.02598	.03464	12	.10825	.14433
48	.02706	.03608	11	.11809	.15745
44	.02952	.03936	10	.12990	.17320
40	.03247	.04330	9	.14433	.19244
36	.03608	.04811	8	.16237	.21650
32	.04059	.05412	7	.18555	.24742
30	.04330	.05773	6	.21650	.28866
28	.04639	.06185	5½	.23618	.31490
26	.04996	.06661	5	.25980	.34650
24	.05412	.07216	4½	.28866	.38488
22	.05904	.07872	4	.32475	.43300
20	.06495	.08660	3½	.37114	.49485
18	.07216	.09622	3	.43383	.57733

d = diameter at bottom of thread.
C = double depth of thread.
D = diameter at bottom of thread.

As an example, showing the use of the above table, find the actual diameter at the bottom of V thread, ¾ inch diameter, 10 threads to the inch. In the V thread column opposite the 10 threads per inch, find the decimal 0.173; this subtracted from the outside diameter of the thread is the diameter at bottom of thread, thus:

	D	C	d
¾ inch	0.750 inch	0.173 inch	0.577 inch

International or Metric System of Weights and Measures.

The meter is the ten-millionth part of a quadrant of the earth's meridian, or the distance from the Equator to the

North Pole. Like the Arabic system of notation and the table of U. S. money, its divisions and multiples vary in a tenfold ratio. All measures, whether of length, surface, bulk, weight, or capacity, are directly derived from the meter, and their names express their value.

TABLE CX.

Metric Measurement of Weight, Capacity and Length.

Weight.	Capacity.	Length.
10 Milli = 1 Centi	10 Milliliters = 1 Centiliter	10 Millimeters = 1 Centimeter
10 Centi = 1 Deci	10 Centiliters = 1 Deciliter	10 Centimeters = 1 Decimeter
10 Deci = 1 Gramme	10 Deciliters = 1 Liter	10 Decimeters = 1 Meter
10 Grammes = 1 Deka	10 Liters = 1 Dekaliter	10 Meters = 1 Dekameter
10 Deka = 1 Hekto	10 Dekaliters = 1 Hektoliter	10 Dekameters = 1 Hektometer
10 Hekto = 1 Kilo	10 Hektoliters = 1 Kiloliter	10 Kilometers = 1 Myriameter
10 Kilo = Myria		

TABLE CXI.

Metric Measures of Length and Equivalents in Inches. Ratio = 10.

Divisions.	Millimeter	(mm.)	=	0.001	m. =	0.03937	inch.
	Centimeter	(cm.)	=	0.01	m. =	0.3937	inch.
	Decimeter	(dm.)	=	0.1	m. =	3.937	inches.
Unit......	Meter	(m.)	=	1.	m. =	39.37	inches.
Multiples.	Dekameter	(Dm.)	=	10.	m. =	393.7	inches.
	Hektometer	(Hm.)	=	100.	m. =	328	feet 1 inch.
	Kilometer	(Km.)	=	1,000.	m. =	0.62326	mile.
	Myriameter	(Mm.)	=	10,000.	m. =	6.2326	miles.

TABLE CXII.

Metric Measures of Weight. Ratio = 10.

Milligramme	(mg.)	=	0.0154	grain avoirdupois.
Centigramme	(cg.)	=	0.1543	grain avoirdupois.
Decigramme	(dg.)	=	1.5432	grains adoirdupois.
Gramme	(g.)	=	15.432	grains avoirdupois.
Dekagramme	(Dg.)	=	0.3527	ounce avoirdupois.
Hektogramme	(Hg.)	=	3.5274	ounces avoirdupois.
Kilogramme	(Kg.)	=	2.2046	pounds avoirdupois.
Myriagramme	(Mg.)	=	22.046	pounds avoirdupois.

TABLE CXIII.

Conversion of English into Metric Weights.

1 avoirdupois ounce = 28.35 grammes.
1 Troy or apothecaries ounce = 31.10 grammes.
1 avoirdupois pound = 453.59 grammes, or about 5/11 of a kilogramme.

The denominations most used in the metric tables are indicated by italics.

TABLE CXIV.

Conversion of English into Metric Lengths.

1 inch	= 25.4000 mm.	= 0.0254 m.,	or about $2\frac{1}{2}$ cm.
1 foot	= 30.4800 cm.	= 0.3048 m.,	or about 30 cm.
1 yard	= 0.9144 m.	=	10/11 m.
1 mile	= 1609.0000 m.	= 1.6090 km.,	or about 1 6/10 Km.

TABLE CXV.

Metric Measures of Surface.—Ratio = 10^2 = 100.

Square millimeter	(sq. mm.)	= 0.000001	sq. m.
Square centimeter	(sq. cm.)	= 0.0001	sq. m.
Square decimeter	(sq. dm.)	= 0.01	sq. m.
Square meter	(sq. m.)	= 1.	sq. m.

TABLE CXVI.

Metric Measures of Volume.—Ratio = 10^3 = 1,000.

Cubic millimeter	(cu. mm.)	= 0.000000001	cu. m.	
Cubic centimeter	(cu. cm.)	= 0.000001	cu. m.	
Cubic decimeter	(cu. dm.)	= 0.001	cu. m.	
Cubic meter	(cu. m.)	= 1.		= 1.308 cu. yards.

TABLE CXVII.

Metric Measures of Capacity.—Ratio = 10.

Divisions.	Milliliter	(ml.) =	1 cu. cm. =	0.061022	cu. in.
	Centiliter	(cl.) =	10 cu. cm. =	0.338	fld. oz.
	Deciliter	(dl.) =	100 cu. cm. =	0.845	gill.
Unit	*Liter*	(l.) =	1000 cu. cm. =	1.0567	liquid quarts.
Multiples	Dekaliter	(Dl.) =	10 cu. dm. =	9.08	dry quarts.
	Hektoliter	(Hl.) =	100 cu. dm. =	2 bu. 3.35 pk.	
	Kiloliter	(Kl.) =	1 cu. m. =	264.17 gallons.	

TABLE CXVIII.

Conversion of U. S. into Metric Capacities.

1 U. S. liquid quart = 0.946 l., or about 1 liter.
1 U. S. dry quart = 1,101 l., or about 1 liter.
1 U. S. gallon = 3.785 l., or about 3.8 liters.
1 U. S. bushel = 35.240 l., or about 4/11 hekloliters.

TABLE CXIX.

To Obtain the Index of a Lathe.

If you will note what thread the lathe will cut when two given gears are in place, you can easily construct a table that will show you just what thread any two gears will cause the lathe to cut. Suppose that two sixty-threes produce 12 threads to the inch. Then place 12 in the space *A* in the table below:

Screw.	Stud.													
	28	33	35	42	49	56	63	70	77	84	91	98	105	112
28	...	...	...	...	...	...	...	...	...	...	...	...	...	...
33	...	...	...	...	...	...	...	...	...	...	...	...	...	...
35	...	...	...	...	...	...	...	...	...	...	...	...	...	...
42	...	...	...	...	...	...	...	...	...	...	...	...	...	...
49	...	...	...	...	*b*	...	...	...	...	...	...	...	...	...
56	...	...	...	...	...	*a*	*C*	...	...	...	...	...	...	...
63	...	...	...	...	...	*B*	*A*	*D*	...	...	...	...	...	...
70	...	...	...	...	...	...	*E*	*c*	...	...	...	...	...	...
77	...	...	...	...	...	...	...	...	*d*	...	...	...	...	...
84	...	...	...	...	...	...	...	...	...	...	...	...	...	...
91	...	...	...	...	...	...	...	...	...	...	...	...	...	...
98	...	...	...	...	...	...	...	...	...	...	...	...	...	...
105	...	...	...	...	...	...	...	...	...	...	...	...	...	...
112	...	...	...	...	...	...	...	...	...	...	...	...	...	...

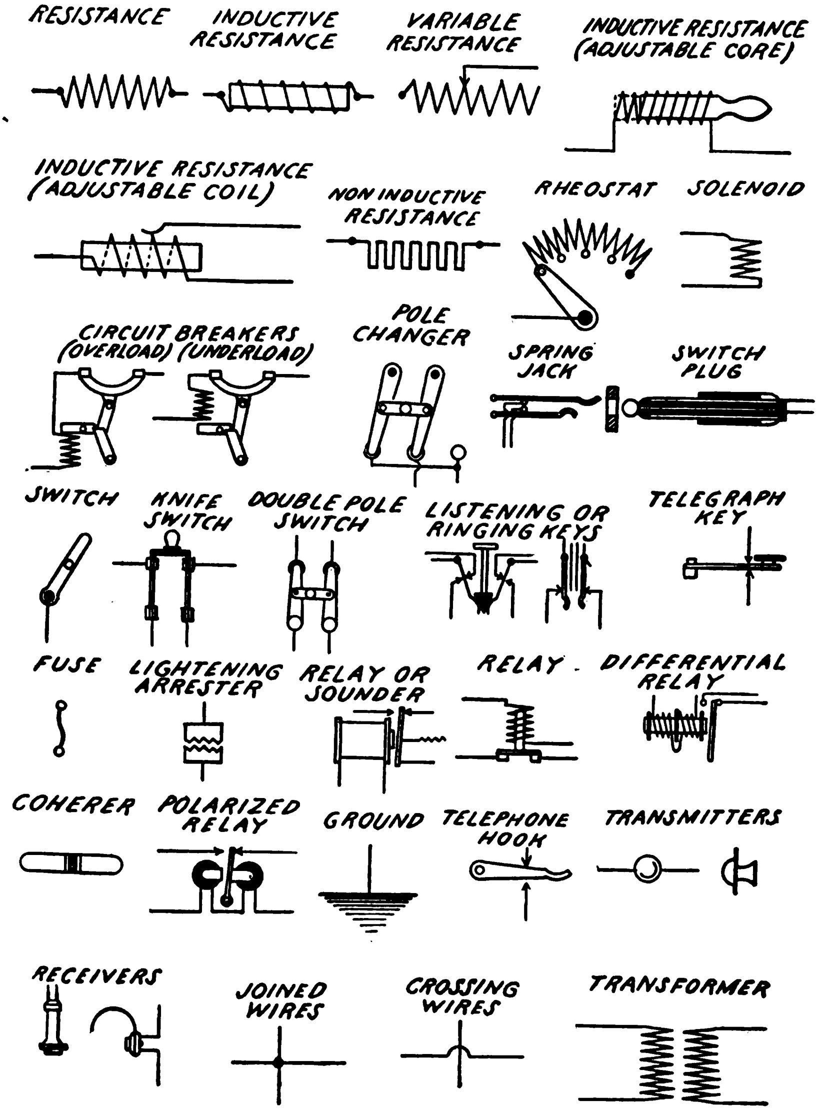
Now $\left.\begin{array}{l} 63 : 56 :: A : C \\ 63 : 70 :: A : E \end{array}\right\}$ Direct proportion

Also $\left.\begin{array}{l} 56 : 63 :: A : B \\ 70 : 63 :: A : D \end{array}\right\}$ Inverse proportion.

The spaces should all be filled except *a*, *b*, *c*, *d*, etc., which is needless as only the 63 gear will be duplicated.

TABLE CXX.

ELECTRICAL SYMBOLS



ELECTRICAL SYMBOLS

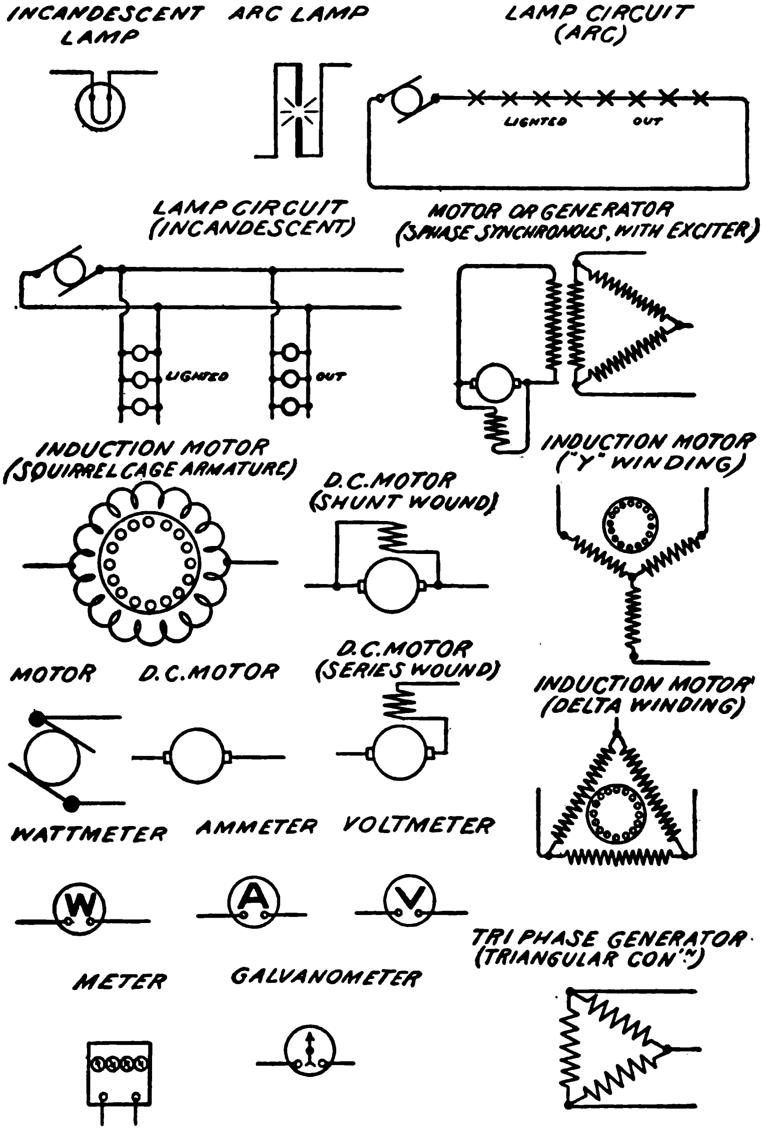


TABLE CXXII.

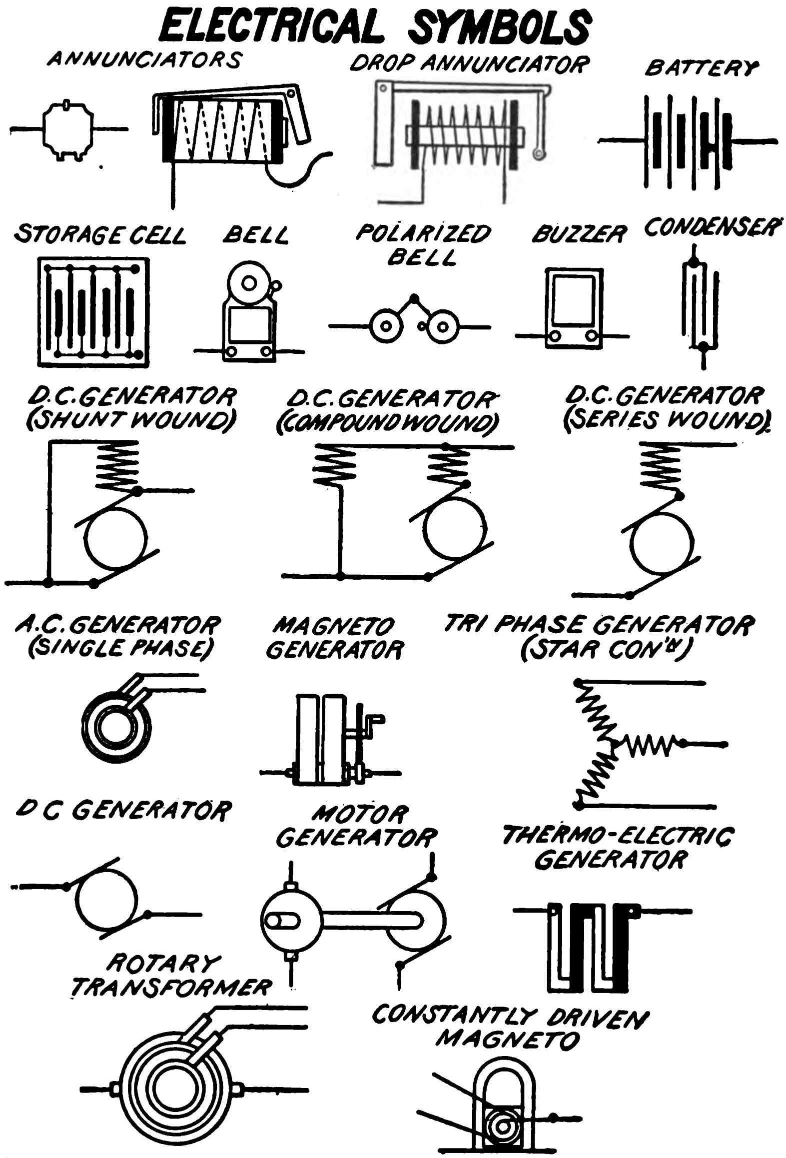
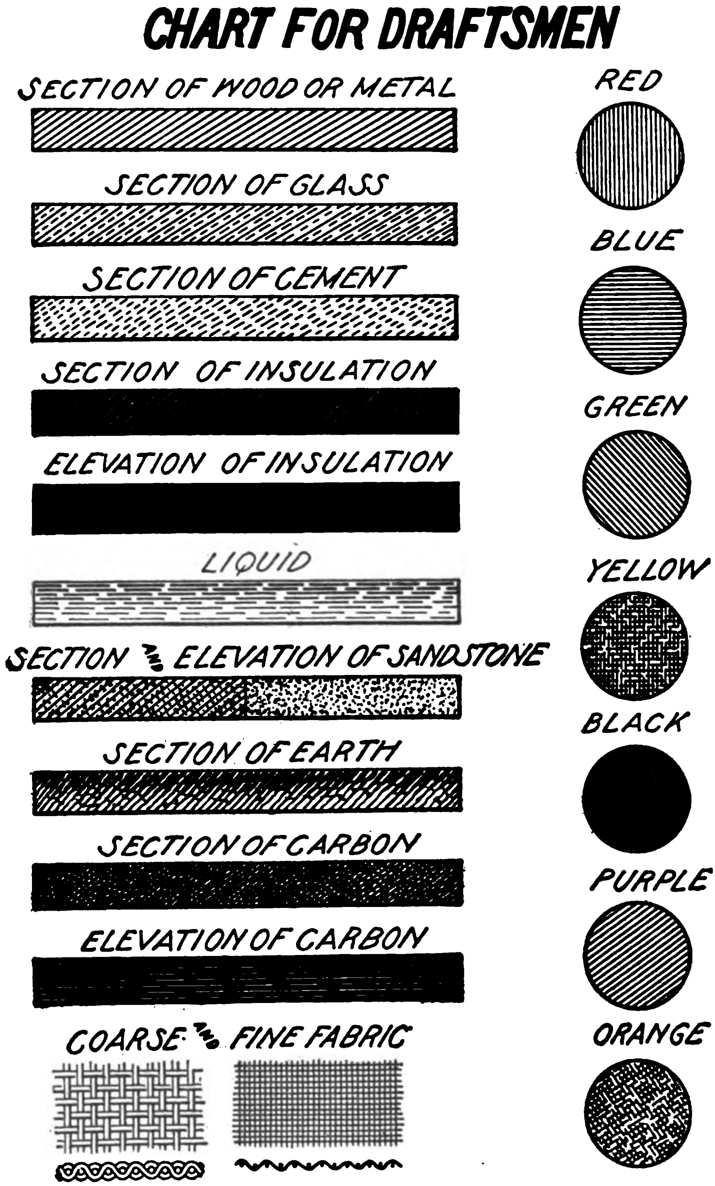

ELECTRICAL SYMBOLS
ANNUNCIATORS
DROP ANNUNCIATOR
BATTERY
STORAGE CELL
BELL
POLARIZED BELL
BUZZER
CONDENSER
D.C. GENERATOR (SHUNT WOUND)
D.C. GENERATOR (COMPOUND WOUND)
D.C. GENERATOR (SERIES WOUND)
A.C. GENERATOR (SINGLE PHASE)
MAGNETO GENERATOR
TRI PHASE GENERATOR (STAR CON'N)
D C GENERATOR
MOTOR GENERATOR
THERMO-ELECTRIC GENERATOR
ROTARY TRANSFORMER
CONSTANTLY DRIVEN MAGNETO

TABLE CXXIII.



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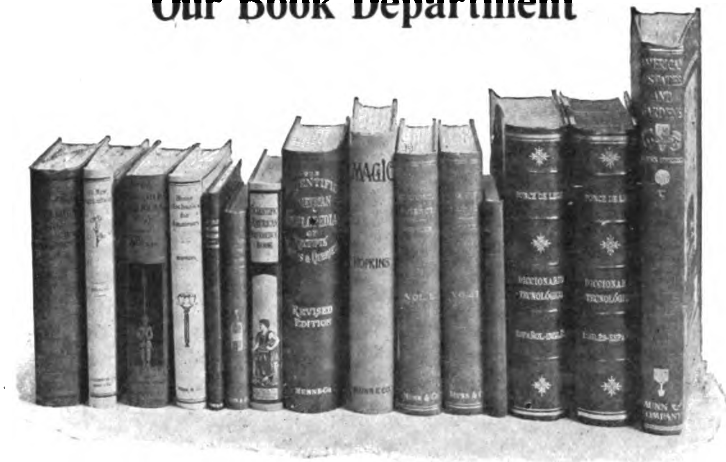

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There is no other publication having the same advertising value for your purpose, because it combines the best elements of the technical papers in your particular line with the large result-giving circulation of a general advertising medium.

In one year it carried successfully the advertisements of 298 different lines of goods, from paper clips at 10 cents, to ice making machinery at $15,000.

We have a department of service to co-operate with prospective buyers.

Will you let us take up your advertising and show you Why?

MUNN & CO., 361 BROADWAY, NEW YORK CITY