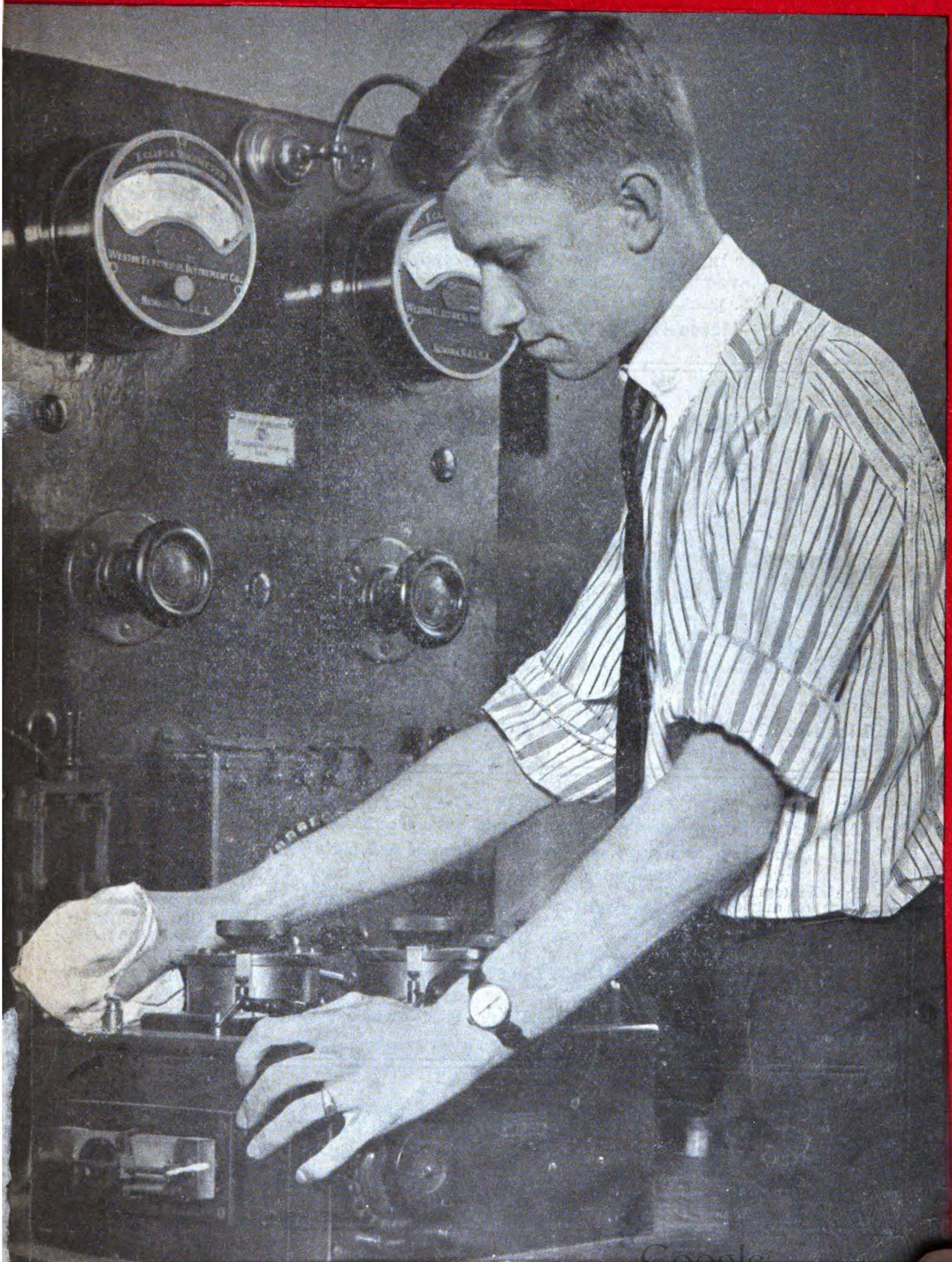
# PRACTICAL AMATEUR WIRELESS STATIONS



# Practical Amateur Wireless Stations

*An Experience Book*
*Containing the Best*
*Suggestions of Thirty-Three*
*Experimenters*
*On Building, Installing*
*and Operating Experimental*
*Stations for Radio*
*Communication*

**Compiled by the Editor of The Wireless Age**

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# Foreword

This volume has but a single purpose. Its intention is to set up a few guide posts for the reader and blaze a clear cut trail to the practical achievement of an amateur wireless station.

It does not aspire to recognition as a textbook on radio communication, in the academic sense; its mission is the simpler but useful one of presenting in convenient form the experience of practical workers in the art of building, installing and operating experimental wireless stations. Where a method is described, it is one which the author of the chapter has worked out and tried out himself; and the same is true whether the chapter deals with a single piece of apparatus or a complete station.

The volume has thereby acquired a peculiar merit, for it records the collective experience of leading experimenters without the restriction of view-point by prejudice or preference which must invariably be associated with the writings of a single author.

A wealth of material has been drawn upon by the compiler, whose privilege it has been for eight years to serve as Editor of The Wireless Age, during which period these selected chapters made their first appearance in the form of magazine articles.

Uncounted hours of patient experimenting are represented in the writings of the thirty-three representative experimenters contained in this volume, and it is their generous spirit of helpfulness to embryo and undeveloped wireless workers that has made possible this record of results and final conclusions.

New York, May, 1920.

J. ANDREW WHITE.

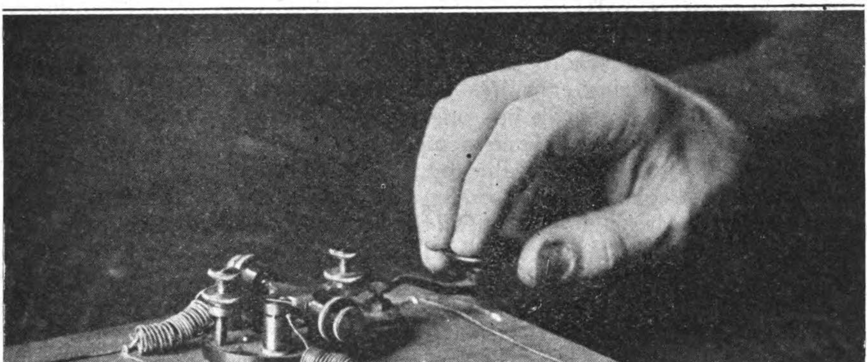
# CONTENTS

# CHAPTER I

## Learning to Send Wireless Messages

AMONG the batch of applicants for enrollment in the New York school of the Marconi Institute, on a Monday morning, were two young men who shall be named, for the purpose of this chapter, Dunbar and Baxter.

They came to the enrollment desk together. They aspired to become wireless operators; each had just turned eighteen years of age. They lived within a few doors of each other in a Long Island suburb of the metropolis, had been classmates in the same prep school and were of the same social status—of clean, unaffected, all-American stock. The spirit of each was equally high; the plans of their parents had been to send them to one of the great universities, but the boys had elected instead to enter



The correct position for telegraphing, a matter of greatest importance to beginners

the Marconi Institute where they expected to become proficient in the radio requirements demanded of all operators.

Their first day at the school found them memorizing the code in dots and dashes. They were told that each succession of dot or dash, or combination of dot and dash, produced a distinctive cadence which they must learn to recognize. They listened to the reproduction of Instructor Chadwick's sending contained in Victor-Marconi record No. 1. They learned the proper "grip" for sending. In the respect noted in the foregoing paragraphs the boys had points of contact in common, but here the resemblance ended.

Telegraphically, as indicated in their "form" in sending, these two students illustrated the extremes of faulty production of the signals. Land line telegraphers have the phrases "in the mud" and "in the air" to designate these two extremes. When sending comes to a receiving operator with scarcely recognizable distinction of dot and dash, with loose construction of components, in a heavy, "sticky" style, he says it is "in the mud." When it is too light, with "split" dots and unrhythmic relationship, one to the other, of the components, the sending is said to be "in the air."

"Pull it up," the receiver will demand when the sending is "in the mud." "Let it down" he will direct if the trouble is of the opposite nature.

Often the source of the trouble is in poor adjustment of the apparatus. A correct balance is then a matter of technical knowledge and skill. If, however, there is nothing wrong with the balance of the apparatus, responsibility of making the correction rests with the sender. The writer, using Dunbar and Baxter as examples, hopes to indicate the way to achieve the happy mean which lies between the two erroneous extremes.

Because with both boys the trouble was largely temperamental, a description of each is necessary. Dunbar was shorter than Baxter, but heavier. He was sturdily set up; an ideal build for guard or center of a football eleven. Baxter was built like a sprinter, with slim waist and long legs. Nervous energy seemed to radiate from him. Dunbar, mentally as well as physically, was of less speed but greater endurance than Baxter. Dunbar's tendency was to think first, carefully and in detail, and act afterwards. Baxter, on most occasions, acted first and thought afterwards; fortunately his instincts guided the majority of his acts in the right direction. Dunbar's heavier features and slower manner of speech in contrast to Baxter's flashing animation suggested to an observer lessened dynamic force. But on better acquaintance Dunbar convincingly showed a potentiality fully as great as his more brilliant friend. Their service-rendering capacity—if that phrase may be used to measure intrinsic worth—was equal, but one was expressed in brilliant, forceful spurts, the other in steady, even-tempered plodding.

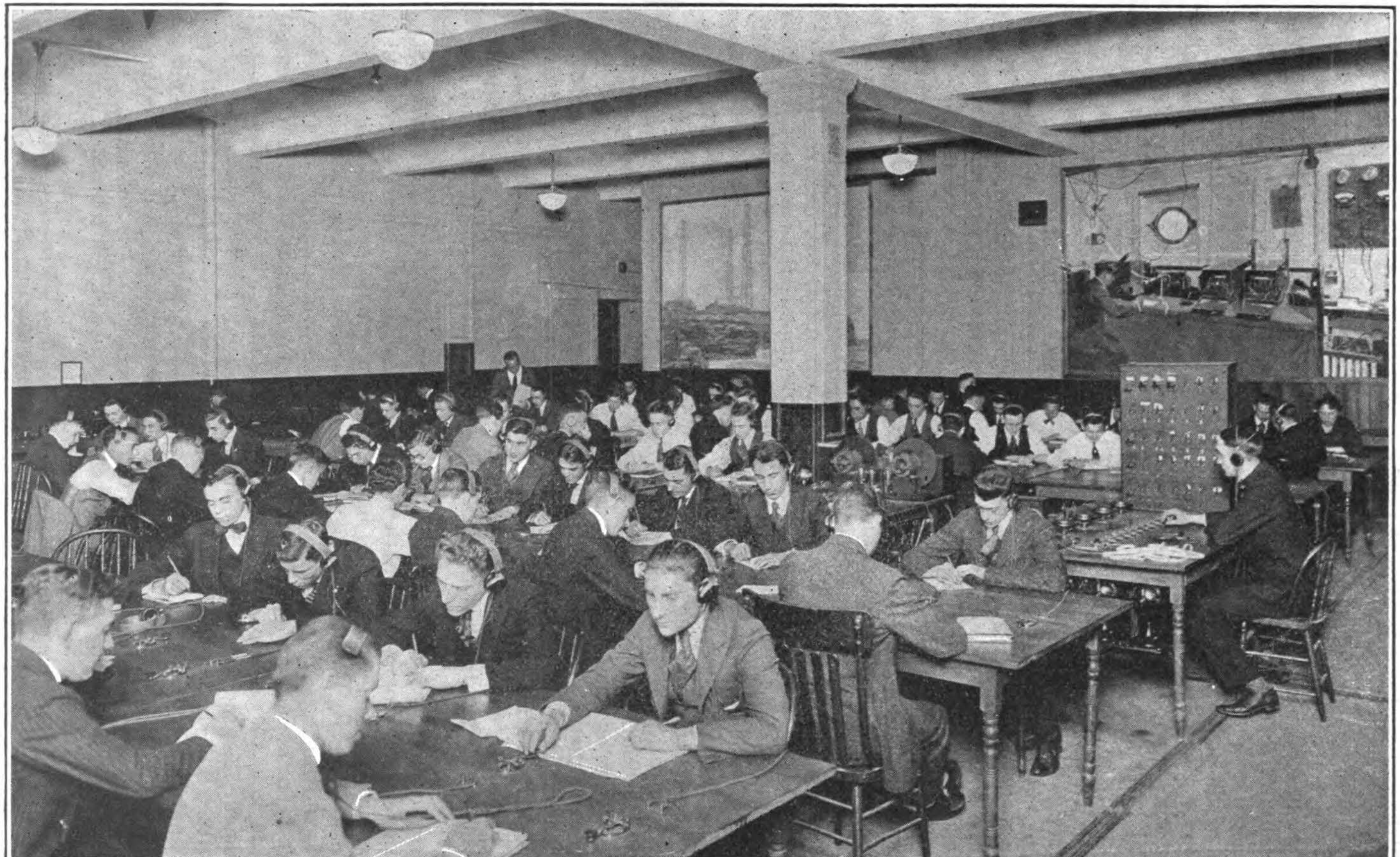
In precisely the ways indicated by the terms "in the mud" and "in the air" each boy began to produce the cadences of the dot and dash combinations in the beginners' room of the Institute. No doubt it would be absurd to state that an analysis of the sending style of a telegraphic aspirant will serve as an infallible guide to that aspirant's personality. In the cases of the two young men who are used here as illustrations, however, their strikingly opposite personalities were so accurately reflected in their opposite methods of faulty production of the code that the sketches of their personalities are worthy of note.

Dunbar's temperament, influencing his production of the code, caused him to cling to the idea that he had to visualize each letter in dots and dashes before he began to send it. He did this persistently, notwithstanding the instructor's efforts to induce him to conceive each signal rather as a cadence—of the letter "A," for example, as a staccato note and a legato note, occurring in quick succession, rather than to consider it as "dot" plus "dash." His mind's tendency toward inertia lost him the facility to adapt himself quickly to varying circumstances or unaccustomed processes of thought. The mind appeared to wrestle with his hand, wrist and arm; he produced the dots and dashes coarsely, heavily, "in the mud." He "let down" in the tension of the members which have to do with sending, or, better expressed, he failed to "pull up" with them sufficiently, so that he was continually without the proper "spring" of wrist and hand to make the immediate recovery of hand after each downward pressure. Physically, the focus point of trouble was in his wrist, the physical source of the trouble with nearly all poor senders. He couldn't seem to strike the correct degree of action at the wrist. His first impulse was to try to construct the signals with completely relaxed hand, with wrist barely clearing the table. That threw the responsibility of making the downward pressures upon his fingers. He concaved his index finger and second finger and tried it that way with negative results. Then he would swing to the other extreme, stiffen his wrist and raise the under part three inches above the table. That is more than twice too high a position for the wrist, as it bows the arm at that point and necessitates a full arm motion. With his wrist at that position, Dunbar's production of the dots and dashes was with a ponderous, punching motion of the arm from the elbow, as impossible a method as that of the fingers alone. His sending was "in the mud," heavy, loose in construction, without individuality of each separate dot and dash and each separate signal.

Baxter had been keenly interested in his friend's struggles at the key. His quick mind had grasped at once the significance of conceiving each signal as a sound, to be dealt with in its entirety. His error was that he wanted to begin immediately at the fourth stage of the development of a sender, before he had mastered the first, second and third stages. He wanted to take up the morning newspaper and send page one before luncheon. The details which produce the proficiency to do that meant little to him. His temperamental impatience manifested itself immediately in his sending. Not having achieved that fine balance of hand, wrist and arm which comes from long apprenticeship at the key—which is necessary before one can send with speed and style, and endure—he called upon his abundance of nervous energy. He was not content to learn to make each downward pressure, whether a dot or a dash, with a distinct action of his wrist. He could not do this speedily enough. So he stiffened his wrist and hand, and drew on the nerves of hand and arm to make the dots. As is always the case in "nerve sending," most of the dots he made lacked substance. They were "split." His sending came jerkily, erratically. He would make a "V," for instance, with a speed of construction that would entail a pace of twenty-five words a minute to be in proper relationship to the other letters. Then he would make an "O," immediately following, perhaps, at a ten-word a minute pace. A plotted line of the progress of his sending would look like the trail of one of those loud-buzzing insects which dart this way and that, covering fifty feet to progress a straight line distance of ten feet. His style was up in the air; too tense, too highly geared, too light in substance and erratic in progress.

Physically, as with Dunbar, the focus point of trouble was at his wrist. There was nothing wrong with the position of thumb, index finger and second finger on the key knob, his hand made the proper graceful curve on the key. His index finger was properly convexed when he began to send, and his second finger lay easily in place over the edge of the key knob. Third finger and little finger were curved without tension, clear of the key, to give his hand the proper balance. He proved to be a proficient telegrapher later, while the progress of Dunbar was slow and painful. The latter, in his mental make-up, was considerably more of the analytical type, without marked keenness of perceptions. Baxter's perceptions, on the other hand, were so keen that he was under continual temptation to exercise them to the neglect of his reasoning faculties. Telegraphically speaking, Dunbar was a trifle "in the mud," while Baxter was "in the air."

To correct the telegraphic errors of each, the instructors gave them "follow copy" practice, to register the sound of each letter in their minds, sending was arranged for half-hour periods at a time. Then they were made to listen over and over to the Victrola reproduction of the same sig-



This view of the northwest corner of the main code room of the Marconi Institute shows the students arranged at progressive tables according to the radio telegraphing speed they have acquired. The equipment provides for 250 students daily, all of whom are preparing for commercial service. Seated at the master table, right center, is the author of this chapter, exponent of the physical and psychological study of pupils to determine the best method of correcting telegraphic errors nals. The burden of correction lay with the boys themselves through the experience gained from day to day.

* * *

In the beginners' room of the Marconi Institute the practice sets are arranged in pairs, a pair of keys and a pair of head telephones on a separate circuit. Until both boys had achieved a speed in receiving of six words a minute, they spent most of the hours of code practice sending to each other. There they worked out their telegraphic problem, in the same manner, no doubt, in which they have worked out other problems, of both less and greater importance than learning the code. One boy's faulty extreme was checked by the other, and a degree of balance was attained. Dunbar gradually "pulled up," while Baxter "let down."

Leaving the two young men at this point in the care of their technical instructors, the writer will note what, in his opinion are the necessary four stages of development to produce a first class sending telegrapher.

The first is when learning to construct each letter, numeral and punctuation mark in accordance with what he terms Rules 1, 2 and 3. They are:

"Make your dot so sharp and short, though firm, that the receiver cannot possibly mistake it for a dash; make your dash long enough—three times as long as a dot—so that the receiver cannot possibly mistake it for a dot; knit together the components of each succession of dot or dash, or combination of dot and dash as closely as possible without weakening the individuality of each dot or dash."

The second stage is when the sender is learning to make a succession of letters to compose a dictionary word, code word or a cipher combination in rhythmic steadiness.

The third is when he is building up strength and power enough of hand and wrist to endure the sustained strain of sending which practical telegraphy calls for.

The fourth is when he puts the final touches to his sending which produce style and speed.

That the word "speed" occurs but once in the outline of these four stages, and then as the last word, should be held significant, as the chief cause of the great number of mediocre and poor hand senders in both land line and radiotelegraphy is that "speed" becomes of too great importance in the telegrapher's mind before he has earned the right to use it.

# CHAPTER II

## Learning to Receive Wireless Messages

IN the previous chapter the writer specified four stages of code sending, through which the code student must pass before he becomes expert in transmitting messages.

Phrased a little differently, though fundamentally identical, four stages may be defined through which the receiver must pass.

The first stage in sending finds the aspirant learning to construct each letter, numeral and punctuation mark in proper form.

The first stage in receiving is when the beginner is learning to *detect,* and write down, each letter, numeral, and the punctuation marks of common usage—to detect each, moreover, as a sound, an individual cadence.

The second stage in receiving is like the second stage in sending. This stage in sending has already been described as: "Learning to make a succession of letters to compose a dictionary word, code word or cipher combination in rhythmic steadiness." Applied to receiving, the second stage would be: Learning to detect and write down, accurately, and with *comprehension* of the word in its entirety, a succession of letters to compose a dictionary word, code word or cipher combination.

It is not enough to write down the letters blindly. Connection of the letters in word form should be made. That part of the brain which has to do with the registration of the cadence of each letter should be co-ordinating with those faculties which consciously recognize the word in its entirety.

Short, commonly used words, arranged in alphabetical relation, should be sent the beginner at this stage. Greater speed of transmission of words of increasing length may be gradually applied. Code words and cipher combinations may be included as part of the practice during this stage.

The third stage in receiving, as in the third stage of sending, is that period during which the student is building up telegraphic endurance, so that he can last throughout the sustained periods which practical telegraphy calls for. Sentence practice should be added to word practice in this stage. Practice, practice, practice, aiming for accuracy and "clean" copy, rather than for speed, is the prescription for this stage.

The fourth stage in sending is when the aspirant puts on his sending the final touches which produce style and speed. In receiving, this stage finds the code man learning, in general, the tricks of the speedy telegrapher. Specifically, his aim should be to learn the forms of telegraphic communication which prevail in the particular branch of the art in which he desires to become a worker. Knowledge of the methods and forms, and of the phraseology employed in each of the branches of the telegraph field is essential to become an "all-round" expert telegrapher. Press, broker, commercial, railroad—radio in its increasingly numerous military and civil sub-divisions—each of these has its bag of tricks to be learned. Not until these become familiar can the telegrapher work at high speed in any particular branch.

Roughly, then, the four stages, in both receiving and sending, may be defined as (1)—The "A.B.C." stage; (2)—The word stage; (3)—The stage which makes for endurance, and (4)—The finishing-touches stage.

It should be noted that these four stages run into one another and are of indefinite lengths. What one student may acquire in telegraphic facility in one month may take another student three months. Every telegrapher, however, must go through these four stages, whether consciously or unconsciously; whether in proper sequence or haphazardly.

A single principle rules throughout the four stages noted in the foregoing. The principle applies to receiving as well as sending, though perhaps not so obviously. It is self evident to even the novice in the code that the correct principle of sending is to keep the members which have to do with the process—the hand, wrist and forearm—in constant balance.

Even in such a physical process as sending, however, the hand, wrist and forearm will not keep in balance if the mind is not in harmony with telegraphic laws of progress.

"Progress in the order indicated by stages 1, 2, 3, and 4," is the writer's conception of the basic law of correct progress in the code. "Do not pass from one stage to another until each has been thoroughly mastered in proper sequence," is its inevitable corollary. If an over-zealous student tries to whip an untrained hand and wrist into a speed which his desire wills, his sending will reflect the mental fault. He is out of balance, telegraphically.

The earnest endeavor of the student should be to resist the temptation to leap from one stage to another before he has thoroughly mastered each one in proper sequence. The practice of the code is peculiar in that one may experiment—after a fashion—and one is continually tempted to do it. The last stages of the art beckon invitingly to the novice immediately after he has learned the alphabet. But the student who tries for speed in sending before he has learned steadiness, is endangering materially his chances of ever becoming either a steady or a speedy sender. And he is not progressing. Time spent in trying to receive press matter, for instance, before he has learned to copy a succession of five-letter dictionary words with comprehension, is wasted.

In applying to the receiving process the principle which is expressed in the one word "balance," the writer conceives the working of the mental apparatus in the same manner he would of a system of telegraphic machinery in proper relation and co-ordination. As a matter of fact, "in balance" is the term applied by technical men to such frictionless interworking of the telegraphic system. The whole will not balance if a part has been neglected. Moreover, the assembling of the apparatus must be done systematically.

The sequence of instruction given the beginner in telegraph receiving should likewise be systematic. Receiving is a process of taking on one conception after another; then of tucking them away—through the effort made by practice—in that part of the mind where are stored the things one knows so well that they function without conscious effort. Not until then is the receiver "in balance" at that particular stage. The test of the student's right to progress from one stage to another should be whether he has learned to fulfill the requirements of each stage with a minimum of conscious effort.

**Instruction in the adjustment of wireless apparatus is given during the period in which the students are perfecting their skill in receiving the code messages**

In the first stage, there must be the correct conception of the letters "A" to "Z," for instance. Throughout all the intermediate stages, to the point where the radio man can detect cipher combinations through heavy interference, or to the point where the speedy press telegrapher, working with Phillips Code, will associate, for example, the letters "az," as sent, with the word "applause," the process of receiving is one of taking on and tucking away a sequence of correct conceptions.

The duty of the code instructor, as the writer sees it, is to render the student's progress as free as possible of needless handicaps. Further, the instructor should lay out a system of practical material. It is the writer's opinion based upon experience and demonstration, that this system should be built around the principle laid down in the foregoing, governed by the law of the code as stated, and its corollary, and arranged in recognition of the four stages of progress which have been specified.

A class of students receiving instruction in radio receiving, at a stage where they are impressed with the importance of resisting the temptation to leap from one stage to another before each one has been mastered in proper sequence. The code instructor emphasizes the fact that telegraphic receiving is a process of taking on one conception after another; then of tucking them away—through the effort made by practice—in that part of the mind where are stored the things one knows so well that they function without conscious effort

# CHAPTER III

## An Improved Code Practice Apparatus

IN using a bank of lamps in series with a 110-volt current supply for code practicing, it is not uncommon to have "static" annoyance which interferes with the successful operation of the device. The trouble may be caused by arcing of the brushes on the generator at the power station. However, the problem is solved by the following changes:

In place of the bank of lights, a small motor is connected in series with the primary of the induction coil. The secondary connections are made in the manner shown in the accompanying diagram.

The accompanying diagram shows how the motor should be connected to the induction coil.

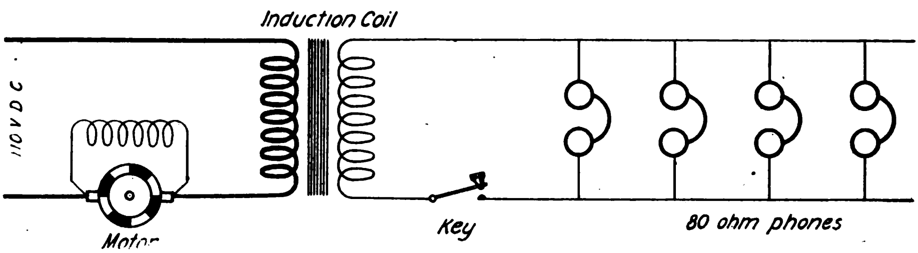



Diagram showing method of connecting the motor with induction coil

In case it is to be run without load only, a shunt motor should be used. If a small series motor is used a load must be kept on it to keep it from "building up" and finally breaking, either electrically or mechanically. If electric fans are used in the class room the motor of one of these may be connected in series with the coil.

The motor is more economical in use of current than the bank of lights and produces a much more regular sound. As a result of this a class can advance more rapidly than with the irregular type of apparatus used before.

Some radio schools have a system in which a small motor is employed to run a cast iron armature past two magnets, one of which is connected to a low potential source of current, generally a storage battery, while the other is connected to telephones. For successful operation this type of apparatus requires that the parts be accurately machined and that they run true. The cost of all this work and material amounts to considerable in times when prices are normal, and now it would be very high.

In the other system, with the motor in series with the coil, no machining is necessary, no storage battery is required, and the power from the motor may be used to run the automatic transmitter, a fan or any small device.

On the whole this system will be found much cheaper to install and to operate and the results will be the same as the more expensive method.

# CHAPTER IV

## The Amateur Radio Station and the Fire Underwriters' Rules

AMATEUR wireless apparatus often is not installed in accordance with the Underwriters' rules and in a few cases the violations are so serious that it constitutes a fire hazard. As a rule, radio amateurs are willing to adopt any changes which are suggested to them that will better their stations if it is within their means, but the conditions necessary for safe and satisfactory service from their power wiring, are only vaguely understood. It is the purpose of this chapter to point out the advisability of modifying the installation to conform to the Underwriters' rules, and the method of doing so. If the suggestions are acted upon the fire risk will be materially reduced.

In many amateur stations the circuits supplying current for the high voltage transformer of the experimental radio transmitter are given little or no attention, and consequently the majority of stations are not as perfect as they might be in this respect. The wiring is sometimes installed in a slipshod fashion from a miscellaneous assortment of material that is unsuited for the purpose. Improper insulation of conductors from each other and surrounding objects, insufficient carrying capacity of conductors, absence of proper protective devices and overloading of circuits are the main shortcomings. It is not uncommon to find wiring that could hardly be considered of sufficient current carrying capacity for battery current, supplying a 1 kw. transformer and a rotary gap besides. The service rendered by such poor construction is usually very unsatisfactory, causing excessive drop in voltage at the transformer terminals, blinking of lights and other annoyances, not to mention the fire hazard sometimes incurred.

In planning the reconstruction of his station, the progressive experimenter should give this subject due consideration and take steps to remedy any defects that may exist in the circuits of his power supply. Of course the chief consideration regarding the installation is that it shall comply as nearly as possible with the rules of the Fire Underwriters, and if these conditions are met even half way a comparatively safe and satisfactory condition will obtain.

If your transformer is of 1 kw. it would be well to first ascertain whether or not the house meter has sufficient capacity to carry the full load plus that of the rotary gap and about half the house lighting load simultaneously. This precaution may save an extended argument with the power company or perhaps the price of a new meter. It is the general practice to install only a 5 ampere meter in residences, since they can stand a 100 per cent overload. It is always good policy to notify the electric company of your new load, and if they do not believe it to be necessary to change the meter, it becomes their risk and if the meter is burnt out it is their loss. I mention this because I had to "kill" two meters before the local electric company consented to install one of increased capacity. No doubt other experimenters have had their troubles in this respect.

If the transformer is on an upper floor of the house, some distance from the meter, it is usually the practice to tap into a convenient fixture or base board receptacle, or else run a short feed which is tapped onto the lighting circuit wires at some point in the room. This should not be done since it is forbidden by the Fire Underwriters. The wiring of the average house is seldom larger than No. 14 B. & S. and in the fixtures it is usually No. 16 or No. 18 B. & S. The voltage at the trans-


Station of the Crescent Bay Radio Association at Santa Monica, Cal., where fire rules could be more rigidly observed

former terminals will be low, and all lamps on that circuit or on the same feeding wires will flicker badly. Choke coils and other paraphernalia are usually resorted to in an effort to prevent this, but they can never be of great value so long as the current is taken from the fixtures. Furthermore no lighting circuit is supposed to carry more than 660 watts, so it is evident that the only method sanctioned by the Underwriters is to run a separate pair of feed wires of proper size to carry the current without excessive drop in voltage, from the meter direct to the transformer terminals. There should be an individual fuse block for these feed wires mounted either at the meter or else in the radio room where it would perhaps be handiest to replace a blown fuse without going down to the cellar while you tell the other fellow to stand by. This usually is done by the light of a candle, as the house lights are out as well.

It will be found a good investment to run separate feeds, for then you will have done the right thing by the Underwriters, and the lights will not flicker and the lights in the house will not go out every time you blow a fuse. This will give the home folks a vastly better opinion of "wireless." The size of these feeds will be governed by several factors; the current in amperes taken by the transformer, the distance of the transformer from the meter, and the loss in volts that is permissible in carrying the current this distance. The formula for finding the size of wire is:

$d^2 = \frac{10.8LI}{e}$ and for finding the drop in volts is: $e = \frac{10.8LI}{d^2}$ in which $d^2$

is the area of wire in circular mils, 10.8 is a constant, "L" is the length of circuit in feet, "I" is the current in amperes and "e" is the drop in volts.

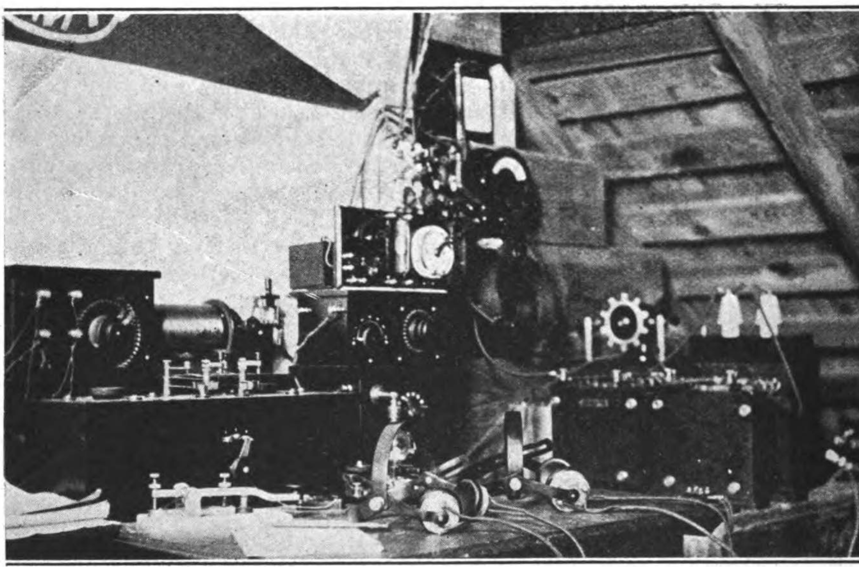
We have, for example, a transformer rated at 1 kw. located on the second floor of the house, and the meter is in the basement. First, determine the path your wires will follow between the two points, then determine the length of wire necessary to follow this path one way. Let us say this is 75 feet. This sum doubled is substituted for "L" in the formula. Assuming that the current drawn by the transformer when operated at maximum load is about 10.5 amperes and that we have a rotary gap motor which takes 1.5 amperes, then the total load will be 12 amperes and this is substituted for "I." Now we must determine the permissible drop in potential for the value "e." The voltage at meter terminals is usually about 115 volts, sometimes a few volts higher or lower. As it is very desirable to have the voltage at the transformer terminals as high as possible, only a very small drop should be tolerated, not more than 2 volts at any rate. Suppose we use 2 volts for the value of

"e" Substituting these values and solving we have $d^2 = \frac{10.8x150x12}{2}$

or $d^2 = 9.720$ circular mils. Referring to a table of wire dimensions we find that the size of wire which most nearly approaches our result is No. 10, and this should be used. Although this would satisfy conditions, it would be still better to keep the drop down to about 1 volt, and use a larger size of wire.

If it is desired to determine the drop in potential in an existing circuit the second formula may be used. A partial table of wire sizes covering those that are most likely to be used by the experimenter, together with those rules of the Fire Underwriters from the 1919 code, class E, section 86, that deal with wireless telegraph apparatus, will be found at the end of this chapter.

In regard to the actual work of installing the feed lines; if you live in a town where it is necessary to have all electrical work done by licensed contractors, or if you do not feel capable of doing the work properly, it is best to have it done by an experienced wireman according to your specifications. If flexible armored cable is employed to protect the wires, it will conform to the Underwriters' rules and will be found very



This station located near the Mexican border and belonging to D. H. Graham of House, Texas has had consideration given to fire regulations

easy to install. It can be run either exposed or concealed under the floor and in partitions. The only thing that requires care is in stripping the armor to make connections, this being done by nicking it with a hack saw and bending back and forth until it breaks; then it can be slipped off. It is necessary to be very careful so that the wires or insulation will not be damaged. A conduit or other end fitting will be necessary at each end of the cable. Any wire supply store will gladly show you how to strip the cable and attach the fittings. The fuse block should be an ordinary two wire branch block for screw fuses, costing only a few cents. The new feeders should be tapped directly onto the wires from the meter that connect to the other fuse blocks for house lighting. While doing this the main switch should be opened so that these wires will be dead. All connections should be well soldered and taped. A ground wire of any kind of insulated wire of a size equal to that in the cable should be connected to the steel armor of the cable and then connected to a water pipe or other good ground. If these directions are closely followed, the radio experimenter of average ability should have no trouble in making a satisfactory installation, but he should make doubly sure that everything is O. K. by having an experienced man go over his work.

One other thing requiring attention is the provision of means to protect the house wiring from high potential surges or "kick back" from the transformer. There are a good many types of kick-back preventers; the electrolytic, needle gap, high resistance shunt of graphite rods, or large capacity condensers, etc. Probably the two best methods are the shunt condensers or the shunt resistance rods. Although the Underwriters' rules specify the condenser type of protection the high resistance shunt is used in commercial installations and is entirely satisfactory.

## "ABSTRACT FROM REGULATIONS OF THE NATIONAL BOARD OF FIRE UNDERWRITERS, CLASS E, SECTION 86, WIRELESS TELEGRAPH APPARATUS

Note.—These rules do not apply to wireless telegraph apparatus installed on shipboard.

In setting up wireless telegraph apparatus (so called) all wiring pertaining thereto must conform to the general requirements of this code for the class of work installed and the following additional specifications:

a. Aerial supports to be constructed and installed in a strong and durable manner, and aerial conductors, with wires leading from same to ground switch, must be supported on approved insulators, and these conductors to be kept at a distance of not less than six inches from the building, except where entering same through approved non-combustible, non-absorptive insulators.

b. Aerial conductors to be permanently and effectively grounded at all times when station is not in operation by a conductor not smaller than No. 6 B. & S. gauge copper wire run in as direct a line as possible to water pipe on the street side of all connections to said water pipe within the premises, or to some other equally satisfactory earth connection or to such other ground as may be allowed by special permission in writing.

c. Or the aerial to be permanently connected at all times to earth in the manner specified above, through a short-gap lightning arrester, said arrester to have a gap of not over 0.015 inch between brass or copper plates not less than 2 1-2 inches in length parallel to the gap and 1 1-2 inches the other way, with a thickness of not less than one-eighth inch mounted upon non-combustible, non-absorptive insulating material of such dimension as to give ample strength. Other approved arresters of equally low resistance and equally substantial construction may be used.

d. In cases where the aerial is grounded as specified in section b, the switch employed to join the aerial to the ground connection shall not be smaller than a standard 100-ampere knife switch.

e. Where supply is obtained direct from the street service, the circuit must be installed in approved metal conduits or armored cable. In order to protect the supply system from high potential surges, there must be inserted in the circuit either a transformer having a ratio which will have a potential on the secondary leads not to exceed 550 volts, or two condensers in series across the line.

f. Transformers, voltage reducers or similar devices must be of approved type.

Wires for Interiors of Buildings
(National Code Standard)

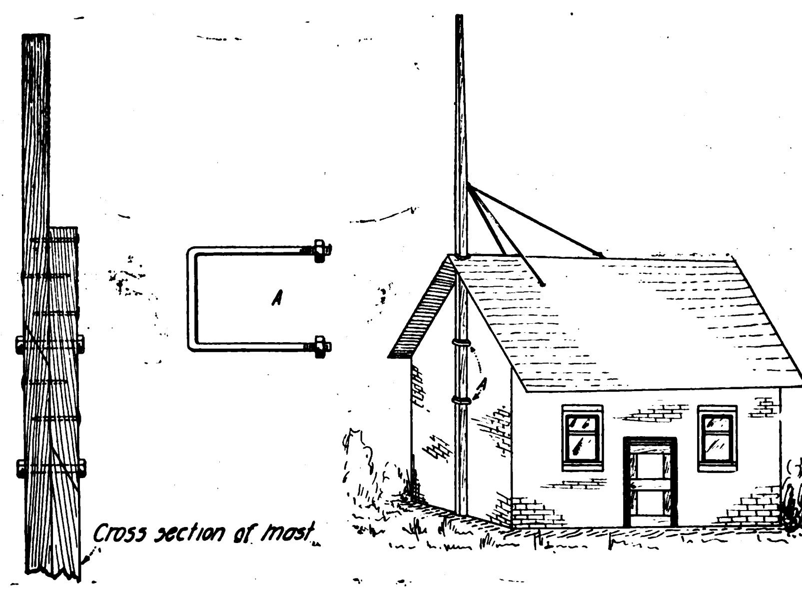
| | | —Carrying | Capacity— |
|---|---|---|---|
| B & S. Gauge Number | Circular Mils | Rubber-covered Wires Amperes | Weather-proof Wires Amperes |
| 18 | 1,624 | 3 | 5 |
| 16 | 2,583 | 6 | 8 |
| 14 | 4,107 | 12 | 16 |
| 12 | 6,530 | 17 | 23 |
| 10 | 10,380 | 24 | 32 |
| 8 | 16,510 | 33 | 46 |
| 6 | 26,250 | 46 | 65 |
| 5 | 33,100 | 54 | 77 |
| 4 | 41,740 | 65 | 92 |

# CHAPTER V

## How to Erect an Aerial Mast

THE amateur located in the country or a small town may be interested in the design of an aerial mast constructed as shown in the accompanying drawings. It will be noted that a hole is cut in the roof of the building through which the mast enters and that the mast is clamped to the side of the building by means of two iron rods of the shape shown in the figure at A, which are threaded at both ends to take a bolt.

The mast may be put together in sections, one at a time, and slid up through the holding clamps. By using pieces of two-by-four lumber 16 feet long, a very serviceable mast is obtained. Two or three 16-foot pieces will be sufficient for the average amateur aerial mast.




Construction of aerial masts, one of the clamps and method of fastening the mast to building

# CHAPTER VI

## How to Build an Efficient Spark Station

OUT of extended experience have grown ideas regarding the ideal radio set which may prove of interest to the general type of radio amateur. All component parts of the transmitting set are mounted separately on a suitable sized table—taking particular care to so arrange the apparatus that the leads in the oscillatory circuit are as short as possible.

The condenser is the usual bugbear in the transmitter. It will be given further consideration. The solution of the condenser problem in the writer's opinion is to make it an oil immersed affair—using a good grade of transformer oil. If automobile windshield plate glass of ¼ inch thickness is used, little trouble will be experienced as far as "puncturing" of the plates is concerned. Twelve ten-inch by fourteen-inch plates in parallel

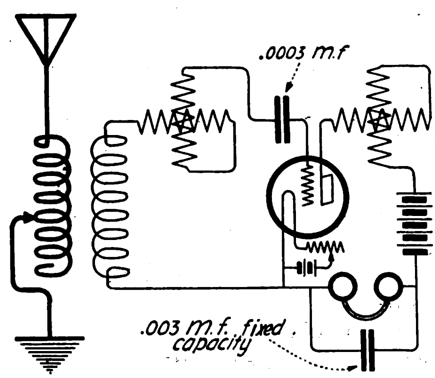



Diagram of the Armstrong circuit for wireless receiving set

give the correct capacity for 200-meter operation. Tinfoil eight inches by twelve inches should be "pasted" onto the glass by putting a few drops of transformer oil on the plates and placing the tinfoil on and squeezing the oil over the surface of the plates with a photographic roller. Then solder copper ribbon at least ½ inch wide to the tinfoil.

After each of the 12 plates have been coated they are stacked together and bound with canvas strip. Next a suitable containing tank should be obtained. It should be large enough to allow at least one inch clearance around all the edges of the glass plate. Wood strips one inch thick should be placed on the bottom of the tank to keep the plates insulated from it. A bakelite or hard rubber panel should be cut to cover the tank and keep out all dust and moisture.

The rotary gap is the next item. A bakelite disc 10 inches in diameter should be obtained. The thickness should be ⅛ of an inch, no more is necessary, and is really harmful, since the lighter the disc the less the amount of power necessary to turn it. Next 10 brass electrodes are constructed from ¼ inch threaded brass rod. They should be one inch long, each end finished in a chisel shape with an edge ⅛ of an inch thick. Eight of these electrodes should be mounted on the periphery of the disc so that they protrude equally on both sides of the disc and should be held in place by means of a nut on each side of it. The stationary electrodes are mounted on brass standards on a marble or bakelite base, one electrode on each side of the disc. The disc itself should be mounted on a polishing lathe, similar to a small jewelers' lathe, which can be bought at any hardware store for the amount of $2.50. The writer prefers a belt arrangement such as this type of mounting requires, to the usual method of mounting the disc directly onto the shaft of the motor. One reason is that it allows the speed of the rotor to be more easily changed than the type driven by an induction motor, and another reason is the elimination of the danger of high potentials burning out the winding of the motor. A fan motor or any other motor of one-sixteenth h.p. is entirely suitable for running this gap.

The oscillation transformer is made of 1½ inch brass strip employing the pancake type of winding. The primary is made of 4 turns, the outside diameter of the first turn being 8 inches. The turns should be at least ½ inch apart. The secondary contains 10 turns of similar size. Both primary and secondary are mounted on bakelite strips. The secondary is mounted on a hinge to vary the coupling. Very heavy helix clips should be used.

Any standard make transformer with a secondary potential of at least 15,000 volts is suitable. The Thordarson 1 kw. 20,000-volt model seems to be the favorite and from a point of efficiency, reliability and cheapness is the best on the market, in my opinion.

The connections from the secondary to the condenser should be made of No. 24 magnet wire. Two choke coils of No. 24 wire on tubes 2 inches in diameter and 3 inches long are sufficient to take care of all "kick backs" from the condenser.

All connections in the oscillatory circuit should be of very heavy copper sheeting. The writer bought copper sheet 1-32 inch thick and 6 inches wide in lengths of 2 feet and cut this to the required length with a width of 1½ inches. If all connections in the oscillatory circuit are made as short as possible and the set is tuned by means of a hot wire ammeter and wave meter, no one should experience any great difficulty in working 1,000 miles during the favorable season, provided a modern type of regenerative set is used at the receiver.

If one cannot afford to buy one of the popular makes of regenerative sets on the market the solution is to construct one. Whether it be mounted in a cabinet or not is optional with the constructor. Personally the writer prefers to leave his unmounted so that he can readily adapt the circuit to the various changes that are necessary in order to keep abreast of the times.

The primary of the receiving transformer is 3 inches in diameter wound with 50 turns of No. 24 S.S.C. magnet wire with switches for single turn variation of inductance. The secondary is 2½ inches in diameter, wound for one inch with No. 31 S.S.C. No taps are taken off the secondary. The necessary changes of inductance are obtained by using a variometer in series with the secondary. A suitable variometer is described in "How to Conduct a Radio Club," by E. E. Bucher. Another variometer of similar size is required in the plate circuit. The diagram of connections as illustrated is the Armstrong circuit. Brandes Superior telephones fill the bill very satisfactorily.

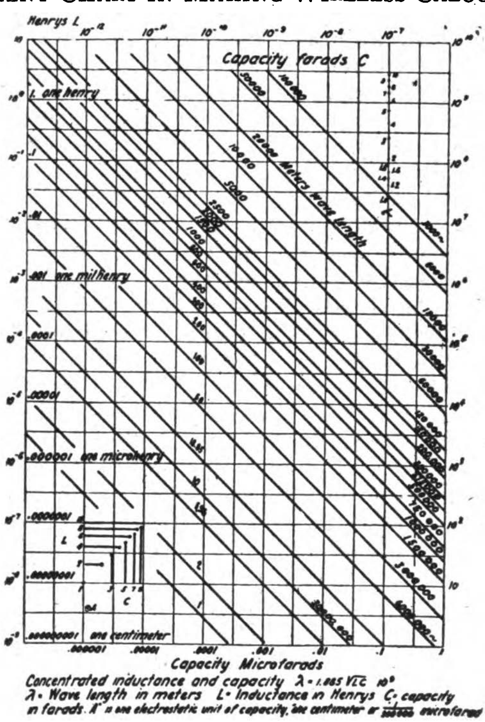
The aerial should be as high as possible and not over 100 feet long unless it is made of the "T" type, in which case it can be 120 feet long.

The ground connection should be attached to water or gas mains and also to a 4-wire counterpoise buried under the ground for a few inches, parallel with and underneath the aerial.

With a transmitting set of the above description, the writer regularly "put" 8.5 amperes into an aerial 80 feet long and 40 feet high and has for his transmitting record a distance of 1,600 miles.

The writer's receiving record is 1,800 miles with a receiving set similar to the one described, having copied 6 EA at Los Angeles, Cal., at Little Rock, Ark., six consecutive nights during the latter part of the 1917 season.

Convenient Chart in Making Wireless Calculations




The accompanying chart will be found convenient in making wireless calculations. It shows the relation between concentrated capacity and inductance, and the frequency of a circuit, and also the relation between the c. g. s. units and the practical units. It could be re-drawn on a larger scale with logarithmic subdivisions and reduced photography. Please note that taking the first space of 10 centimeters for inductance as one inch, which it is, the diagram is 16,000 miles in length!

# CHAPTER VII

## The After-the-War Type of Amateur Wireless Station

THE first and most important part of any wireless station using a short wave, is the aerial. The ideal station should have the aerial supported by a mast at least seventy feet high, if the aerial is near any buildings, trees or wires. Iron pipe masts, wooden towers, or structural steel towers may be used. A very serviceable and satisfactory mast may be constructed of common iron pipe, which may be purchased at any hardware store. By the use of reducing couplings heights up to ninety feet can easily be secured. Some masts over one hundred feet in height have been made, but require a very extensive system of guying and are not easily constructed. Another method is to use wooden 4 by 4's. The transmitting aerial should be seventy-five feet long, and the long wave length receiving aerial two hundred and fifty feet long. The former should be composed of six wires placed three feet apart. The "L" type is preferred. The longer aerial should have at least two wires spaced four feet apart.

The lead-in from the aerials should be composed of the same size wire as the aerials, preferably stranded phosphor bronze. It should be supported at only one point between the aerial and oscillation transformer. The insulation throughout the aerials should be Electrose insulators. The lead-in may be brought through the wall in a Marconi desk insulator.

The instruments should be five feet or less from the ground connection, which may consist of buried plates, either tin or copper, buried wires or netting, or iron pipes driven in the earth in the form of a circle. In any case the connections should be well soldered. The underground part of the earth plate should extend under the horizontal part of the aerial. The aerial connection should be made directly to the oscillation transformer, the antenna switch breaking only the earth connection.

The oscillation transformer should be made of heavy brass or copper ribbon. The primary should have three turns eleven inches in diameter and the secondary five turns of the same diameter. The transmitting condenser should be made of one-quarter inch plate glass. The plates should be built in a frame and spaced one-quarter inch apart. They should be coated with heavy tin foil, the whole to be immersed in oil. Copper coated Leyden jars may be substituted. A series multiple connection must be employed for potentials above 15,000 volts.

The spark gap may be a rotary, quenched air cooled, or stationary quenched cooled gap. An efficient non-synchronous rotary gap may be substituted. The transformer should be of the well known ½ to 1 kw. closed core type. All connections in the closed oscillation circuit should be made of heavy copper or brass ribbon. The key should have heavy silver contacts and a long arm.

The power lines should be protected by micrometer gaps and condensers. Choke coils may be used between the secondary circuit of the transformer and the condenser. The aerial or antenna switch may be any of the types offered by manufacturers. A marble base is preferred. In selecting a switch the accessibility and efficiency should be considered.

The receiving set should have three separate tuning transformers. The first for waves from 80 to 600 meters, the second for waves from 600 to 3,000 meters, and the third for waves from 3,000 up to about 15,000 meters. The first should be used in connection with a regenerative circuit. The second is preferably the so-called Navy type, having all variations of inductance made with switches. One turn variation of the primary and ten turns variation of the secondary should be provided for. The secondary should be shunted with a variable condenser. The third transformer is similar to the second, and larger. If large enough only a primary loading inductance is needed, although very good results may be secured by the use of both "wing" and "grid" inductances with a smaller transformer. All three sets should be used in connection with a good vacuum tube. Any of the types offered are good, although some are more sensitive than others.

The three transformers are used for reception from amateur and boat stations, medium long wave spark and arc sets, and long wave arc and spark stations respectively.

In the foregoing specifications a few things have been omitted for separate discussion. The location of the instruments is a very important item for efficient operation. If possible an operating hut should be constructed so as to place the instrument directly under the aerial. This allows short connections which are important. A good hut can easily be constructed by any amateur.

Another thing to be taken into consideration in the ideal station is the matter of connections. Many different circuits especially for the receiving set have been published. Before making permanent connections different circuits should be tried. Although one gets good results it may be possible to still further improve on them. This applies especially to the long wave receivers.

The transmitter circuit is not susceptible to various connections. The secondary of the transformer is connected in multiple with the condenser, the gap and primary of the oscillation transformer being in series with the condenser.

# CHAPTER VIII

## An Ideal Amateur Transmitter and Receiver

THE ideal amateur wireless station should be, if possible, located on the ground floor of a building. If above the first floor, the ground wire may be so long as to cause some loss of radiation. On the other hand, if located in the basement, the lead-in where it enters the building will be too close to the ground and in some cases may cause a serious brush discharge to the earth.

The aerial should consist of six or more stranded copper wires, spaced at least four feet apart. A 10½ inch hard rubber or bakelite insulator should be placed in the end of each wire. Insulators should be placed every fifteen or twenty feet in the guy wires to prevent loss of current to ground.

A good earth connection is formed by burying squares of copper or tin sheeting about eight feet beneath the ground, in a circle of fifteen or twenty feet and bringing the connections from the plates in a rat-tail formation to the surface where the ground wire to the apparatus is attached. The ground wire should be at least a No. 4 stranded cable. The plates should be placed flat on the ground.

Care should be taken when wiring the station to run the lighting wires as near at right angles to the aerial as possible, to prevent destructive currents from being set up in the power circuits. All wiring should be done in accordance with the underwriters' specifications, which can be obtained from any local electric light company.

The transformer should be both substantial and efficient, and the voltage should approximate 20,000, in order that a small condenser may be used to permit the use of a reasonable amount of power on the 200-meter wave. A transformer with considerable magnetic leakage should be used as it can be adjusted to resonance and will not pull heavily on the lighting circuits.

A good oil-immersed condenser for a ½ to 1 kilowatt transmitter may be constructed as follows: Obtain 10 plates of triple thickness glass, each 9 inches by 12 inches; coat eight of them on both sides, and two of them on one side each with heavy tinfoil 6 inches by 9 inches. The lugs and foil are to be cut in one piece. Corners should be rounded to prevent brushing. Shellac can be used for the adhesive, and pieces of fifteen ply cardboard 6 inches by 9 inches in size should be placed between the plates for separation, so the oil can get between the plates. Be sure to cut the foil so as to bring the lugs out wherever convenient; then after squaring the plates evenly, tape them together tightly and place them in a box of transformer oil, on their edge, so the oil will force the air-bubbles out between the plates. The box can be made oiltight by pouring boiled sealing-wax along the cracks and letting it harden, then giving it a few coats of shellac.

The Marconi type of discharger is simple and efficient. On the shaft of a one-tenth h.p., 3,600 r.p.m. induction motor, mount a 10-inch "Victor" record with eight equally spaced holes drilled around the periphery about ½ inch from the edge, large enough to insert a battery binding post bolt. Then obtain some battery binding posts; file off their heads; put them in these holes and fasten them with small nuts on both sides of the disc. The stationary electrodes should be so placed that the rotary plugs will pass between them. This gap gives an excellent tone.

The oscillation transformer should be of the "pancake" type with 5 turns of No. 6 and 10 turns of No. 8 copper wire, or 1½ inch ribbon (copper), for the primary and secondary, respectively. The frame should be made of bakelite or well seasoned wood, and must be constructed so that the primary and secondary windings are accessible to the clips at nearly all points.

All leads connecting together the elements of the closed oscillation circuit should be as short and as heavy as possible. They should have no sharp bends or kinks in them.

The antenna switch should be so constructed that when in sending position it connects the aerial to the oscillation transformer, closes the circuit to the current mains and starts the rotary. When receiving, it should connect the receiving tuner to the aerial and open the circuits to the transformer and rotary gap. It should be extremely well insulated and be capable of quick and easy operation. The current carrying parts should be capable of carrying the antenna current without loss.

A long wave regenerative vacuum tube receiver fitted with mica diaphragm telephones and a tubular or other type of bulb should be used. If the set is built into a cabinet, dust can be kept away from the instruments and both the appearance and efficiency improved thereby. Any regenerative connection is good if constructed in accordance with fundamental principles. In place of loading coils for long wave lengths the writer has successfully employed condenser units connected across the primary so that one or more may be cut into the circuit. They are just as efficient under some conditions as the loading inductance and take up far less room. A good storage battery should be used to light the filament, because they are more economical in the long run than dry cells.

Every amateur should own a short wave regenerative set as the range is greatly increased when receiving short wave amateur stations. Any of the several types being sold under various trade names may be employed to advantage.

With the apparatus described the station will be very near present-day amateur perfection.

# CHAPTER IX

## Housing the Amateur Radio Station

ONE matter which might receive the amateur's attention, is the design of a wireless bungalow for housing his apparatus. The plans of a shack which the writer constructed are shown in figures 1 to 4 inclusive. This building was erected at a comparatively small cost and afforded a neat wireless room which was away from noises of the house and yet was very comfortable. The best location for the building is directly underneath the the aerial.

The foundation for the floor is made from six two-by-fours arranged as in figure 1. The necessary dimensions are shown in the illustration. The foundation is then covered with three-quarter inch matchboards.

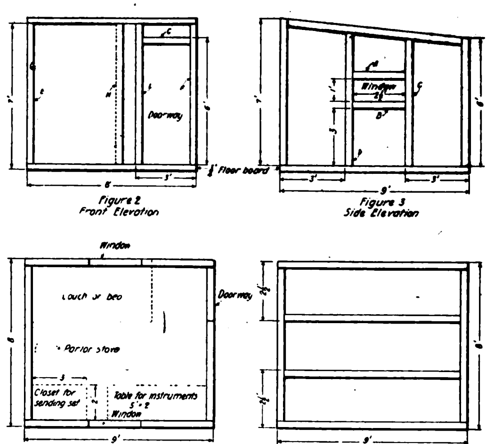


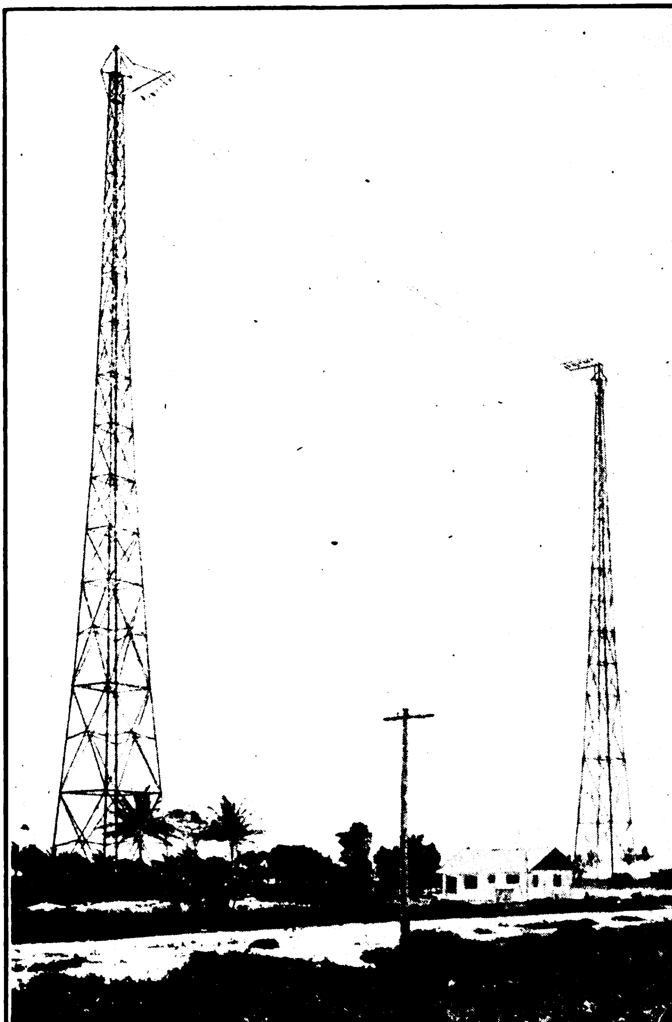

Diagram of building plans for a wireless bungalow

When the floor is completed, the framework should be started.

Figure 2 shows the necessary dimensions for the front frame. The frame for the back is similar except that pieces *E* and *F* are six feet high instead of seven. Also in the back frame, piece *C* should be left out and piece *D* moved to the position shown by the dotted lines *H*, figure 2.

The sides are constructed as in figure 3. A space is left on both sides for a window. If the dimensions of the window need to be altered, they can be changed by moving any of the pieces *A*-*B*-*C*-*D*. The writer found that two windows of the size shown afforded plenty of light.

The framework for the roof can be made very similar to the floor. As soon as the framework is completed, the building is covered with matchboards and the roof with tar-paper to make it waterproof. If the owner so desires, he can cover the whole outside with tar-paper, and this will keep out much of the wind and cold. After the wireless cabin is finished, it is an easy matter to fix up the inside and lay out the instruments. In one corner the writer made a closet, or sound-proof room in which he placed his sending set only. Figure 4 shows the exact layout. This left plenty of room for the instrument table, a bed, three chairs, and a stove to drive away the cold on winter evenings.



This view of a commercial wireless station supports the opinion of the author that the best location for the building is directly underneath the aerial

# CHAPTER X

## Things Which Any Amateur Can Make

THE detector in figure 1 was constructed mostly of parts of a telegraph sounder and a telegraph key. The support *U* for the swinging arm *A* which also carries the contact point, originally was the support of a telegraph sounder which held the lever. The crystal holder *H* is made of a *U* shaped piece of brass and an 8-32 screw is passed through it at the top to clasp the mineral on its ends. The adjusting knob *K* is an 8-32 screw with a key knob for its handle. A small piece of tapped hard rubber somewhat similar to the handle of the switch handle on the key gives it a finished appearance.

The main advantages of this detector are that, immediately a good adjustment is secured the point can be raised while sending and when receiving it can be returned to the exact spot merely by turning the handle and

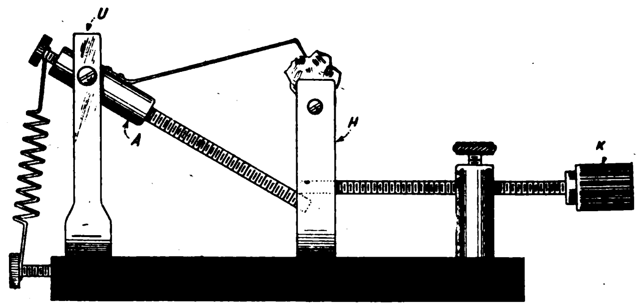


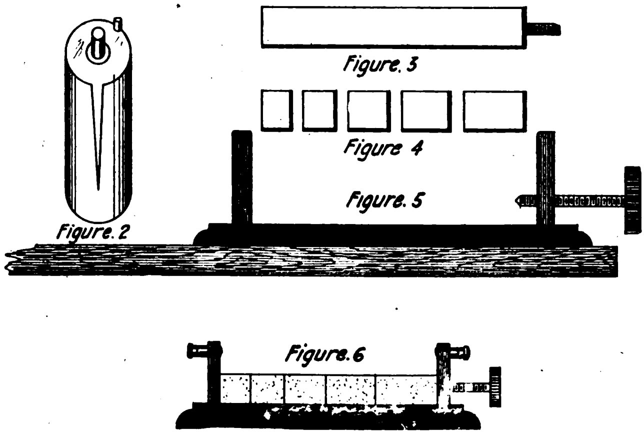

Figure 1—View showing the construction of the detector stand

lowering it to its original position. This is a feature that cannot be obtained from any other form of detector holder. It is optional what kind of mineral is used as the adapter is made to hold any of the well known types. The writer finds this to be one of the best detectors he has had the pleasure to work with, owing to the fact that whenever one desires to send he merely has to take the point off the mineral and after sending is completed, lower it gradually until the point comes in contact with the exact spot used before.

### A Compressed Carbon Rheostat

The variable resistance element of this rheostat is the carbon electrode of an ordinary Columbia No. 6 dry cell. As shown in diagram figure 2, this may be removed by simply splitting the zinc down the edge with the sharp edge of a hatchet. Figure 3 shows the carbon when removed, and figure 4 shows the same carbon with the binding post removed and cut into small blocks of different lengths. Figure 5 shows a suitable stand for the blocks which permits a variable pressure, thereby raising and lowering the resistance at will. Figure 6 shows the completed apparatus.

The blocks can be cut into very thin strips, that is, about 3/8 or 1/2 inch in thickness thereby increasing the resistance. This is a very good in-




**Figures 2, 3, 4, 5—Detailed construction of the compressed carbon rheostat. Figure 6—The complete device**

strument for the laboratory and one which is easily constructed and operated.

### A Cat Whisker Detector

Figure 7 shows the drawings of a novel type of cat whisker detector. The mineral (galena or cerusite) is clamped in the stationary wood sup-

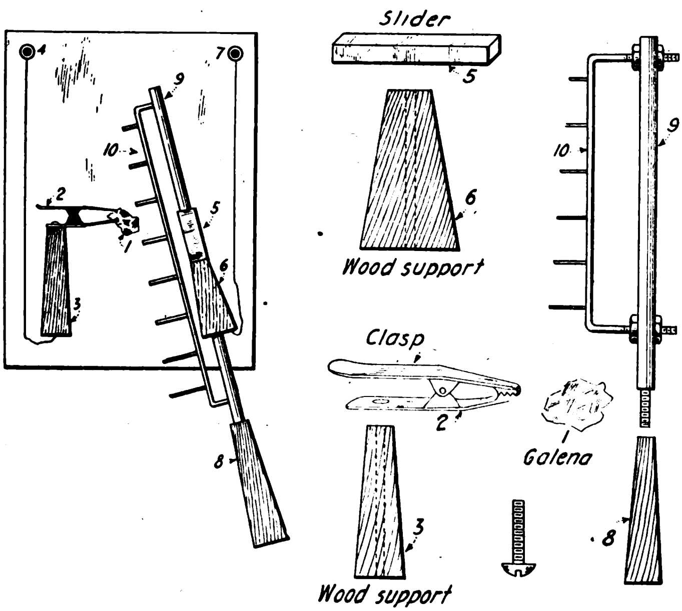



**Figure 7—The cat whisker detector illustrated in detail**

port (3) and held by clamp (2). The points are mounted on the copper wire (soldered) which in turn is made fast to the 1/4 inch square brass rod preceding one, or they can all be the same length but each of different gauge spring wire making each a little more "springy" than the preceding one. The sliding arrangement (8-9 and 10) should be constructed to allow the rod to move to and fro easily on the wood support (6). The detector as a whole is very efficient and a point is readily found by sliding the arm (8-9-10) backward and forward—slowly.

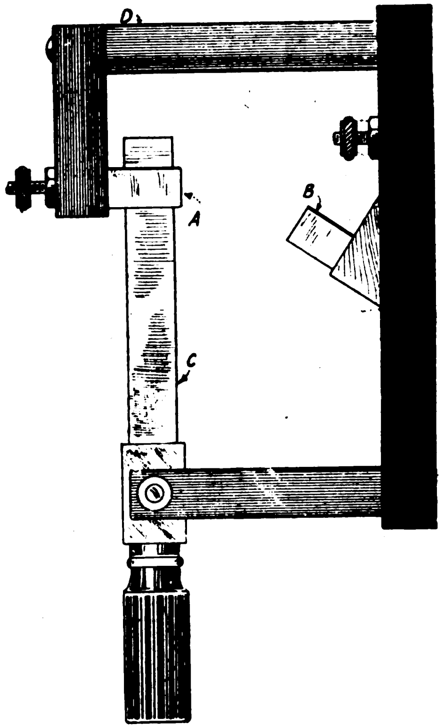



Figure 8—"Quick throw" switch

## "A Quick Throw" Switch

As shown in figure 8, *A* and *B* are knife blade contacts for connection with the switch arm *C*. The handle is preferably of hard rubber or hard wood. *C* is supported by an overhanging arm *D* which is of hard rubber. This ought to make a good antenna change-over switch or a lightning switch. It may be used for many purposes around the amateur station.

# CHAPTER XI

## Novel Holder for Crystal Detectors

SOME two or three years ago the author constructed a detector holder as per the accompanying drawing. The arrangement is an invaluable one in making extensive tests with various crystals.

It will be noted finally that the holder not only shows the pressure on the crystal, but also indicates the particular mineral being used at the time that the test is taken.

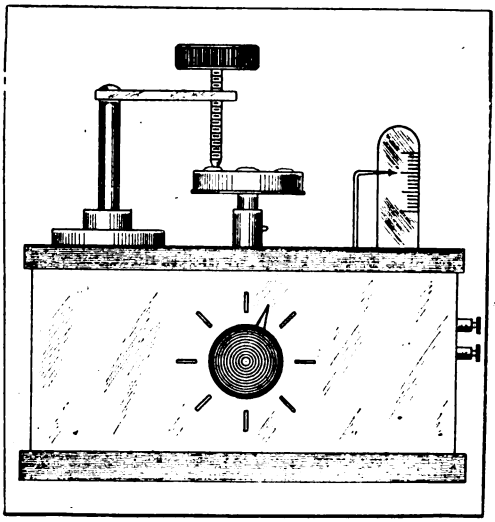


Figure 1—Front view of the detector holder

No direct measurements for this apparatus has been given, first because the essential parts may differ in construction and material, and secondly because different size gear wheels may be used.

The advantages of this detector are as follows: The pressure each mineral requires can be determined accurately, thereby affording a better idea of the correct adjustments of the various types of crystals.

It will be noted that each mineral is so arranged in conjunction with the calibrated pointer and scale, that the particular mineral under test is indicated.

As clearly shown in the drawings, the detector cup is movable by means of the cog wheel. A graduated scale on the front of the box shows the mineral under test at each change. It will be noted also, that even though

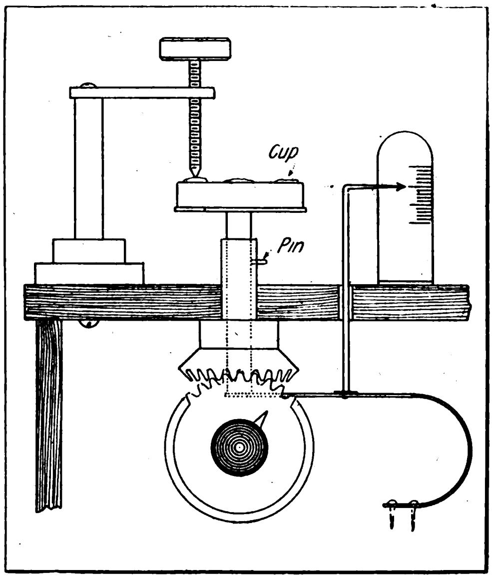
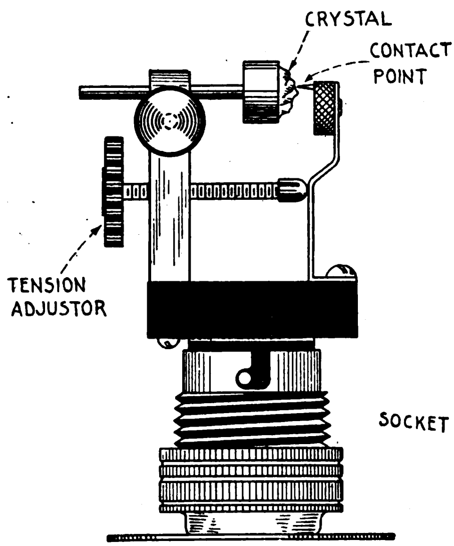



Figure 2—Showing construction plan of the detector holder

the cup is allowed to revolve, this does not in any way interfere with the contact pressure of the mineral under test.



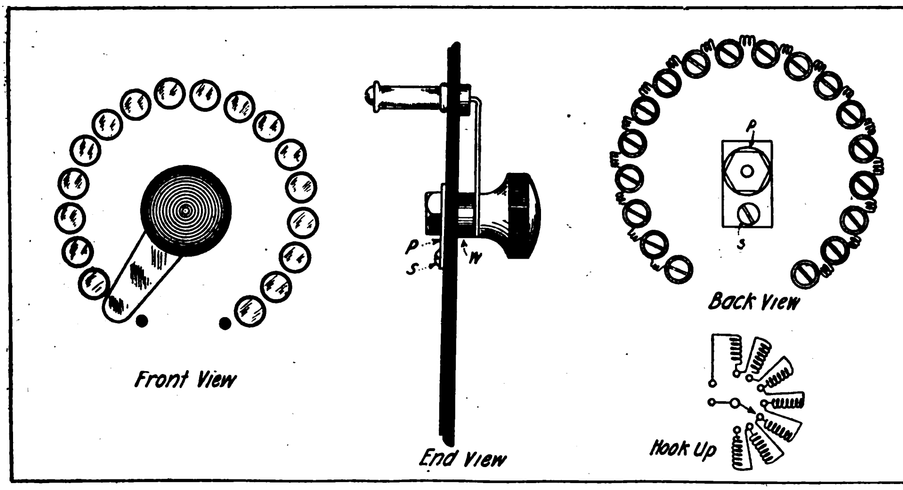

A commercial development of interest that provides for a crystal holder to fit a vacuum tube socket

# CHAPTER XII

## A Positive Vacuum Tube Circuit Control

IN designing the vacuum tube cabinet the amateur is confronted with the conventional porcelain base rheostat, which, although it is quite acceptable for the ordinary set, would be wholly out of place in an efficient set. In the following paragraphs is described an improvement over the usual rheostat.

For the filament circuit the variable resistance need not be more than 9 ohms, and an eighteen-step variation will be sufficient when a proper circuit is used. The most important part of this controller is the resistance



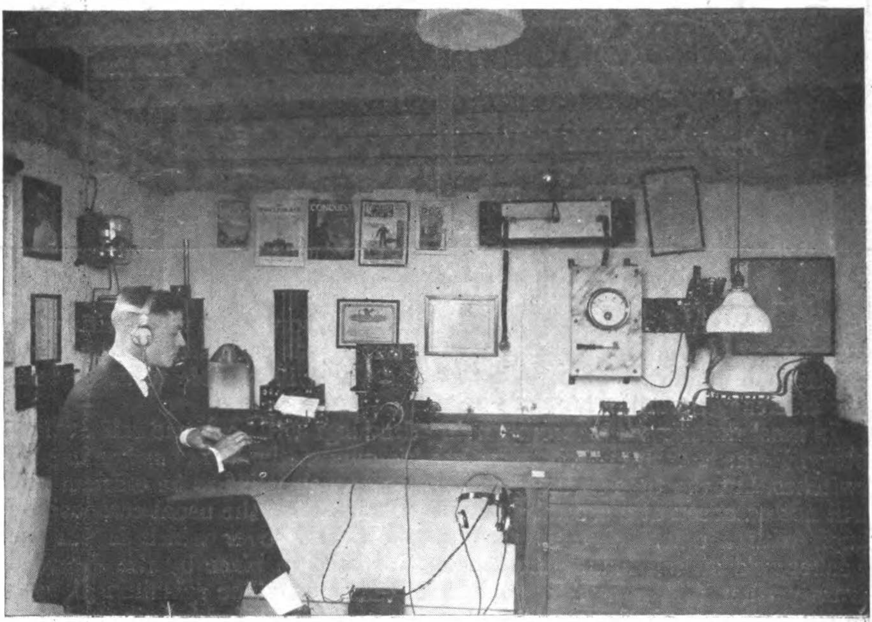

Showing construction of the positive vacuum tube circuit controller

units, the Ward-Leonard being preferable. If you order units with a resistance of ½ ohm each then you will know that each step in your controller will cut in ½ ohm resistance and you will be able to make tests for efficiency accordingly.

In most instances the accompanying drawings will be found self-explanatory. Perhaps each experimenter has his own method of constructing his switches, but the type in the drawing has proven itself to be efficient and will not unloosen at a crucial moment. It consists of the usual composition knob with a machine screw through the center, over which is put the washer and switch blade; these being fastened in place by the threaded brass washer (*W*), which is ¼ inch in diameter. The remaining length of machine screw is then run through the carefully drilled hole in the bakelite-dilecto panel and a rectangular brass plate *P* put over the screw and is kept from turning by the machine screw *S* which is threaded into the panel. Next, a heavy brass hexagonal nut, ¼ inch thick, is screwed over the machine screw and is kept from turning by a small screw in a hole drilled here and tapped into one of the faces on the edge of the nut.

The resistance units are composed of porcelain tubes wound with a special resistance wire and then covered with vitrified enamel, which completely eliminates oxidization. These tubes are fastened to the inside of the panel by long machine screws passing through the inside of the tubes and through the panel, and screwing into the brass switch contact on the other side. A flexible wire tap is placed at each end of the resistance unit. One of these (the one happening to be nearest the head of the machine screw which passes through the tube) is soldered to the head of this machine screw and then brought down to the tap of the neighboring unit which lies nearest the panel, and so on, until all the units are connected in this manner. The best kind of wire for inside connections is rubber-covered stranded wire. All leads should be as short as possible and connections soldered in every case. The connections to the switch arm should be soldered to the brass plate *P*.

This same idea may be carried out in designing a potentiometer, but the resistance of each unit should be 500 ohms instead of the value of the rheostat units, making 9,000 ohms in all for the potentiometer. Of course the potentiometer must be connected in a different way than the rheostat. A lead must be brought from each end of the arc of switch contacts and another lead from the switch arm. If this design is used for both rheostat and potentiometer on the vacuum tube cabinet a much more uniform appearance will be obtained, due to the fact that each switch has the same outward appearance.



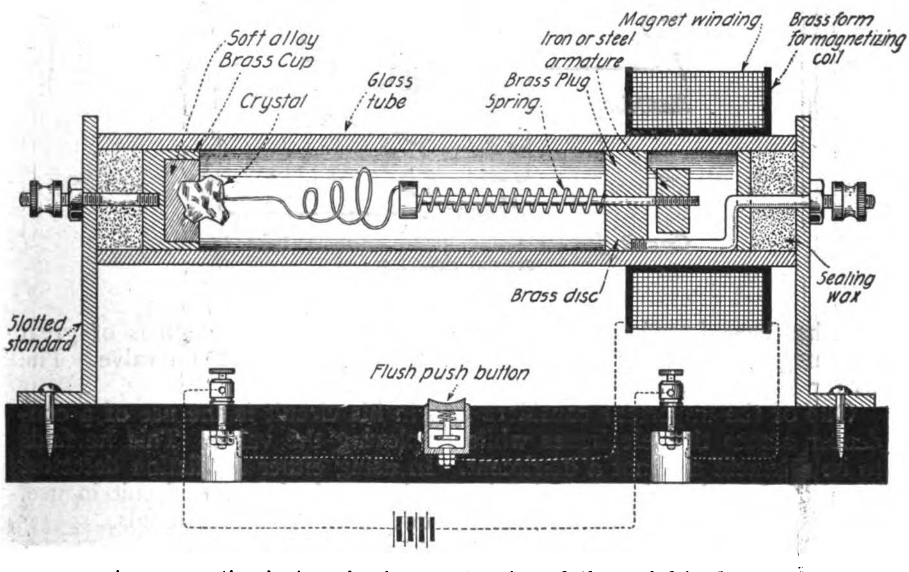
A representative amateur station which uses vacuum tube equipment

# CHAPTER XIII

## A Sealed-in Crystal Detector With Magnetic Adjustment

THE object of this device is to allow both the crystal and contacting means of a mineral detector to be effectually and permanently excluded from the surrounding atmosphere and its deteriorating effects. By modification of the glass container and means of bringing out the connections it may be operated in a vacuum, or even surrounded by various gases for purposes of experimentation, still permitting the detector to be adjusted as easily as if it were exposed.

The design of the air-tight detector given herewith is intended to be suggestive and not conclusive, as the main idea may be adapted to any



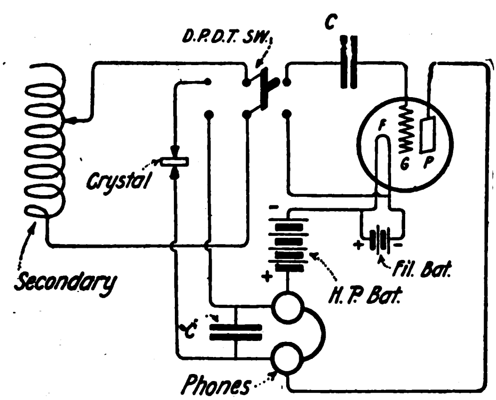

A cross sectional view showing construction of the sealed-in detector with magnetic adjustment

form of detector design that will suit the builders' fancy, but this one has considerable merit in its simplicity of construction and operation.

As the cross-sectional view given in the sketch renders the construction and operation quite obvious, only a few words need be added. The mineral cup and metal plug carrying the movable contact should be turned to a snug fit for the inside of the glass tube, and a bit of glue applied before inserting so that they will remain in position without additional holding means. The spring of the movable contact should be relatively light, and its pressure should be adjusted to suit the crystal used before the tube is finally sealed. The armature should be made from a piece of round iron or steel rod. These parts must work free and easy. The binding post terminals of the tube are used to support it by engaging them with two slotted sheet-metal standards fastened to the base. The form for the magnetizing coil should be made of light sheet brass or copper. It must be easily rotated and moved along the tube and may be wound with about No. 22 or No. 24 wire.

A flush push button should be mounted on the base, and connected in series with the coil and battery terminals. This button is depressed while adjusting the detector, and of course, the magnetic field is present only while doing so. The magnetic field does not cause any noticeable effect on the rectifying action of the detector.

CHANGING FROM THE VACUUM TUBE TO THE CRYSTAL DETECTOR




*Circuit for changing from vacuum tube to crystal detector*

It has been found that a double-pole, double-throw switch is of great advantage in changing from a crystal detector to a vacuum valve. The writer has used a circuit like this quite successfully.

One of the important considerations in his circuit is the use of a condenser across the telephones while employing the valve. This he finds to be a benefit and not a detriment. In using either oscillation detector, parts of the other detector circuit remain attached to the circuit in use, but his experience indicates that this does not affect the signals.

# CHAPTER XIV

## An Inductively-Coupled Receiving Transformer

A RECEIVING transformer does not necessarily require variable coupling. The writer has found that for the average work the primary and secondary coils may remain in a fixed relative position provided the construction is carried out as per the accompanying sketch, figure 1. The design shown does not possess any advantage in efficiency over the ordinary coupler, but it is easier to construct.

The principal part of the apparatus is an old-fashioned tuning coil. The windings are removed from one end for about two or three inches and ten or fifteen taps taken from the remainder.

A piece of card-board is cut just to fit over the bare end of the coil. It should be about two-and-a-half inches in length. A coil is wound over this.

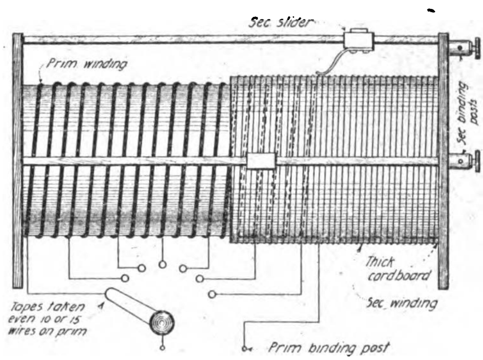



Figure 1—Diagram showing construction of inductively coupled receiving transformer

An ordinary piece of stiff card-board can be made pliable and fitted without cracking, by wetting it and then gluing it around the coil when dry. A layer of wire similar to that wound on the secondary of a receiving transformer, say No. 28 or No. 32, is wound over the cardboard. The coil is scraped in two places and sliders attached for variation of the inductance. The two original sliders of the tuning coil can probably be arranged to pass over the bare surfaces. The secondary coil is wound partly over the primary coil and partly over the bare end. It is to be observed, however, that the secondary is outside the primary and not inside as in the usual design.

The operation of this tuner is comparatively simple. The number of secondary turns in use can be varied by the position of the sliders, and the degree of coupling in the same way. For example, if in the secondary fifteen turns are required for resonance, these turns can be taken at either end of the coil, and the coupling between it and the primary can be correspondingly changed. For close coupling both sliders are moved along the secondary coil until they are directly over part of the turns of the primary winding.

No definite dimensions are given for the coil as they would naturally vary with the wave length range required. A tuner of this kind will be found to give very satisfactory results.

A typical amateur station showing two co-workers listening-in at the same time. In many instances stations are owned jointly by experimenters who share the expense and secure equal enjoyment at half tne usual cost.

# CHAPTER XV

## How to Make Dry Batteries for Vacuum-Tube Use

ONE of the primary requisites of a modern radio receiving set, is the vacuum tube detector. Of the two sources of direct current necessary to operate this instrument, the high voltage battery gives the most trouble. Flash-light batteries are expensive and short-lived compared to the amount of current used. For those who are content to have test-tubes or other containers arranged in racks, filled with acid, the high voltage storage battery solves the problem, provided they have a convenient source of charging current. From the writer's point of view, he believes that dry cells of a special design, easily constructed by the amateur and small enough to be contained in the receiving cabinet, solve the problem for portable as well as stationary sets.

The best shape for the cell is that of a disc. The best method the writer has found for making the cells, is to use fibre or cardboard rings

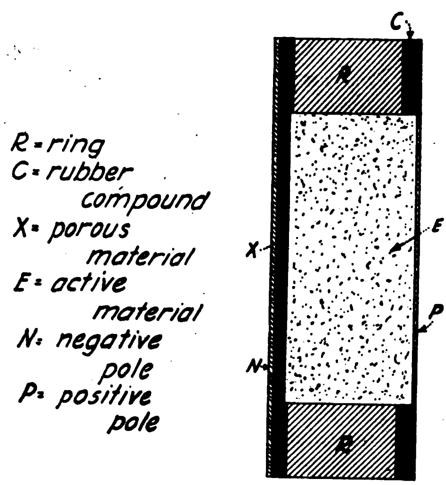



Figure 1—Detailed construction of cell for high voltage battery

to separate the metal electrodes. The outside dimensions are about 1¾ by ⅜ inches. The fibre or cardboard ring has the same outside diameter as the finished cell and the cross section should be about ¼ by ¼ inches square. The rings are soaked in melted rubber compound, such as is used to seal storage batteries, and then hung on a rod or nails so they may be removed easily when cold. The negative electrode is a zinc disc the size of the cell and the positive electrode may be copper or other metal depending on the active material in the cell. Carbon cannot be used in this type of cell to advantage.

The method of assembling is to place a zinc on one of the rings and then press it down with a hot flatiron until the rubber compound is melted. Then a cold one is put on with pressure until the compound is cold. A tight fitting disc of blotting paper is placed next to the zinc on the inside and the electrolyte, in the form of a paste, is next applied. A layer of some depolarizing agent such as black oxide of manganese should complete the filling. Then the other electrode should be sealed in position in the same manner as the first.

Amateurs with equipment of modern type employing the vacuum tube with portable apparatus for outdoor receiving experiments

# CHAPTER XVI

## A Long-Wave Variometer for Vacuum-Tube Receiving Sets

THE variometer possesses a number of features that make it suitable for close tuning but the conventional type with concentric coils limit the range of wave length over which it is possible to tune. This is due mainly to the fact that the winding space must be made very narrow if the coils are to fit closely. Increasing the space results in an instrument with the coils so widely separated that the range is limited and quite a lot of inductance remains in the circuit when tuned to the lowest point on the scale. Realizing the advantages of close tuning and lack of end-turns, the writer has designed an instrument with these advantages that will respond to the higher wave lengths.

This type of variometer can be built for any range of wave length with the simplest of tools. The instrument described will work up to 10,000 meters and is intended for use in oscillating or Armstrong circuits, as a plate circuit loading coil.

Instead of two concentric windings it employs four coils so mounted that by revolving two of them about an axis their magnetic lines can be made to assist or oppose those of the stationary coils and thus obtain a gradual variation of inductance without any dead wire in the circuit. The dimensions of the coils can be changed to suit conditions, the instrument described being merely an example of this type of instrument.

The four coils are all similar in construction, being wound on wooden cores three inches in diameter and two inches long. Heads four inches in diameter are cut from thin fibre and fitted to the ends with glue and brass pins.

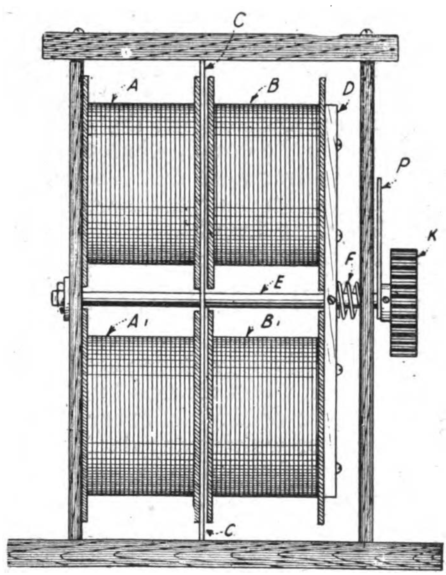
The winding is put on in four layers. The first being wound on the core, then a strip of corrugated board being cut to fit snugly around the winding and put in place. Four layers will fill the coils.

The method of assembling the coils is shown in the illustration. The cabinet used with the above coils should measure 9x9x5¼ inches inside. Two of the coils *A* and *A*-1 are mounted on the back, one above the other with a space of ¼ inch between them to pass the brass rod *E* forming the axis for the movable coils. The windings of these coils are so connected that when viewed from one end the current will flow around them in opposite directions.

A sheet of thin fibre or stiff paste-board with a ¼ inch hole in the center is fitted into the box in front of the coils to form a smooth surface over which the coils *B* and *B*-1 can turn. The moving coils are fastened to a strip of wood *D*, ¼ inch thick, ½ inch wide and 7¼ inches long. When mounted the coils have a space of ¼ inch between them at which point a hole is drilled in the wood strip to pass the brass rod. A small wood screw is put in one side of the strip opposite the hole to clamp the strip to the brass rod. The connections of the moving coils are similar to that of the fixed coils, so that the current will flow around them in opposite directions. Flexible leads are used to make connections to these coils.

The instrument can be completely assembled by passing the brass rods through the back of the cabinet and the fibre sheet, and slipping the strip over the rod so the coils rest against the separator, making sure to clamp coils *B* and *B*-1 by means of the small screw provided.

The four coils are then connected in series, with leads brought out to binding posts. The small spring *F* is slipped over the rod and the front of the cabinet put in place. A knob and pointer are attached to the projecting end of this rod to operate the instrument. A scale is mounted




Showing method of assembling the coils of the long-wave variometer

on the front of the cabinet. This is in the form of a semi-circle since one half-turn will vary the inductance from minimum to maximum. The pointer should be attached so that when at the highest point of the scale the coils are in such a position that the current will flow around both top coils in one direction and around the lower ones in the opposite direction.

The instrument is now complete and ready for use. By bringing out separate leads from the coils numerous experiments are possible that will make the instrument a favorite of the experimenter.

# CHAPTER XVII

## How to Make a High-Voltage Storage Battery for Vacuum-Tube Use

ONE of the principal drawbacks of the vacuum tube detector for amateur use is the expense of keeping up the high voltage battery. The constructional details of a storage battery of about 60 volts will therefore be described. The battery may be charged from 110 volts A.C. by placing it in series with a 75 watt lamp and a one jar rectifier of the electrolytic type.

For the stand in figure 1, take two boards about 31x4x¾ inches and bore in each thirty one-inch holes, in two rows, the holes being one inch apart.

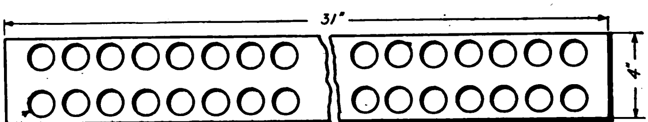



Figure 1

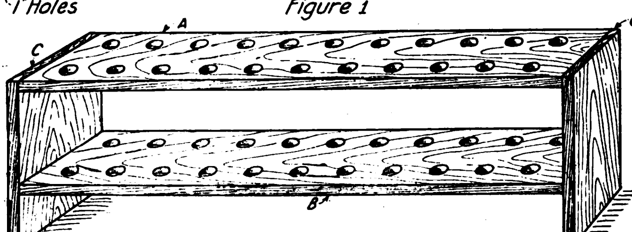



Figure 2

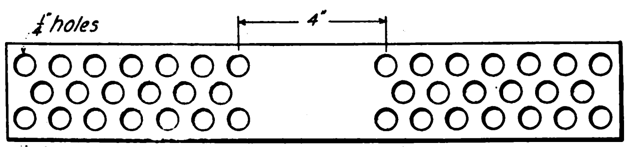



Figure 3

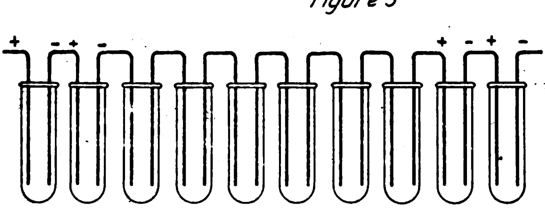



Figure 4

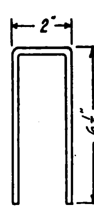



Figure 5

Diagrams showing construction plans of the various parts of the high voltage storage battery

Now take two pieces of wood 8x4x¾ inches and by means of one-inch wood screws, complete the stand as in figure 2. The shelf *A* should be flush with the tops of the end pieces *CC*, and shelf *B* should be about four inches below *A*. The frame should now be well coated with hot paraffin.

Cut thirty pieces of lead 15x¾x⅛ inches, and then using a ¼-inch drill, bore the lead strips full of holes, except for four inches in the middle of each strip as in figure 3.

Next bend the strips as shown in figure 5. Take a little red lead, and make a paste with a 10% solution of C.P. $H^2SO^4$. In one end of each strip fill the holes with the red lead paste, and in the opposite end of each strip fill the holes with a similarly prepared paste of yellow lead. These form the positive and negative plates, respectively. Two of the strips should be cut in half, these being used at the ends of the two rows.

For the containers use thirty test tubes 1x6 inches. Set the test tubes in the rack and place the lead strips in their proper positions, so that a positive and a negative plate are in each tube. (Figure 4.)

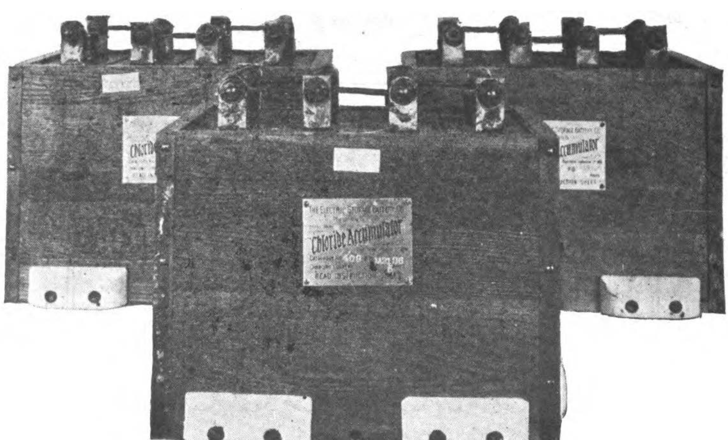
Some difficulty may be experienced in keeping the strips of lead an equal distance apart in the tubes. However, this may be overcome by taking pieces of heavy cardboard, previously soaked in silicate of soda and dried, placing them between the plates.

The two rows of cells should be connected in series with a small lead strip.

When this is done, fill each tube to within ½ inch from the top with a 20% solution of C.P. $H_2SO_4$. The tops of the test tubes and the parts of the plates above the electrolyte should be painted with hot paraffin to prevent the acid from creeping.

The battery is now ready for charging and should be connected to a source of direct current of from 65 to 75 volts. The charging rate of this size battery is from ½ to 1 ampere, and the capacity is about 2 ampere hours.

Care should be taken to see that the battery is never run down, and that the electrolyte is kept at ½ inch from the top of the tubes.

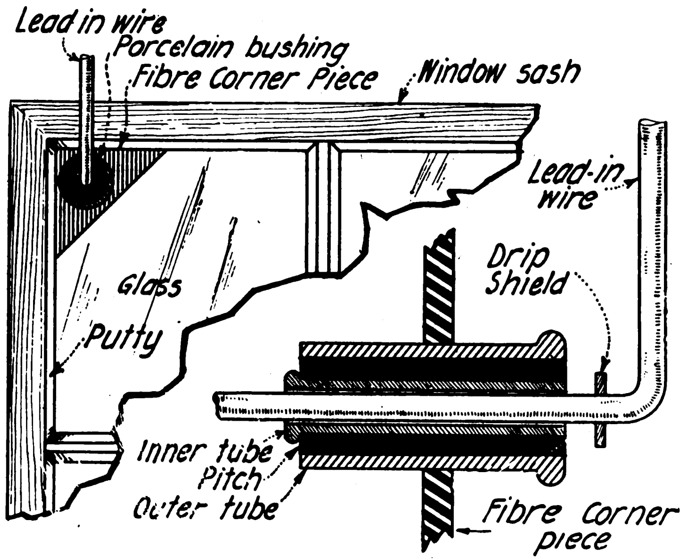



Commercial storage batteries which are of greatest convenience but more expensive than the home-made variety described

# CHAPTER XVIII

## A Satisfactory Lead-In for the Amateur Aerial

THE following is a satisfactory method of bringing the aerial lead-in into the radio room where it is undesirable to drill through the window frame. A pane of glass is removed from one of the sashes and one corner is cut off; then it is replaced and a thin piece of either wood or fibre, drilled to pass a porcelain bushing, is fitted into this space in the corner of the sash. It is fastened in with brads and putty the same as the window pane. This bushing consists of two tubes placed inside




**Details of the aerial lead-in, showing its construction and application**

of one another with pitch run in between. The wood or fibre corner should be well varnished to prevent warping. It will also be well to provide a small drip shield cut from sheet metal and soldered to the conductor near the point where it enters the bushing to prevent the beads of rain from following the lead-in into the room. The accompanying drawings are self-explanatory.

# CHAPTER XIX

## A Simple Locking Device for the Variable Condenser

WHEN variable condensers employed in wireless telegraph apparatus are subjected to jar and strain such as the equipment installed on an airplane, it is essential that they be provided with a locking device that will prevent the movable plates from rotating without putting a severe strain on the condenser mechanism itself.

The movable plates of the average variable condenser are not balanced with respect to the rotating shaft and a tendency therefore exists for them to work out of position when subjected to vibration. Also during shipment it is desirable to have these plates locked in position to protect the apparatus from damage due to rough handling. If there is but a slight separation between the movable plates and the fixed plates, it is highly desirable that the locking device employed be constructed so as to prevent any possibility of the strain changing the separation between the two sets of plates.

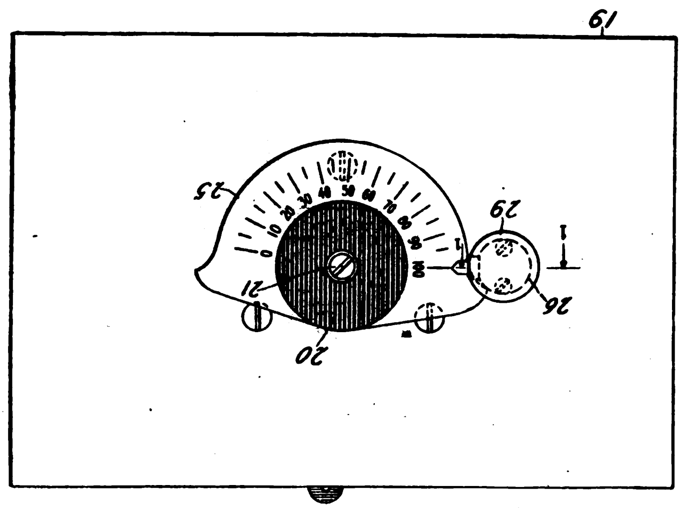


Figure 1—Plan view condenser locking device

An experimenter has recently shown a design for a variable condenser embodying this construction as shown in the accompanying figures 1, 2 and 3; figure 1 being a plan view, figure 2 a side elevation, and figure 3 a detail of the locking device.

In the detail of figure 3 the locking device comprises the clamps 27 and 28 which grips the plate 25 attached to the handle of the variable condenser. It consists of a hollow post 26 rigidly secured to the mounting plate 19 and provided with a longitudinal slot through which extends a pair of floating jaws 27 and 28. The jaw 27 is assembled to lie in a

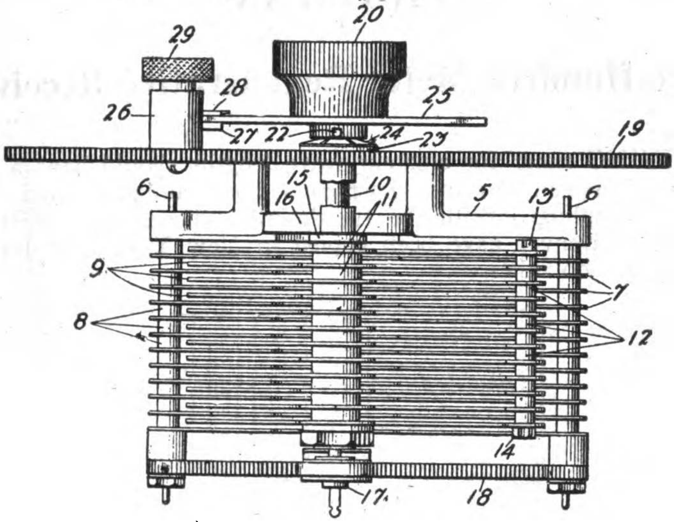



Figure 2—Side elevation of the locking device

plane below that of the indicating plate 25 and its inner end is provided with a threaded opening adapted to engage corresponding threads in the knurled head screw 29. The inner end of jaw 28 is provided with an opening through which the threaded portion of screw 29 passes freely and its outer end is shaped to serve as a pointer for the indicating plate 25. Between the jaws 27 and 28 within the post 26 is located a washer 30 of a thickness somewhat less than that of the plate 25. Upon turning the screw 29, the shoulder portion 31 of the screw engages jaw 28, thereby clamping the indicating plate 25 firmly in position.

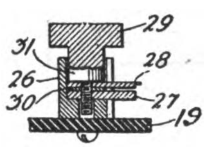
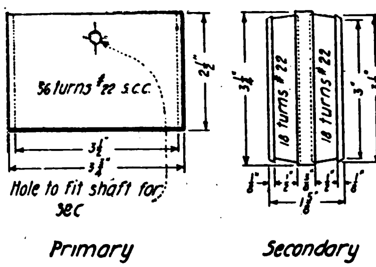



Figure 3—Showing a detail

# CHAPTER XX

## A Two-Hundred Meter Regenerative Receiver

A RECEIVING tuner for amateur wave lengths should have a range of tuning between 180 and 580 meters, and should be fitted with a regenerative coupling. With the set described here, amateur stations as far west as Denver have been copied in New York, a distance of approximately 1900 miles.




Figures 1 and 2—Dimensions of the primary and secondary coils of the receiving tuner

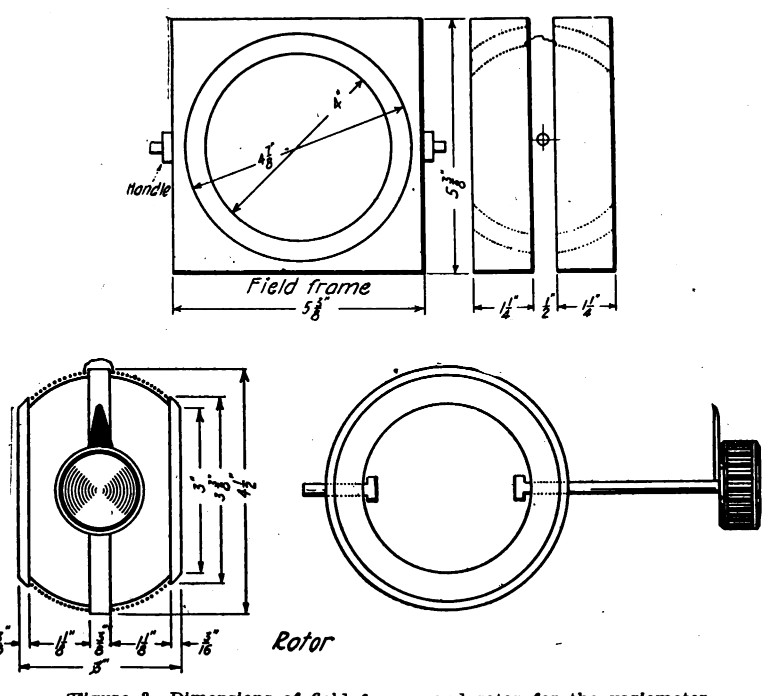



Figure 3—Dimensions of field frames and rotor for the variometer

### Aerial

The amateur aerial should consist of from 4 to 8 stranded wires with a horizontal length of 80 to 100 feet and a vertical height of 30 to 100 feet, with an approved type of modern lead-in insulator. All connections must be securely soldered.

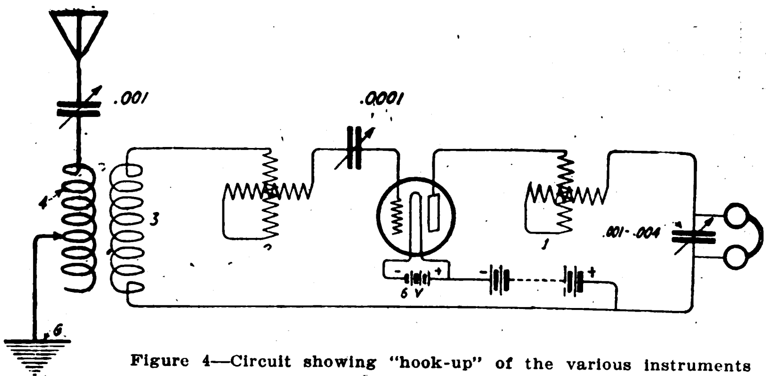



Figure 4—Circuit showing "hook-up" of the various instruments

### Earth Plate

A good earth plate can be formed by burying square sheets of copper or brass about three feet below the surface under the whole length of the aerial. In addition, the ground lead should be connected to all gas and water pipes available in the building.

### Receiving Tuner

Special care should be taken in the construction of the tuning transformer. The regenerative valve short wave receiver, consisting of two variometers and a coupler which can be mounted together, or separately, constitutes the most efficient set.

The primary should consist of a cardboard or bakelite tube 2½ inches in length by 3¾ inches in diameter, wound with 56 turns of No. 22 SCC wire with a tap taken from it every eight turns. These should be brought out to the switch. The dimensions are shown in figure 1.

The secondary should consist of a ball turned to the shape of a variometer, 3¾ inches long by 1⅝ inches in diameter, wound with 18 turns of No. 22 SCC wire on each side, or 36 turns in all. Both coils are wound in the same direction and no taps are to be taken off. The inductance is varied by turning the rotating coil. The dimensions are shown in figure 2.

### Variometers

The variometers are turned from wood and should consist of two field frames and one rotor, sizes as per the drawing, figure 3. Two are required, both of the same size.

The field frames of the variometer for the grid circuit are wound with 30 turns of No. 20 SCC wire, wound clockwise; the rotor is wound with 32 turns of No. 20 SCC wire, wound counter clockwise.

The field frames of the variometer for the plate circuit are wound with 25 turns of No. 18 SCC wire, wound clockwise; the rotor has 27 turns of No. 18 SCC wire, wound counter clockwise. The dimensions of the rotors are given in figure 3.

The design of the variometers should be such that they may be rotated throughout 180 degrees. Coil 3 in figure 4 must rotate through 90 degrees. Coil 4, the primary, is stationary.

The field frames are stationary and must be separated ½ inch. The horizontal axes of the variometers must be at least 12 inches apart.

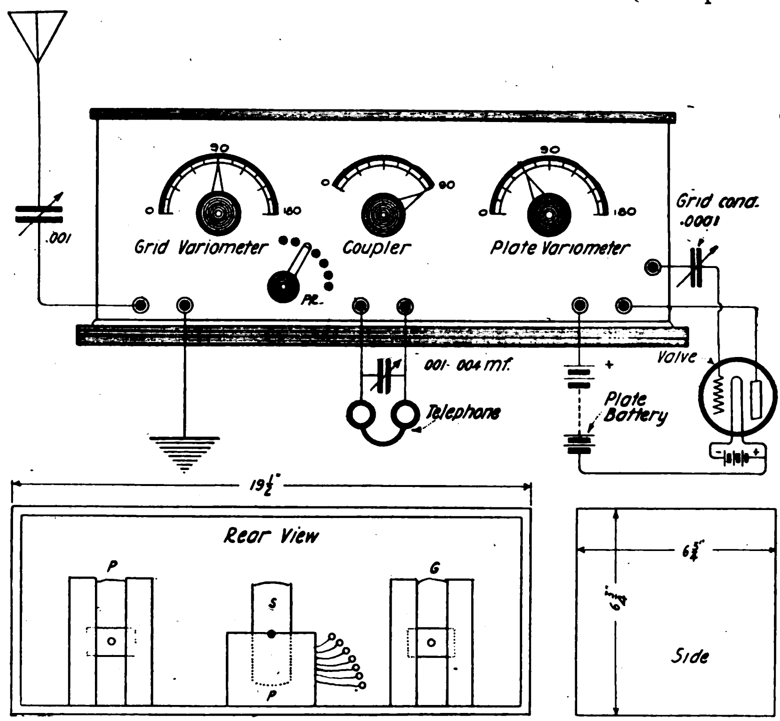



Figure 5—Design of a cabinet set

TELEPHONES

For the best results a pair of Baldwin amplifying telephones should be used, but any pair of 2,000 ohm telephones will prove satisfactory.

DETECTOR

It is essential that a good three element valve detector of either the round or tubular type should be used and special attention paid to the voltage adjustments. A storage cell should be used for lighting the filament, as it is important that the current be constant. For the plate circuit, flashlight batteries or a bank of small storage cells may be used. For maximum signals, a single cell adjustment of the plate battery should be provided for.

VARIABLE CONDENSERS

Three variable condensers of the following capacities are required, viz.: one of .001 mfd. for variation of the primary wave length, one of .0001 mfd. for the grid circuit; and one of .001 to .004 mfd. for shunting the telephones.

If these instructions are carefully carried out, a set capable of amplifying 100 times will result. All connections should be thoroughly soldered and the dimensions of the coils and the capacities of the condensers duplicated in detail.

For those who prefer the cabinet type of apparatus, a suggested design is shown in figure 5.

# CHAPTER XXI

## A Long-Wave Long-Range Receiving Set Using Vacuum Tubes

THE ideal amateur station should be designed to permit reception from all stations, irrespective of the type of transmitter or the wave length employed. The apparatus should be installed to permit the conduct of experiments to determine the best method of connection for a particular set of conditions. Such a station has many possibilities, but it may prove too expensive for some experimenters.

In order that it will not be necessary to duplicate certain parts of the apparatus which are essential to all circuits, the instruments should be assembled so that the connections are easily accessible. The principal receiving set should not, however, suffer any loss of efficiency by complicated connections and combinations of switching devices.

The station the writer has in mind is composed of three receiving sets with one or more transmitters. Any one of these sets may be installed without interfering with the operation of the others. An amateur is likely to be fully satisfied with his first set, but he will later install additional apparatus from time to time which gives the station the appearance of an experimental laboratory. The main set described in this article has a receiving range of 450-3,000 meters, mounted in a cabinet which is always ready for use. Two additional sets are provided to take care of the upper and lower ranges of wave lengths.

### The Aerials

Two aerials are to be used, one for transmitting and the other for receiving. The transmitting aerial should be 60 to 75 feet long and 40 to 60 feet high, with a natural wave length of about 160 meters. A pole erected on the roof directly above the transmitting set permits a short lead-in. Six wires, two feet apart, will give the necessary capacity. This aerial is to be used in receiving stations from 150 to 500 meters and a special transfer switch should therefore be provided.

A larger aerial, running at a right angle to the transmitting aerial, is employed for receiving wave lengths above 400 meters. It should be from 300 to 500 feet long and 50 to 100 feet high, consisting of two wires. The natural wave length should be near to 800 meters. With this aerial it is possible to receive wave lengths down to say, 450 meters with a series condenser. By approximate loading inductances, waves up to 12,000 meters may be received.

### The Transmitter

The transmitter consists of a 1 kw. transformer having a secondary voltage of 15,000 volts, connected to a 110 volt, 60 cycle, alternating current circuit. An impedance coil is necessary to regulate the current in the primary circuit. A hot-wire ammeter in the primary circuit permits

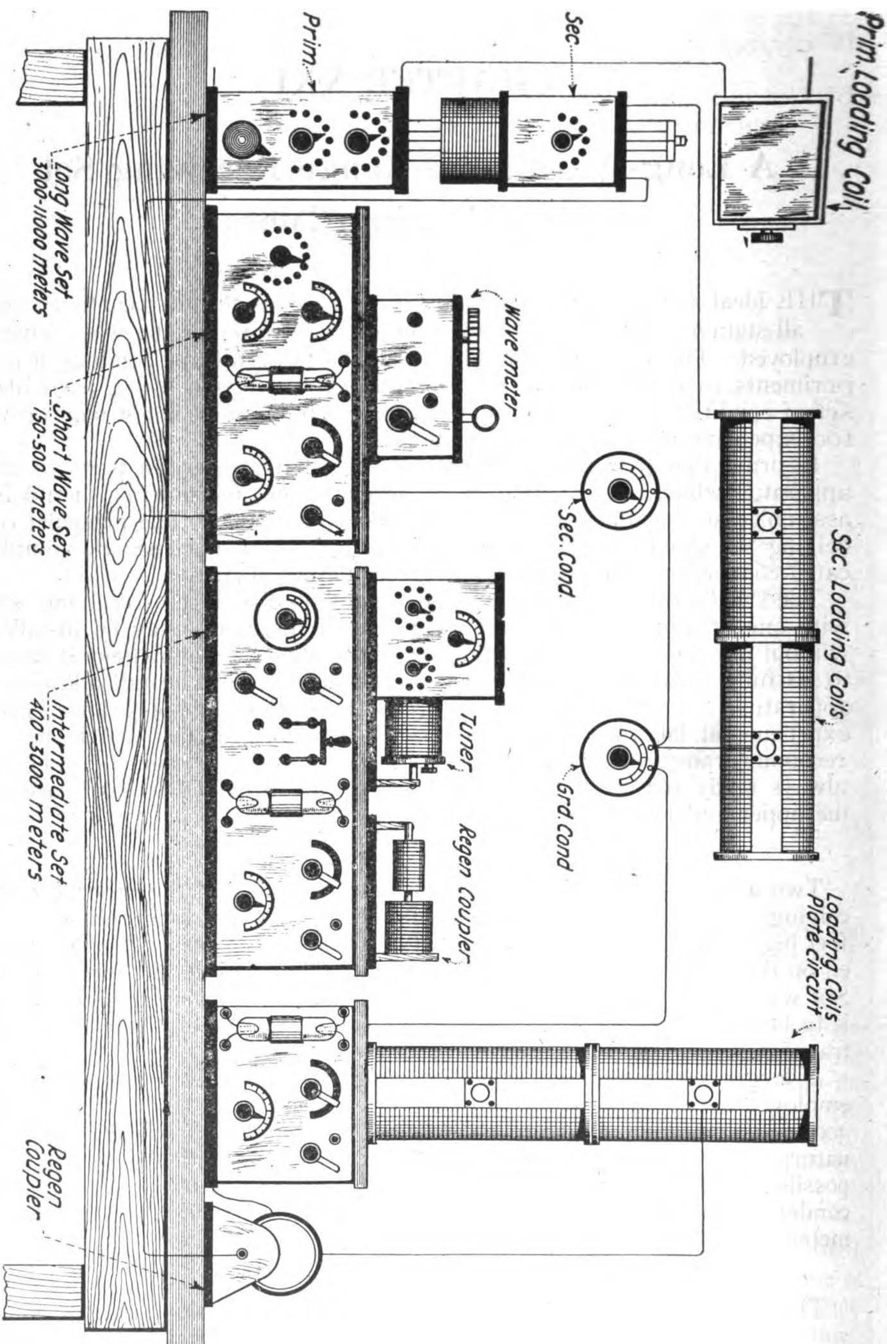



Figure 1—Front view of cabinet with the secondary tuning conden ser, vacuum tube controls and the necessary switches mounted in place

an approximate indication of the power consumed, since the power factor is fairly high and the line voltage remains practically constant. A good key and kick-back preventer are necessary, of course.

A rotary spark gap having studs protruding from the circumference, the studs and outer rim forming the casting, is the most suitable gap for operation with 60 cycle current. This type of rotary gap has two distinct advantages over that type in which the studs are perpendicular to the face of the disc. First, slight variations of the disc due to warping have no effect on the spark length. (The writer has not yet found any material that will not warp slightly in time.) Second, if the fixed electrodes are brought into contact with the rotating studs while in motion, no damage will be done to the disc. The motor on which the gap is mounted, must have generous bearings. It is much better to use a motor that is a little larger than necessary so that silent operation will be obtained.

A molded high voltage condenser is the best type for amateur use. It will withstand high voltage and have long life. An oscillation transformer of the pancake type is very satisfactory. If the secondary is provided with a rotating contact to permit tuning with the key closed, considerable advantage is gained.

A hot-wire ammeter is accurate enough to measure the antenna current. A thermo-couple type of meter may be a little better, but its greater cost may make it prohibitive.

## Receiving Sets

The receiving apparatus shown in figures 1 and 2 consists of three complete sets, each being provided with a vacuum tube connected in a regenerative circuit. One set is used for reception from amateur stations and has a range from 150 to 500 meters. It is connected to the transmitting aerial. The second set is the main stand-by set and has a range from 450 to 3,000 meters. The third set is used for receiving from high power stations and has a range from 3,000 to 11,000 meters, or greater.

The first set consists of a small loose coupler with a multiple point switch to vary the antenna inductance. The secondary has but one tap. A variometer is employed as a secondary loading coil; all tuning in the secondary circuit is effected with this instrument. It has been found that a secondary condenser, even if set at zero value, has too great a capacity for short wave lengths. A variometer is also used to tune the plate circuit. A plug is provided for inserting a pair of telephones or coupling the output circuit to the input circuit or another vacuum tube for amplification.

The second, or intermediate wave length set consists of a series antenna condenser, a coupler, and a secondary circuit with a regenerative coupling. Condensers are used in the secondary and grid circuits. A double-throw double-pole, and a single-throw double-pole switch are provided. The first switch marked *S*-1 shifts the connections from the vacuum tube detector to crystal detectors; the second switch, marked *S*-2, shifts from a regenerative connection to a simple vacuum tube detector connection. Another single-throw single-pole switch, marked *S*-3, connects in an auto transformer so that the tube may be used as an amplifier for either of the other sets. The secondary circuit coils are placed in a cabinet on top of which is mounted the tuning coupler, the regenerative coupler and a series condenser. Most any loose coupler of the proper range will prove satisfactory if the inductance is changed by a multiple point switch. The regenerative control switch is located on

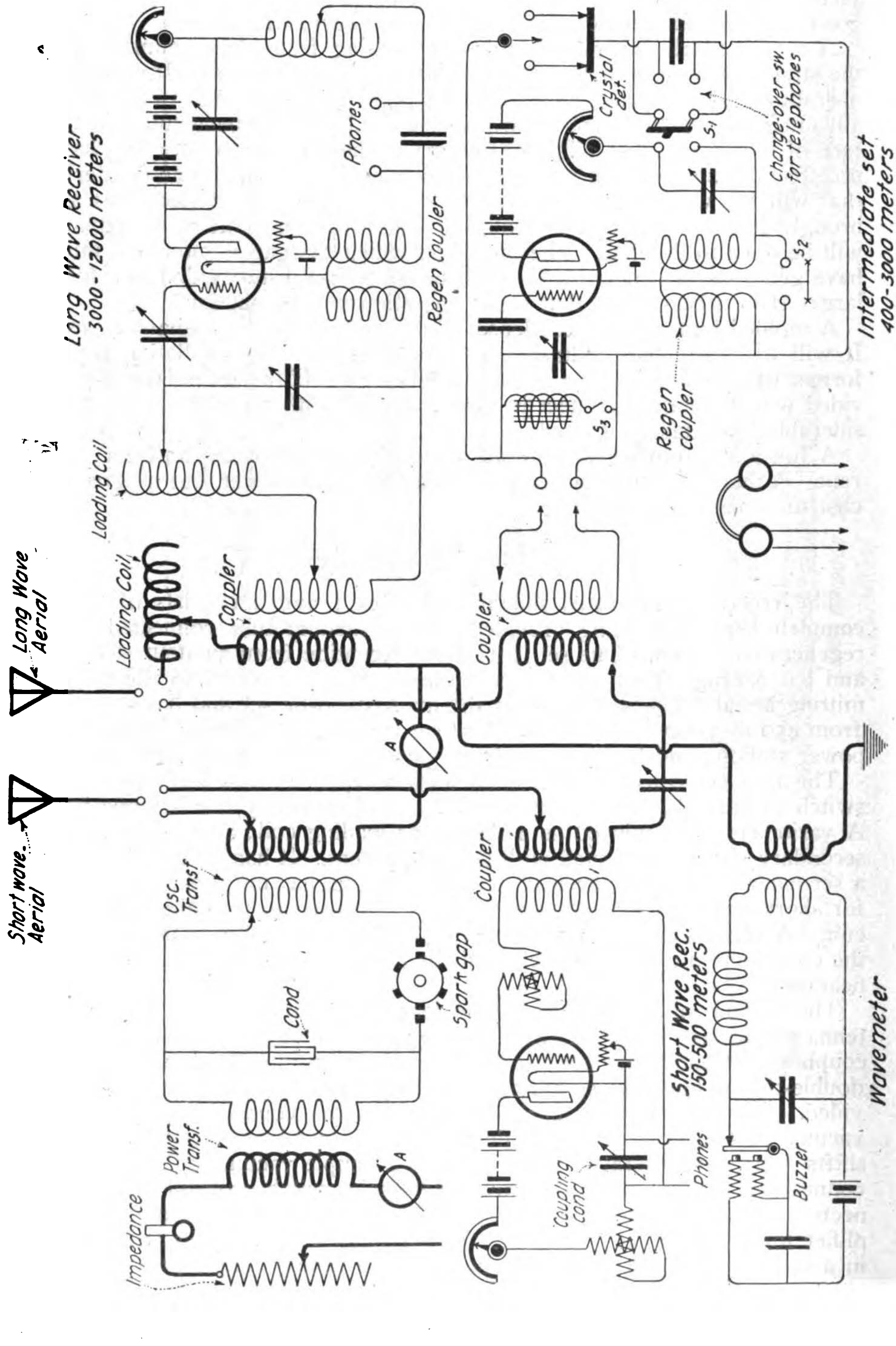



Figure 2—Diagram of connections for the receiving apparatus of an up-to-date amateur radio station

the back of the regenerative coupler. On the front of the cabinet are mounted the secondary tuning condenser, vacuum tube controls and the necessary switches.

The third set consists of a 3,000 to 7,500 meter coupler, a regenerative transformer with a vacuum tube and loading coils of sufficient inductance to raise the wave length to 12,000 meters. The coupler is of the multiple point type, with a secondary which moves in a vertical plane. This design is economical in space and, as shown in figure 1, it is desirable that all the nearby inductances shall be perpendicular to each other. Each loading coil is built in two sections, which makes it possible to remove unused units from the circuit.

The primary loading coil is mounted on the wall to the left. The secondary loading coils are shown mounted on the wall over the main set with the secondary and grid condensers below. The tuning switches on the coupler and the secondary tuning condenser must have long handles for operation.

On the right are shown the plate circuit inductances, vacuum tube, and regenerative coupler. The output of this detector circuit may be coupled to the input of the vacuum tube of the principal set, as in the case of the short wave set. Audio frequency amplification is employed. Radio frequency amplifying circuits may be a trifle more sensitive but the slight advantage gained is lost in the complex operations that a radio frequency amplifier introduce. Copper tubing or flexible wire may be used to connect the apparatus as shown in figure 1. The apparatus in the writer's opinion, is arranged for convenience and for maximum efficiency.

A telephone headset of 1,500 ohms each is used for recording the signals. If the experimenter will run a pair of separate cords to each receiver and attach plugs at the ends he can connect one receiver to one of any two sets. This makes it possible to hold communication with another station and at the same time stand-by for a high power station. Both receivers may be plugged in on the same set if desired. Auto transformers may be installed in the long wave and short wave sets so that a detector and two-step amplifier may be added to the circuit.

A wave meter (shown above the short wave tuner) is a very convenient accessory. A small wave-meter inductance may be used for tuning the transmitting set and a large inductance for tuning the long wave receiving set. Long distance stations usually have a fixed schedule and fixed wave lengths. This makes it possible to pre-adjust the receiver to the required wave length by the wave meter.

# CHAPTER XXII

## A Four-Tube Cascade Amplifier for Radio Reception

THE following is a description of a four-tube high-frequency amplifier. It is a complete wireless receiving circuit and possesses the peculiarity and great advantage to amateurs and experimenters of having no inter-valve or step-up transformers. Another advantage is that all the vacuum tubes, except the first, detect, rectify and amplify incoming oscillations. The first tube is only for amplification purposes. The accompanying diagram, figure 1, shows the complete circuits.

The open or aerial circuit, which has a variable condenser *C*-1 in series with the aerial, is coupled to the grid oscillatory circuit of the first tube. Another variable condenser *C*-2, is placed in parallel with the secondary inductance, and although this condenser is for tuning purposes, the inductance should be used as much as possible, and the capacity reserved for fine tuning.

By means of the potentiometer *P* the grid potential of the first vacuum tube is adjusted to a point where best amplification of the oscillations in this circuit is obtained. The separate filament rheostat *R*-1 also assists in the selection of a suitable adjustment for better amplification.

A small condenser *C*-3 (about .004 mfd.) placed across the potentiometer allows high-frequency oscillations to pass freely. In the plate circuit is a resistance *R*-2, of 80,000 ohms. There are similar resistances in the plate circuit of the third and fourth tubes.

The high-frequency oscillations which are reproduced in the plate circuit of the first tube are communicated to the grid of the second, as the plate circuit resistance *R*-2 offers too much resistance to the flow of such high-frequency currents. In each grid circuit except the first is a leak *R*-3 connected between grid and filament. The resistance of the leak is 4 megohms.

As the functions of the third and fourth tubes are similar to the second, the filament current should be the same. A rheostat *R*-4 of 5 ohms, connected as shown, will give a uniform current to these three tubes.

The high resistance *R*-2 can be easily made by scratching grooves, about 1 to 3 inches long, with a sharp instrument on a piece of ebonite and filling them with graphite by simply rubbing a pencil along them. Terminals should be fitted to the ends in such a way as to ensure good contact.

The telephones *T*, if connected directly in the plate circuit of the last vacuum tube, must be of high resistance; but if a step-down telephone transformer is used low resistance telephones will give better results. The latter arrangement is preferable.

The battery which supplies the potential to the plates should be of about 80 to 100 volts, while a 4-volt accumulator is usually best for the filament.

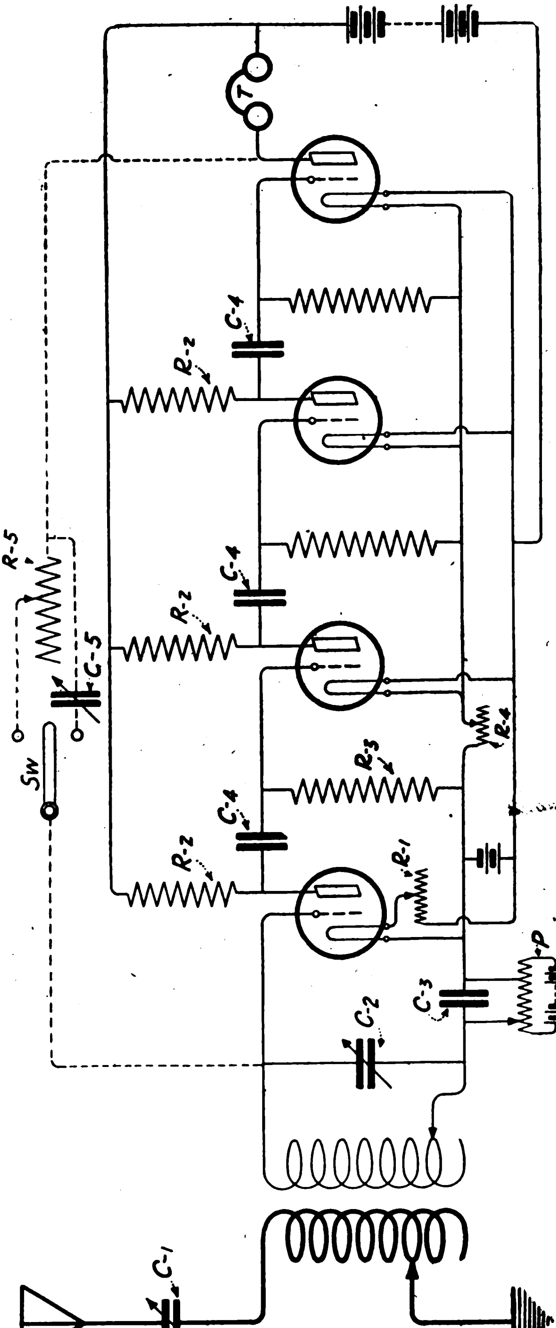
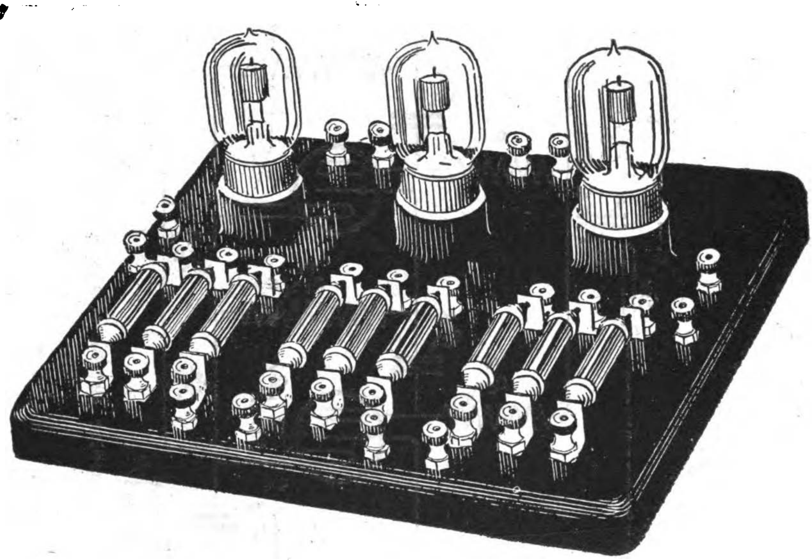



Figure 1—Diagram showing circuits of the four-vacuum tube cascade amplifier for radio reception

If the plate of the last tube is connected through a small variable condenser *C*-5, or a very high resistance *R*-5, to the grid of the first tube, a further increase in the strength of the signals is noted. By suitably adjusting the resistance or condenser, the circuit can generally be made to oscillate and continuous wave signals may then be received. The resistance and condenser together with a switch *Sw* and connections are shown on the diagram by dotted lines.

The results obtained with such an amplifier are very satisfactory. The adjustments are simple, when compared to the circuits employing inter-tube transformers. With transformers the rectification of signals is chiefly left to the first tube which often has to deal with very weak signals and therefore small variations of grid potentials. In this circuit the incoming signals are first amplified.

So simple and economical an amplifier should appeal to amateurs. Its sensitiveness and peculiarity of amplifying weak signals to a far greater extent than strong ones should be of great assistance to those who wish to receive from stations which hitherto have been unreadable owing to the great distances being spanned or because of using too small an aerial.



A convenience for the amateur who wants to use cascade amplification is this 3-tube adapter, complete with tubes, binding posts, condensers, resistances and filament rheostats, giving special facility in changing connections

# CHAPTER XXIII

## A Short-Wave Regenerative Receiver

THE receiving tuner here described is designed for use on an average amateur aerial having a natural wave length of about 175 meters. An inverted L type aerial, 80 feet long and 60 feet high, answers these requirements, although the length and height may be varied to fit the location. A natural period greater than 175 meters is not recommended if the station is to operate on 200 meters, as an aerial of such dimensions will not permit sufficient inductance in the primary of the receiving tuner, nor in the secondary of the transmitting oscillation transformer, for efficient transformation.

In choosing a type of receiver for amateur purposes, and for construction by amateurs, three fundamental points should be considered: 1st, efficiency; 2nd, simplicity of construction; and 3rd, ease of operation. That these three points have been carefully kept in mind in the tuner described, the following will bear out.

With respect to efficiency, it should be noted that this type of circuit has been adopted by the Navy Department, the U. S. Signal Corps, and by many foreign governments. The size of wire for the coils herein specified will give maximum conductance, which IS IMPORTANT, contrary to the popular belief that, because the vacuum tube is a potentially-operated device, its efficiency is not lowered by using fine wire. The absence of variometers eliminates another source of energy loss, and the tuning of the secondary by a condenser instead of taps, makes a further improvement.

The simplicity of construction will be apparent after noting the details given. There is an efficient circuit employing variometers, but the construction of a variometer is much more difficult than the simple coils required in this tuner.

This receiver consists of three coils, a primary, a secondary, and a tickler coil. The primary and secondary are each shunted by a variable condenser of 0.0005 mfd. capacity, and a variable condenser of 0.001 mfd. capacity is shunted across the high potential battery.

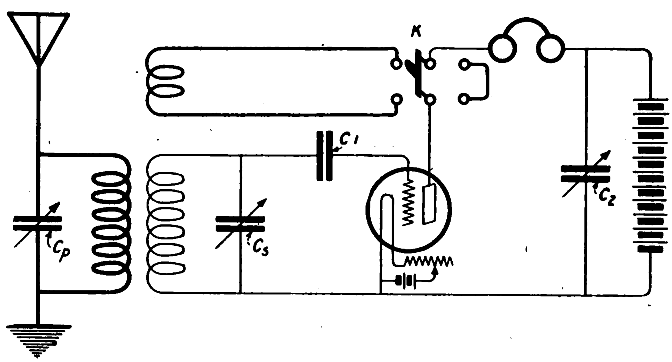
The primary coil is a tube three inches in diameter, wound for a distance of one inch with 30 turns of No. 22 D.S.C. magnet wire, and tapped to two 5-point switches for single turn variation. This coil has a total inductance of 0.1 millihenries, and if used on the aerial described above, with the shunt condenser, will respond to wave lengths ranging from 200 to 600 meters.

The secondary coil is a tube 2½ inches in diameter, wound with 50 turns of No. 24 D.S.C. magnet wire. No taps are taken from the secondary, the variation of wave length being obtained by the variable condenser. The secondary has an inductance of 0.14 millihenries, and will respond to the same range of wave lengths as the primary. A maximum separation of 6 inches between the primary and secondary coils should be provided, but the constructional details can be varied as individual requirements may dictate.

The tickler coil is wound on a wooden ring, the center of which is turned out large enough to permit sliding the ring over the secondary. A groove is cut out on the edge of this ring, the inside diameter of which is 3 inches, the width 3/8 inch. In this groove are wound 12 turns of No. 18 annunciator wire, in 3 layers of 4 turns each. A D.P.D.T. switch is provided for throwing the tickler coil out of circuit when a plain valve connection is desired, and the coil is so designed that its insertion will not detune the secondary circuit.

When operating this receiver, the desired signal is tuned in with the switch *K* to the right. When this is accomplished, the tickler coil is thrown into the circuit and moved over the secondary until regeneration occurs. Condenser *C*-2 is then adjusted, and the coupling gradually loosened, so that freedom from interference will be obtained. It is possible to receive strong signals with a very loose coupling, as the amplification obtained (3 to 6 times) will compensate for the loss of energy resulting therefrom.

By the use of suitable loading coils in the primary and secondary circuits this tuner will respond to waves as long as 2,000 meters, but it is advisable to remove these coils completely from the circuits when short waves are being received.




Wiring diagram for a simple regenerative receiver

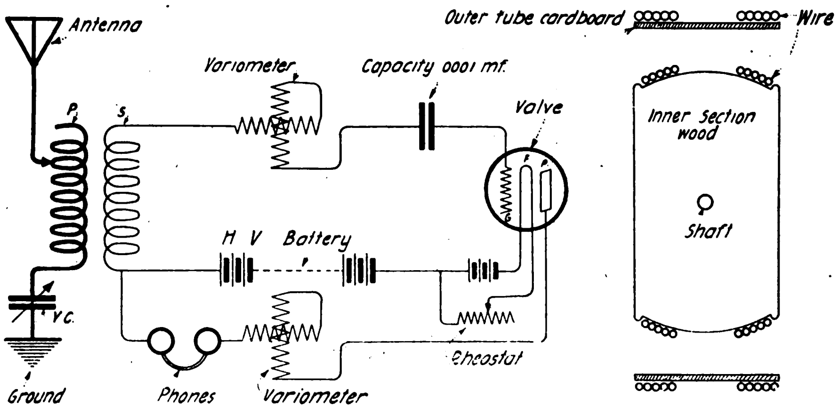
The construction of this tuner will prove a revelation to many amateurs who have been content with the simple vacuum tube connections heretofore employed, and will certainly repay anyone for the time and material expended.

# CHAPTER XXIV

## A Vacuum Tube Receiving Set for Amateur Wave Lengths

THE amateur is, of course, primarily concerned with the reception of signals from amateur transmitting sets which usually operate at the wave length of 200 meters. To do this most efficiently he ought to design a set especially for short waves. Such a set was constructed by the writer and exceptional results were obtained with it. Amateur stations in Ohio, New Jersey and even Nebraska were heard far above readable loudness. The wiring diagram appears in figure 1.

A regenerative vacuum tube receiver is used. With such a set it is advisable to use small capacities and provide a means for carefully reg-




Simple receiving set making use of a vacuum tube for the detector

ulating the inductance continuously from a minimum to a maximum. Such variation may be effected by placing two coils, having equivalent values of inductance, concentrically with provision for rotating the inner one to vary their self-inductance.

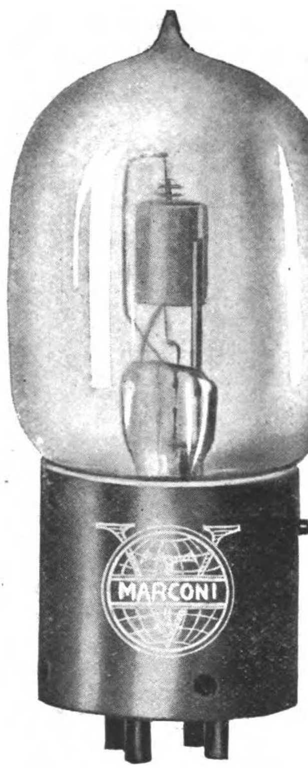
The mutual induction between two wires varies inversely as the distance between them. It is, therefore, well to construct the inner coil of the variometer so that its winding will be as close as possible to that of the outer coil. In order to do this the inner coil is wound on part of a spherical surface, that is, a section of a ball, made of wood. This section is 3 inches in diameter and 1½ inches wide. It is made to rotate by means of a brass shaft, within a cardboard tube 1½ inches wide of the correct diameter to allow clearance. The tube and the inner core are both wound nearly full with equal quantities of No. 28 copper wire in one layer. The coils are then arranged in boxes and provided with a handle carrying a pointer which travels over a scale of 180 degrees.

Two of these variometers are connected in circuit of a specially constructed coupler. The primary of the coupler contains some 20 turns of No. 28 wire on a cardboard tube about 6 inches in diameter. The secondary coil has 15 turns of wire on a tube 5½ inches in diameter. Provision is made to allow very loose coupling between the primary and secondary. A complete circuit diagram is shown in figure 1.

It would be of further advantage to wind the outer coil on a curved surface to bring the two outer windings in close proximity. This, however, is difficult without proper tools. The side drawing of figure 1 gives the constructional details of the variometer.

The antenna should be as high as possible. A two wire aerial 150 to 200 feet in length with the wires spaced 4 to 6 feet will do. The variable condenser in series with the primary circuit gives very close tuning and is essential for very short waves. An additional variometer might be connected in the antenna circuit.

Although amplifiers are in use at the college laboratory, the records mentioned above were made without an amplifying device of any sort.




The Marconi V. T., or vacuum tube

# CHAPTER XXV

## An Inexpensive Vacuum-Tube Receiving Set

THE set described in this chapter is very efficient for wave lengths between 200 and 3,000 meters. It is easily constructed, low in cost and employs but one vacuum tube. It makes use of two couplers and two aerials. One aerial and tuner are built specifically for 200 meters, and the second combination for wave lengths up to 3,000 meters.

The large coupler may be any good make of transformer the operator has on hand, but the writer recommends that the 200 meter be specially constructed. By means of a change-over switch either coupler and aerial may be employed as desired. He considers the "T" type antenna to be the most efficient for short wave work, but for longer wave lengths he would advise a separate antenna of the "L" type about 175 feet long and as high as possible above the earth. The higher it can be elevated the longer the range. The "T" type should be 100 feet long and 60 feet high of 2 wires of stranded phosphor bronze spaced about 8 feet

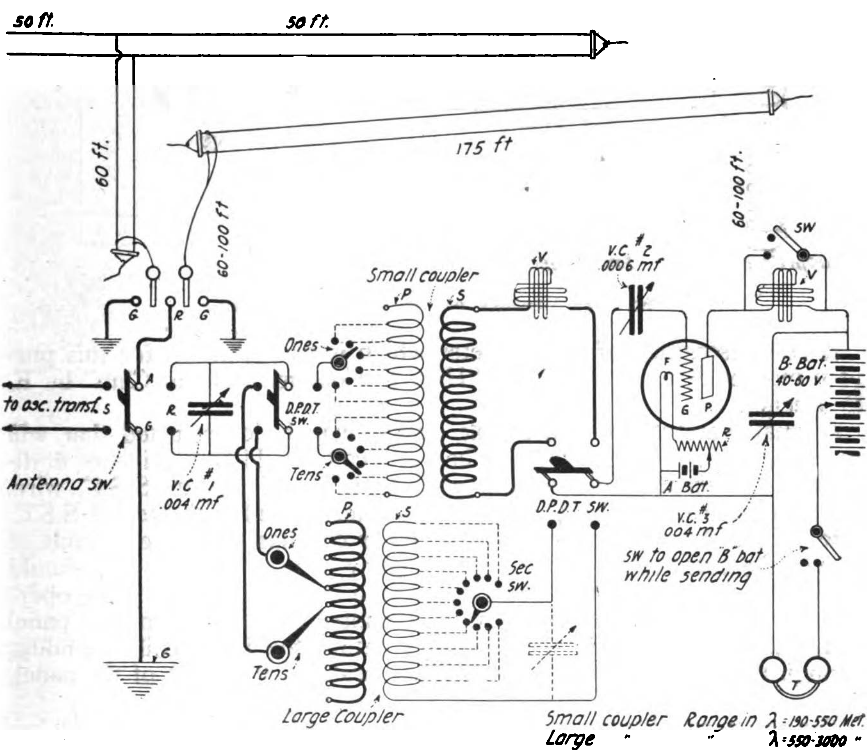



Figure 1—Combination receiving set making use of two aerials for long and short wave reception

apart, the vertical section being separated about 15 feet above the earth by an 8 foot spreader. For the "L" type only one wire is necessary, 175 feet long and 60 to 100 feet high.

The primary coil for the short wave coupled in figures 1 and 2 should be 3 inches long, 3 inches in diameter, wound with No. 24 S.S.C. wire tapped so as to allow a variation of one turn at a time. The secondary should be 2½ inches long and 2½ inches in diameter wound for 1¾ inches with No. 28 S.S.C. wire. It is not necessary to take any taps off of the secondary. A small variometer is used in the secondary circuit to allow very fine tuning.

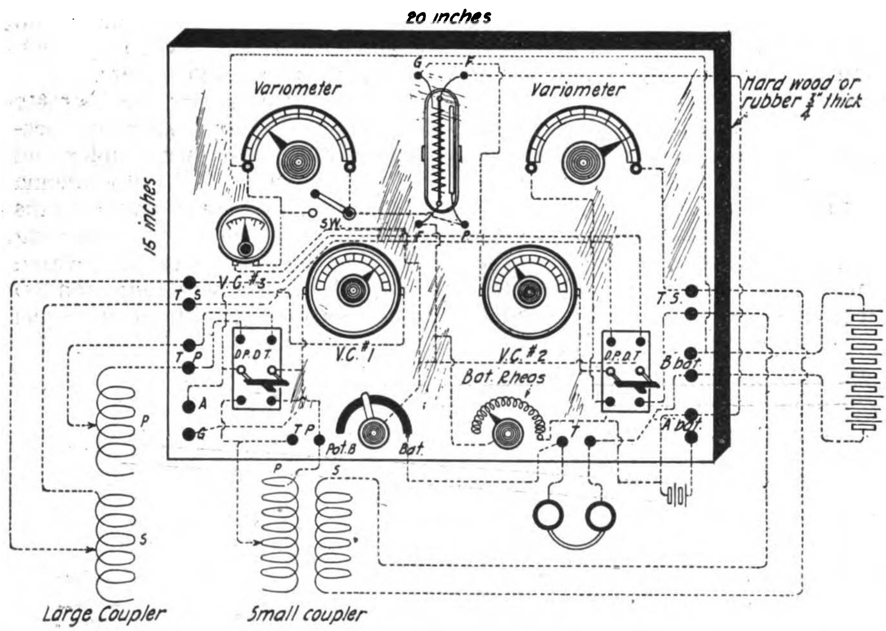



Figure 2—Assembly of the receiving apparatus

A full description of a variometer which is very efficient for this purpose may be found in the book "How to Conduct a Radio Club" by E. E. Bucher.

A small variometer of a simple design may be constructed that will answer this purpose very well. The outer coil should be 3½ inches in diameter, 1½ inches wide, wound with 25 turns of No. 28 S.S.C. wire. The inner coil should be 3 inches in diameter wound with No. 28 S.S.C. wire. Care should be taken that the inner coil has the same amount of wire as the outer coil. Cardboard tubes may be used and the wire should be well shellacked. It may be mounted on a base and placed on the operating table, or if so desired it can be mounted on the back of the panel board, with the rod that is used for rotating the inner coil extending through the panel. With the pointer and scale on the front of the panel, it presents a very neat appearance.

The large coupler has a primary 5 inches in diameter and 6 inches long wound with No. 24 S.S.C. wire tapped so as to allow a variation by one turn at a time. The secondary should be 4 inches in diameter, 5 inches long wound with No. 28 S.S.C. wire, tapped every ⅜ of an inch.

Variable condenser No. 1 should have a capacity of about .004 mfd. Variable condenser No. 2 has about .0006 mfd. capacity. The variable condenser shunted across the telephones has a capacity of .004 mfd. It can be replaced by a fixed condenser of similar capacity but it reduces the efficiency especially in the short wave set. Variable condenser No. 3 can also be replaced by a small fixed condenser made of a piece of mica 2x4 inches covered on each side with tin foil; but for the best results a small variable should be used.

The variometer in the plate circuit should be the same in design and size as the one described above, and if properly constructed will give considerable increase in signals on the low waves. It should be shunted by a small switch so that it may be cut out when using the larger transformer.

By means of the two double-pole double-throw switches shown in the diagram, either of the couplers may be connected to the valve detector. This does away with the dead end effects that are particularly noticeable on the two hundred meter wave lengths. This set may not look so well as the cabinet type of short wave regenerative receivers on the market for amateur use, but if properly constructed it will give equal results. The appearance of this set can be increased considerably by mounting it on a panel except the tuning couplers which should be mounted on the operating table. The telephones can be any standard make such as the Brandes or Murdock 2,000 ohm type which have been found to give equal if not better results than the telephones ordinarily employed. A fundamental wiring diagram appears in figure 1 and the assembled apparatus with all connections in figure 2.

# CHAPTER XXVI

## Some Receiving Circuits for Vacuum-Tube Apparatus

IT has been the writer's good fortune to meet many hundreds of radio amateurs, and it has been his observation that their main concern has been to obtain the details of the design of a receiver that will permit reception over great distances for relay work. Although a variety of opinions and designs have been set forth as to what constitutes the best

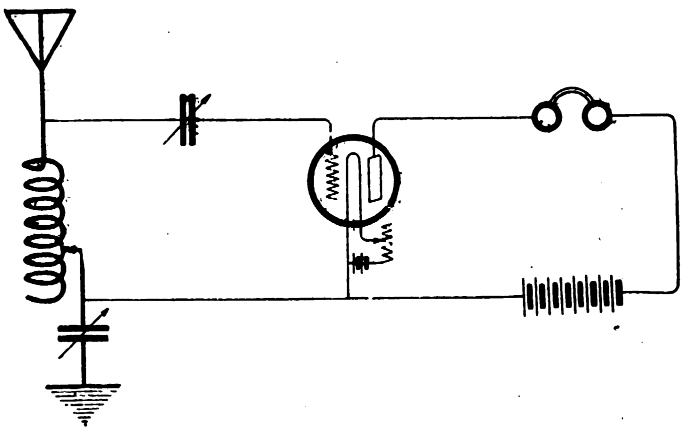


Figure 1—Fundamental circuit showing three-electrode vacuum tube connected across a tuning coil in series with the antenna circuit

all around receiver, the most of them are, in the author's opinion, either too difficult to construct or too expensive for the average amateur's pocket-book.

The writer has given the matter his serious consideration for some time and has finally evolved a set which it is believed possesses many desirable characteristics. Keeping in view the desirability of an efficient receiving set that would occupy a minimum of space, a set was eventually produced that would give a range of tuning from 130 to 1850 meters with a small antenna of .0005 mfd. capacity. As will be noted further on, this same set gives a three mile range either as a radio telegraph or radio telephone transmitter. A single bulb is used for all work and the circuit has proved especially efficient on short amateur wave lengths. The entire set occupies a space less than a two foot cube. It is not only feasible for the reception of damped and undamped waves, but it gives regenerative amplification and constitutes a very neat and efficient wireless telephone set.

### Fundamental Circuits

A series of exhaustive experiments with various types of circuits have been carried out. Very good results were obtained with the circuit shown in figure 1, where a three electrode vacuum tube is connected across a

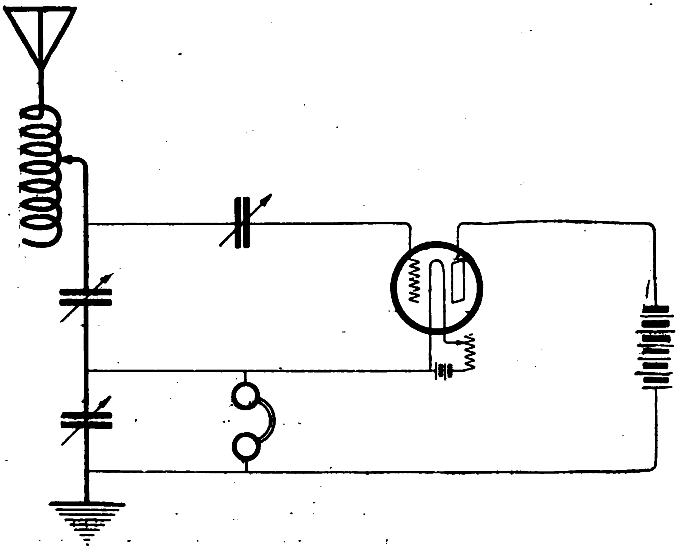


Figure 2—Another circuit using two variable condensers

tuning coil in series with the antenna circuit. The principal objection to this particular circuit was that it was not capable of receiving continuous wave signals.

The circuit of figure 2 was found to give very good results, but the local oscillations were not easily controlled and, furthermore, it necessitated the purchase of two variable condensers as shown.

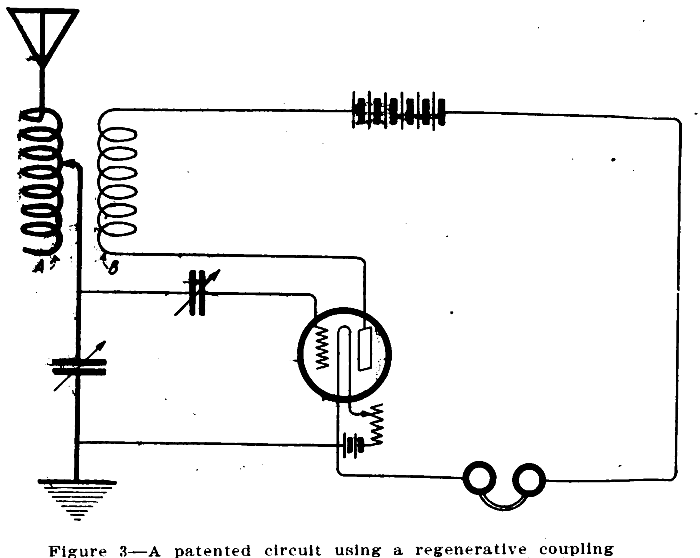



Figure 3—A patented circuit using a regenerative coupling to transfer energy from the plate to the grid circuit

Very satisfactory results were obtained with the circuit of figure 3 which it is stated, has been patented by C. V. Logwood. In that diagram coil *B* is a tickler coil of a comparatively few turns of wire mounted inside of coil *A,* constituting a regenerative coupling by which energy can be transferred from the plate to the grid circuit. It is a feature of

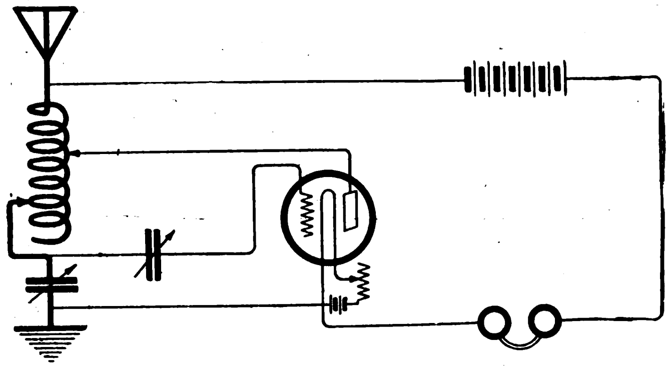


Figure 4—Circuit using one coil and one condenser and employing direct regenerative coupling between the plate and grid circuits

this circuit that the oscillations can be started or stopped simply by moving the coil *B* in and out of the coil *A.*

Having determined the good and bad features of the circuits described, further experiments were carried out with the view of obtaining greater simplicity. In fact, the writer was determined to have one coil and one condenser, and researches to this end eventually culminated in the circuit shown in figure 4, in which direct regenerative coupling between the plate and grid circuits is employed. Once having discovered a fundamental basis upon which to work, and having observed that the mutual

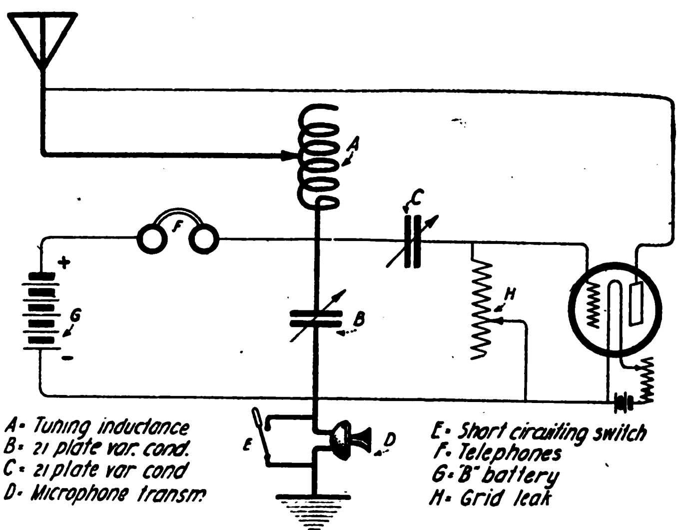



Figure 5—The perfected circuit of simple design and extremely sharp tuning

inductance between the plate and grid circuit could be controlled by a single coil, various combinations were tried employing grid leaks, negative grid voltages, etc. Some useful results were obtained, but the experiments finally terminated in the universal circuit shown in figure 5, which it is believed is the acme of simplicity and moreover gives extremely sharp tuning.

The notations in the diagram are explained in the accompanying drawing.

Coil *A* in the diagram has three taps. The switch is placed on one tap and the condenser *B* is varied over its range until the desired signal is heard. Since the tuning is exceedingly sharp, care must be taken while adjusting this condenser not to miss the signal. It is understood, of course, that the switch *E* is closed while receiving; but it is interesting to note that by varying the capacity of the condenser *C*, the bulb can be made to give regenerative amplification or to generate powerful oscillations, hence the circuit can be used for wireless telephone transmission as well.

By way of further explanation of the circuit, *H* is a grid leak which is of the order of 60,000 to 100,000 ohms resistance for the audiotron or the round bulb. This leak can consist of a pencil mark, between two binding posts of a Ward Leonard porcelain resistance or a graphite potentiometer such as is used in the *B* battery circuit. The latter type is particularly handy because it is variable. It must be understood that the grid leak is essential for proper working of the system, but once adjusted it need not be touched during the life of any particular bulb. The plate circuit voltage in this system varies between 60 and 80 volts or even higher if possible.

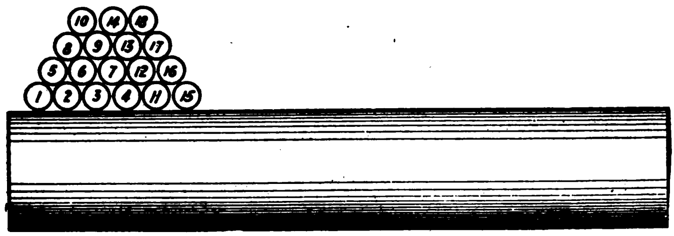


Figure 6—A four-bank winding showing the order in which the turns are placed upon the tube

To engage in wireless telephone conversations, open the switch *E* and speak into the microphone distinctly, making sure that the bulb is in a state of oscillation. An indicating device of some sort, such as a small ammeter should be placed in the antenna circuit to determine the maximum antenna current. The plate voltage should be as high as possible without causing the bulb to ionize; that is, to give the characteristic blue glow. And if any amateur possesses a "hard" bulb that proved inoperative in an ordinary receiving circuit, he should now put it into use, because for transmitting purposes, the "harder" the bulb the better will be the results obtained.

In order to telegraph by means of continuous waves, place the key in series with the grid leak. This will cause the bulb to stop oscillating whenever the key is up.

In the construction of this apparatus it is preferable that the receiving cabinet proper contain only the tuning inductance and the 21-plate variable condenser. The vacuum tube control panel is separate, and a sufficient number of binding posts are brought out to allow any desired connection to the tube. The connections from the inductance switch are brought to the binding posts on the receiving panel. Other posts are provided for connection to the antenna and ground. Additional leads are brought out from the variable condenser to binding posts.

The tuning coil is wound with litzendraht or No. 18 B & S D.C.C. wire on a tube three inches outside diameter. A four bank winding is employed as shown in figure 6, the numbered circles showing the order in which the turns are placed upon the tube. A section of fifty turns is wound on the spool and a space 3/8 of an inch is left after which another section of 240 turns is wound on with a tap placed at each 55 turns. The writer employs, preferably, litzendraht cable composed of 42 separate strands or No. 36 B & S enameled wire with a double silk covering.

Figure 7 shows a general outline of the panel for the vacuum tube. It contains a variable condenser, the vacuum tube holder and a filament rheostat, all mounted inside the box. The panel is of 3/8 inch bakelite. The connections are brought out in such a way that any desired hook-up can be employed.

A feature of construction that the average amateur would do well to incorporate in his set is the method of fastening the panels to the box. Several right angles of 1/16 inch brass are made and screwed to the side of the box. The panel is then lowered and rests on the angles as a support, leaving the panels flush with the top of the box. Holes are then drilled through the panel and spotted in the brass angles. The holes are then reamed out to give clearance for a small machine screw;

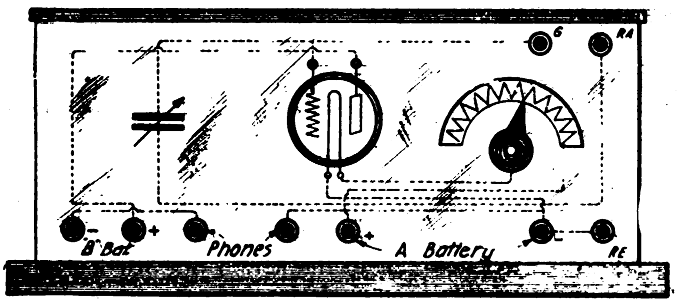



Figure 7—General view of the panel for the vacuum tube with connections

the brass is then drilled and tapped to fit the machine screw. Constructed in this way, the panel can be removed from the box as often as desired without stripping the thread in the wood, as might happen if wood screws are employed.

In closing, it is well to remark that the final circuits shown in this article can be used directly with the Western Electric "E" type tube fed from a 220 volt direct current source of supply. The bulb will give antenna current of 0.8 ampere and telephone conversations with this amount of current have been heard seven miles away. Other types of bulbs employed by the writer permit transmission over distances of three miles.

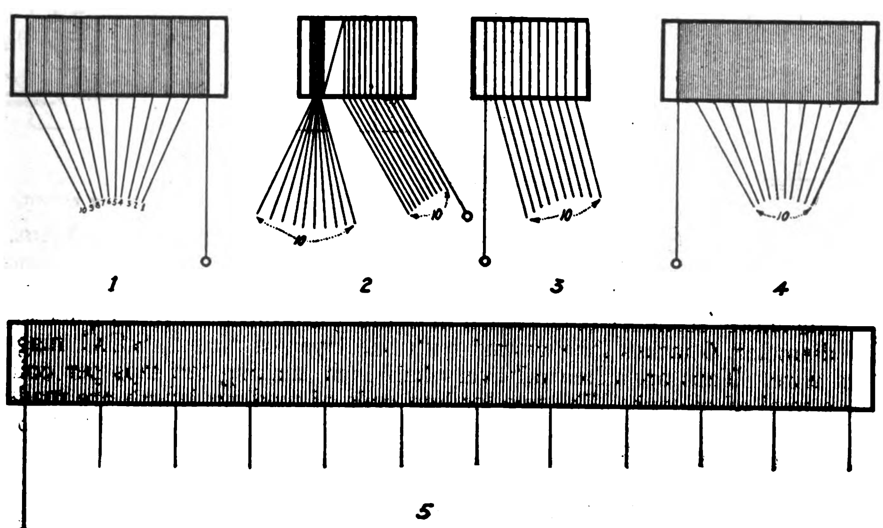
# CHAPTER XXVII

## A Radio Receiving System Involving Weagant's "X" Circuit

THE author has experimented with many circuits for the reception of damped and undamped waves, but the one described here gives better, all-around results than any other he has used. The complete circuit acts as a detector, oscillator and amplifier for both long and short damped or undamped waves. An outstanding feature is that but one bulb is required for reception over great distances.

With a circuit of this kind the writer copied signals from Nauen and Eilvese, Germany; Canarvon, Wales; Koko Head, Hawaii; Pearl Harbor, Hawaii; not to mention the arc stations located in the United States, the signals from which come in at audibilities of approximately 5,000. Signals have been read from the new high power station in Japan testing with Koko Head. These signals were plainly readable at New Orleans at 8 o'clock in the morning. One point that stands out particularly in connection with the operation of this set is, that by careful variation of the condenser capacity in the grid and plate circuits, adjustments can be obtained whereby the circuits are just on the verge of radio frequency oscillation, causing great amplification of spark signals; and by further adjustment of the condenser capacities, the circuits may be set into oscillation at any desired frequency permitting the reception of undamped waves.

Still another feature of this apparatus which perhaps will appeal to




Constructional details of the receiving system using Weagant's "X" circuit the amateur experimenter, is that wave lengths, ranging from 600 up to 20,000 can be received without having the usual duplex receiving transformer, a multiplicity of change-over switches, etc. In fact, the entire series of experiments leads one to believe that too much praise cannot be given this circuit for general experimental work. It is described in pages 102 to 105 of Bucher's "Vacuum Tubes in Wireless Communication," which explains vacuum tube detector circuits in detail.

Constructional details and dimensions of the tuner which have been found very satisfactory under the most exacting conditions follow: the antenna loading coil is wound on a tube 4 inches in diameter and 12 inches long covered with one layer of No. 24 S.C.C. magnet wire. Taps are taken off every inch, making a total of 10 taps. The winding is eleven inches in length. A general view is shown in figure 1.

A direct coupled receiving transformer is employed as shown in figure 2. It is wound on a tube 4 inches in diameter and 6 inches long covered with one layer of No. 24 S.C.C. wire. Taps are taken off every 10 turns, making a total of 20 taps. Two switches with ten contact points

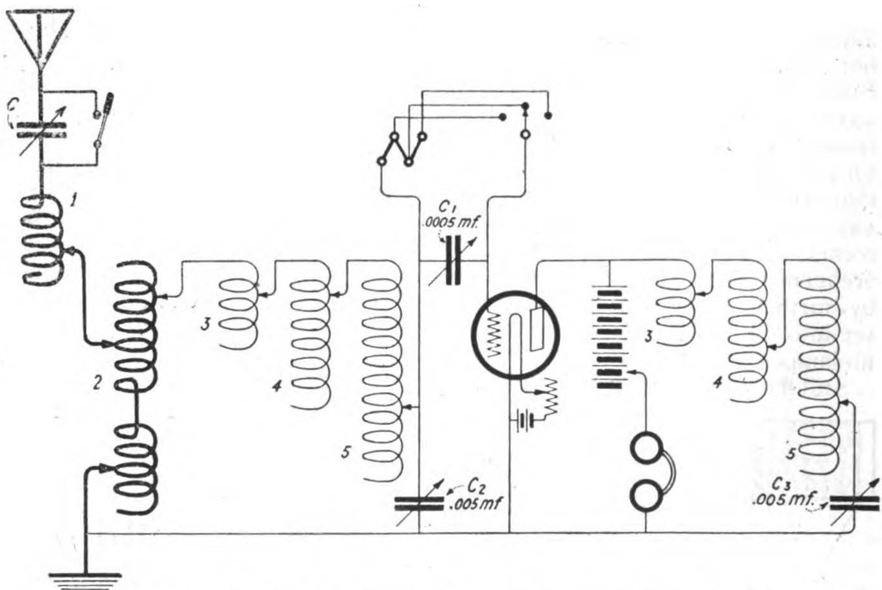



Figure 6—Diagram of connections and circuit used in the receiving system

are provided. Each contact point is connected to successive tenth turns. A unit switch is also supplied which connects to the first ten turns, one at a time, as shown.

The short secondary coils shown in figure 3 are made on tubes 4 inches in diameter, 6 inches long wound with one layer of No. 24 S.C.C. magnet wire. Taps are taken off every half inch, making ten taps per coil, or a total of 20 taps. The two loading coils of medium length are made of tubes 4 inches in diameter, 12 inches long wound with one layer of No. 24 S.C.C. magnet wire. Taps are taken off every inch, making a total of 20 taps for the two coils.

The large loading coils for long wave lengths are made on tubes 4 inches in diameter, 36 inches long, wound with one layer of No. 24 S.C.C. magnet wire. Taps are taken off every three inches. The details are shown in figure 5.

The variable condensers in the secondary circuit and plate circuits should have a capacity of at least .001 mfd. and for the very long wave lengths a capacity of .005 mfd. is desirable. The grid condenser should not exceed a capacity of .0005 mfd. or thereabouts. A grid leak of the type shown in figure 6 is necessary for stable operation. It may be made of high resistance strips of graphite or lead pencil lines drawn in a groove, or of carbon typewriter paper. A three point switch is connected as shown in figure 7.

The receiving system shown in figure 6 is not only exceedingly stable in operation but simple of adjustment and by proper selection of inductance at the antenna loading coil 1, at the tuning transformer 2 and at

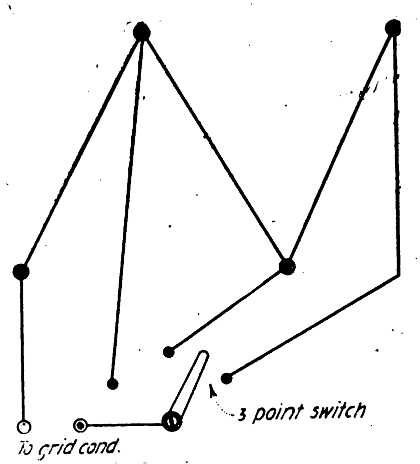



**Figure 7—Diagram of connections for the three-point switch**

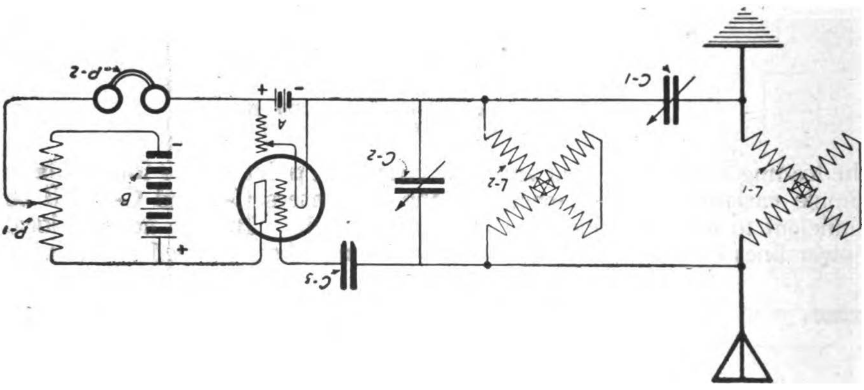
the loading coils in the grid and plate circuits, a point can be found where simple variation of the capacity of the condensers C-2 and C-3 will be sufficient to cover a wide range of wave lengths. In case near-by local power lines cause interference, the filament may be grounded to earth.

# CHAPTER XXVIII

## A Short-Wave Vacuum Tube Receiver for the Amateur Station

IT is generally held that the most efficient type of short wave receiver is that which employs variometers as the primary and secondary inductances. Hence the amount of inductance required to reach a wavelength of 200 meters is relatively small, and the losses in the variometers themselves are negligible.

The diagram shows the circuit preferred for amateur use. *L*-1 is the antenna variometer and *L*-2 the variometer which acts as one of the tuning elements of the secondary circuit. It is shunted by the variable condenser *C*-2. In series with *L*-1 and *L*-2 is the variable condenser *C*-1 which has the effect of changing the coupling, between the antenna and detector circuits. A small grid condenser *C*-3 of about .0005 mfd. is connected in series as shown. The plate circuit of the vacuum tube is energized by the battery *B* shunted by the potentiometer *P*-1, which



Circuit of the short wave receiver suitable for amateur stations

may be of 3,000 ohms resistance. For additional amplification some part of the plate cricuit may be placed in inductive relation to the grid circuit of the tube, but very good results will be obtained with the simple circuit shown.

The variometers are identical in construction. Each consists of two cardboard cylinders 1½ inches wide. The larger cylinder is 4½ inches in diameter and the smaller one 4 inches in diameter. Both are wound with the same number of turns of No. 26 S.C.C. wire.

Some prefer to mount the variometers and variable condensers in opposite corners of a cabinet. The panel on which the vacuum tube detectors are mounted can be secured to the top, giving a very neat appearance.

# CHAPTER XXIX

## Langmuir's Circuit and Apparatus for the Operation of Vacuum Tubes

A PATENT granted to Dr. Irving Langmuir of the General Electric Company shows a vacuum tube of unusual construction connected in a receiving set circuit for the detection of electrical oscillations. Figure 1 indicates a cascade system where the plate or output circuit of tube *A* is coupled to the grid or input circuit of tube *B*, through a resistance *R*. This usually has a value of 20,000 ohms.

The filament *F* is not heated by a battery as in the usual tube but it consists of potassium, sodium or other metal which emits electrons when illuminated by the source *L*.

A monochromatic source of light such as a mercury vapor arc in a quartz or glass envelope has been found to give off electrons of uniform velocity. The anode or plate preferably consists of tungsten and the bulb is exhausted of gas by electron bombardment during the exhausting process. The pressure in the envelope is reduced to a value at which no appreciable gas ionization can occur.

A two-way switch *S* is provided between the plate and grid circuit

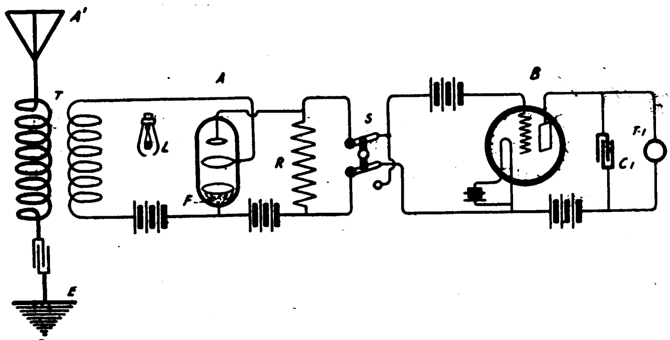



Figure 1—Langmuir's circuit and apparatus for amplifying variable currents

of figure 1 and when it is placed so as to connect the positive terminal of the resistance *R* to the grid circuit of the second tube, which contains a battery for making the grid negative, an increase of plate current in the circuit of the tube *A* will produce an increase in the plate current of the circuit of the tube *B*. When the connections are reversed the converse is the case. As in the usual receiving circuit the receiving transformer with its primary and secondary windings is indicated at *A*, the aerial at $A^1$ and the earth connection *E*. The current translator is the telephone *T*-1, which is connected in the plate circuit and shunted by the condenser *C*-1.

The apparatus shown in figure 2 is the usual cascade radio frequency amplifier—a circuit applicable to the reception of damped oscillations. Through the tubes *A* and *B*, the incoming radio frequency currents are progressively amplified, the transformers *T*-1, *T*-2 and *T*-3 being air core radio frequency transformers of the necessary dimensions for tuning to an incoming signal. The secondary of the three transformers are shunted by variable condensers as usual. It is to be noted that the vacuum tube *C* includes in its grid circuit a series grid condenser *C*-1 which is shunted by the battery *B*-1 and the resistance *R* connected in series. The object of the condenser *C*-1 is to secure an integral effect of each group of incoming oscillations so that the effect in the plate circuit of the vacuum tube *B* is to produce an audio frequency pulse of current—one pulse for each spark at the transmitter.

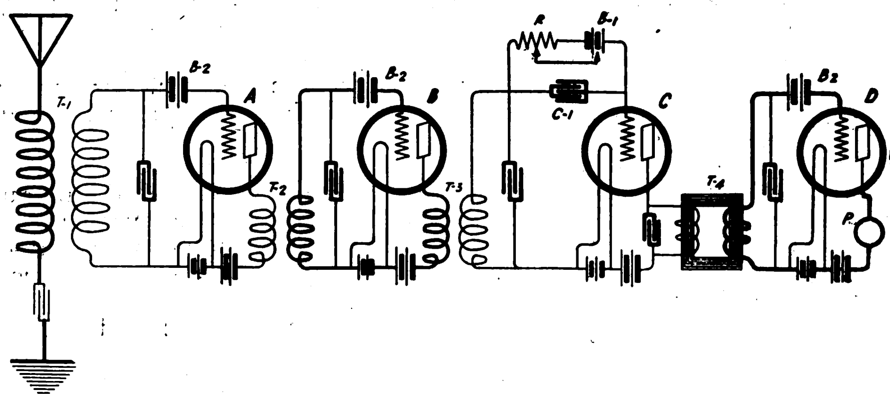



**Figure 2—Usual cascade radio frequency amplifier**

The operation of this part of the circuit is well understood by the field at large, the amplified incoming radio frequency currents being rectified, accumulating a change in the condenser *C*-1 over the duration of a wave train which makes the grid increasingly negative, reducing the plate current. At the termination of the wave train the charge leaks out, the condenser *C*-1 being assisted in discharging by the battery *B*-1. Thus the grid potential of the tube is restored to normal value between each group of oscillations and consequently the maximum effect is obtained in the plate circuit.

Tuning to audio frequency or, in other words, to the spark frequency of the transmitter is accomplished through the transformer *T*-4 which

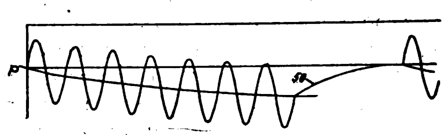


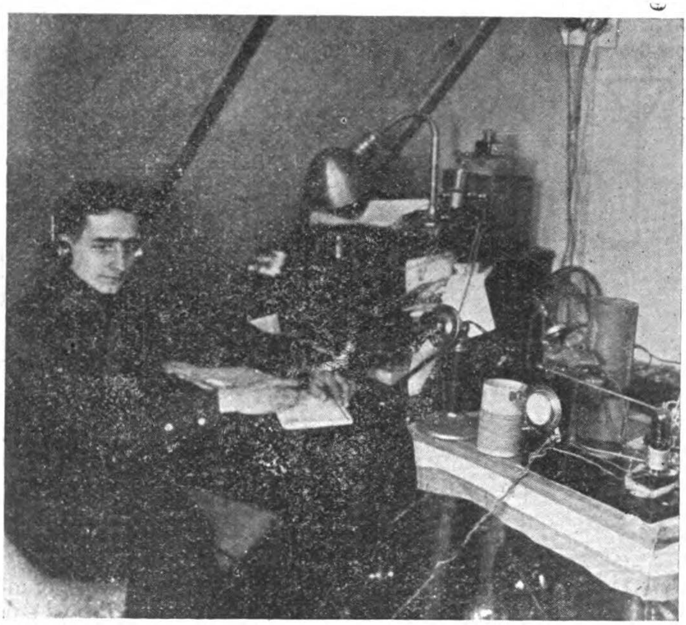
**Figure 3—Graph showing how the potential of grid to filament varies**

contains an iron core and is of the necessary dimensions to be resonant to frequencies around a thousand per second. The secondary terminals of *T*-4 are connected to the grid circuit of the tube *D*, the plate circuit of which contains the telephone transmitter *P*.

Both tubes have a source of grid potential—the special battery *B-2*—the object of which is to adjust the potential of the grid in respect to the filament to a slightly negative value, for this has been found to give the best signals.

The effect of the series condenser in the grid circuit of the tube *C* in figure 2 is shown by the graph in figure 3 where the successive cycles indicate how the potential of the grid to filament varies during the passage of a group of radio frequency currents. It will be noticed that the effect of the first half cycle is to make the grid slightly positive but as rectification occurs and a charge piles up in the grid condenser *C-1*, the grid becomes increasingly negative; at the termination of the wave train the grid potential returns to its normal value as indicated at *P*.

A feature of the cascade amplifier is, that by tuning successive circuits the undesired oscillations are reduced in each case in geometric proportion. The additional selectivity occasioned by the use of the group frequency tuner, reduces the problem of interference to a minimum.

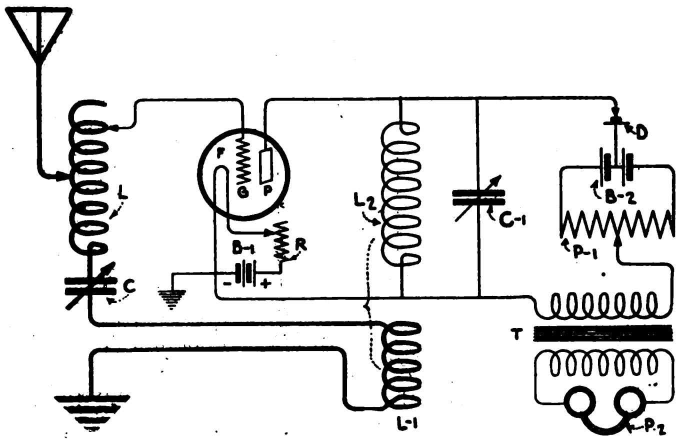


Tucked away in the corners of garrets in homes all over the country are amateur sets similar to this one, where it is not out of the ordinary to receive a message from a station a thousand miles away.

# CHAPTER XXX

## A Combination Receiving Circuit for Vacuum Tube and Crystal

THE English Marconi Company has developed a novel circuit for the combined or individual use of the vacuum tube and the crystal rectifier. The scheme of connections is shown in the accompanying diagram. *C* is a short wave condenser, *L* is the antenna inductance, *L*-1 a coil which acts as a primary winding of a receiver tuner for use with the crystal detector *D,* or as a regenerative coupler for amplification by the vacuum tube. *L*-2 is the secondary of the tuning transformer for use with the crystal or a tuning element of the plate circuit for regenerative coupling in connection with the vacuum tube. *C*-1 is the plate cir-

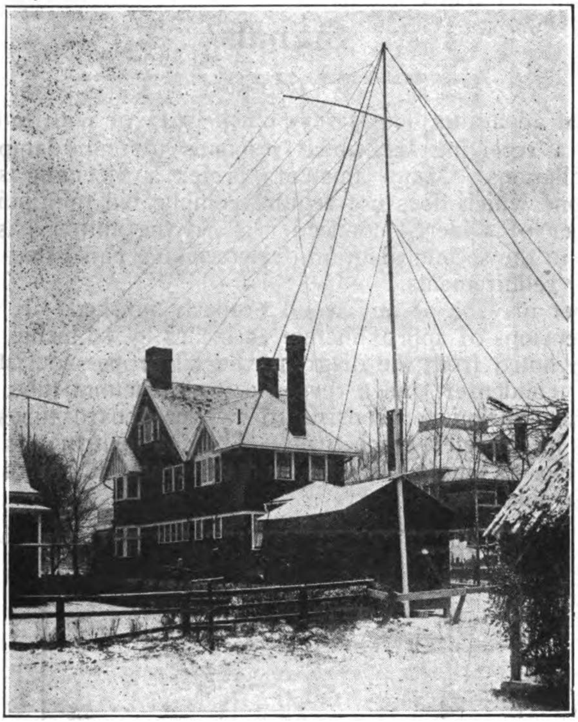



Circuit for the combined or individual use of vacuum tube and crystal rectifier

cuit tuning condenser. *D* is a carborundum rectifier, *P*-1 a potentiometer, *B*-2 the plate battery, *T* a telephone transformer and *P*-2 a pair of low resistance telephones.

It will be clear, from close observation of the diagram, that if the filament *F* of the vacuum tube is cold, the crystal detector *D* alone may be employed to detect spark signals. *L*-1 is then the primary of the tuning transformer and *L*-2 the secondary. If, on the other hand, amplification of the incoming signal is desired, the filament *F* is brought into play. The grid element *G* is then connected to the antenna inductance *L* and by suitable adjustment of the reaction *L*-1, *L*-2 and of the grid circuit potentiometer *P*-3 the circuits of the tube will be set into self-oscillation. The apparatus then receives by the phenomenon of beats or by careful adjustment of *L*-1 and *L*-2. Amplification of the incoming signal can be secured without the beat phenomenon.

There is thus provided a receiving apparatus which is independent of the vacuum tube, for should it become inoperative, such as by burning out of the filament, signals can still be received by the crystal detector alone. For longer distances, the vacuum tube circuits are brought into action for amplification. The apparatus clearly is responsive to undamped waves as well as damped waves.



An impressive type of amateur aerial

# CHAPTER XXXI

## How to Make a Set for Damped and Undamped Signals

ONE type of apparatus that is very much in favor with radio amateurs today is a receiving set which responds to both damped and undamped oscillations. Many amateurs prefer a receiving set of great simplicity—one which does not require complicated multipoint switches, and a number of soldered connections. So the author has shown the construction in the second diagram of a receiving panel that will be suitable for their requirements.

The cabinet may be of any wood properly finished. It should have over all dimensions of approximately 15 inches by 10 inches by 7 inches.

As will be noted from the diagram, the set proper consists of 3 variometers, one condenser, and a three-electrode vacuum tube.

The antenna variometer consists of two cardboard tubes $3\frac{1}{2}$ inches and 3 inches in diameter, respectively. The $3\frac{1}{2}$ inch tube is wound with 45 turns of No. 32 single silk wire, and the other tube with 50 turns of No. 32 single silk wire.

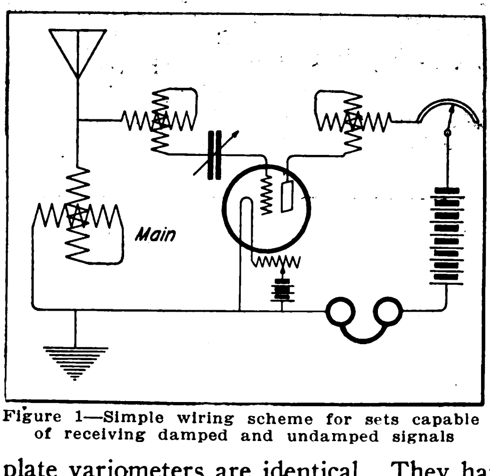



Figure 1—Simple wiring scheme for sets capable of receiving damped and undamped signals

The grid and plate variometers are identical. They have the same dimensions as the antenna variometer except that they are wound with 30 turns on the outside tube, and 35 turns on the inside tube.

The variable condenser has a capacity of .0005 mfd.

Referring to the drawing of the panel, the lower left hand knob controls the antenna variometer, the upper left hand knob the grid variometer, and the upper right hand knobs control the condenser and the variometer in the plate circuit, respectively.

The control knob directly under the vacuum tube is attached to the filament rheostat within the box. The remainder of the diagram, and construction of the panel is self explanatory.

It is to be noted that by this method of connection, the plate circuit is tuned to the frequency of the incoming oscillations, and that the required regenerative coupling is furnished by the tube itself. If, however, greater amplifications are required, inductive coupling can be provided between the grid plate circuit by placing the grid variometer and the plate variometer in proximity.

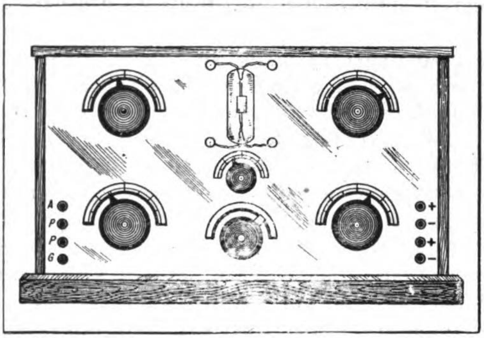



**Figure 2—Panel set showing the arrangement of instruments**

The advantage of this apparatus lies in the fact that there are no variable contacts or multipoint switches, the necessary tuning being done simply by turning the variometer.

In some cases it may be of advantage to shunt the plate battery and the head telephone by a variable condenser.

## A Multi-layered Tuning Coil

The multi-layered tuning coil herewith described proves very efficient in receiving undamped waves. It can only be used with a vacuum tube. Good receiving ranges have been obtained with two of these coils ten inches apart. They are wound on a form five inches in diameter and twelve inches long, with grooves one-half inch deep, one-quarter inch wide and one-half inch apart. The ends are made of wood six inches by six inches by three-quarters of an inch. On one of the ends is mounted a switch base in the form of a semi-circle. It has twelve contact points.

Seventy-five turns of No. 32 B. & S. wire are placed in each groove. The terminal of each coil is attached to a switch point and soldered on to it. One wire is brought from the switch lever to a binding post and the beginning of the coil is attached to another binding post. The coil should makes a valuable addition to any wireless set.

# CHAPTER XXXII

## A Receiving Set for a Wide Range of Wave Lengths

THE receiving set described herewith was designed to give a wide range of wave length with the least possible number of switches, and to afford the greatest convenience in tuning to a given station.

The general appearance of the front of the cabinet is shown in figure 1, a rear view wiring diagram in figure 2, and constructional details appear in figures 3 and 4. The connections for the vacuum tubes are shown in figure 5, and for the crystal rectifier in figure 6.

The cabinet is made of mahogany one-half inch thick; the base should be three-quarters of an inch in thickness. The front panels are four inches wide and eighteen inches long, held in place by brackets 6 anl 7 of figures 3 and 4,—6 for the top panel *B* and 7 for lower panel *A*. The brackets for panel *A* are fastened by three-sixteenths of an inch 6-32 round head screws on the inside of the panels, which hook over a round head wood screw in the side and bottom of the cabinet. Since panel *B* is movable, and has a contact spring for throwing the mineral detector in circuit, all four brackets are constructed so that the panel can be pushed straight in. The wood screws on the inside of the cabinet are then taken up to hold it in place.

In the lower left hand corner of panel *A* is a push-button for the buzzer tester. It may be, however, that one can secure the same results by throwing the variable condenser in series with the aerial and then placing it on short circuit. The discharge of the condenser produces a characteristic click which enables one to find the best adjustment of the oscillation detector.

The variable condenser of the primary circuit is connected in series with the aerial and when thrown one point beyond full capacity is placed on short circuit. This does away with the use of a single pole switch.

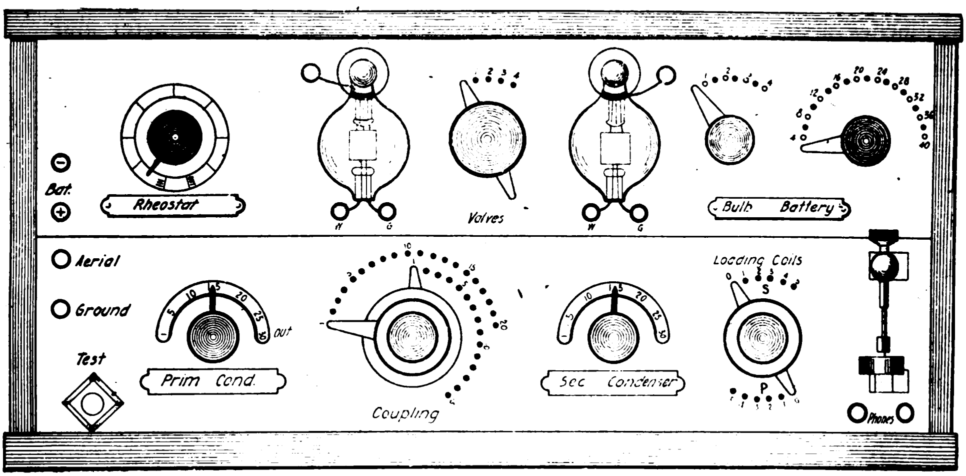



**Figure 1—Front view of cabinet**

The tuning transformer is built along the lines of the famous "Blitzen" except that it is arranged so that the primary and secondary switches require but a half turn. The reader must keep in mind that this set was built some time ago, and of course, the author added many improvements. In building another set of this kind, he would design the tuner like a Blitzen except that he would have the switch contacts on the front after the present design, using the larger circle of contacts for groups of "tens" and the smaller for single turns. The Blitzen permits sharper tuning than his design.

In respect to the secondary, the reader will note that it is tapped and connections are brought out to the front of the panel in the same manner as with the primary coil. The terminals of the secondary taps are connected to small screws in the side of the hard rubber ring. Connection is made through a flexible 15-conductor silk-covered cable. As the secondary can only make a quarter turn this cable never gets caught or twisted and does not put undue strain on the connection. (Note particularly the diagrams figures 2, 5, and 6).

The secondary condenser is connected across the secondary inductance as usual but is not generally used with the valve. It is found very useful, however, when the mineral detector is employed. These two variable condensers were bought disassembled from the Clapp Eastham Company.

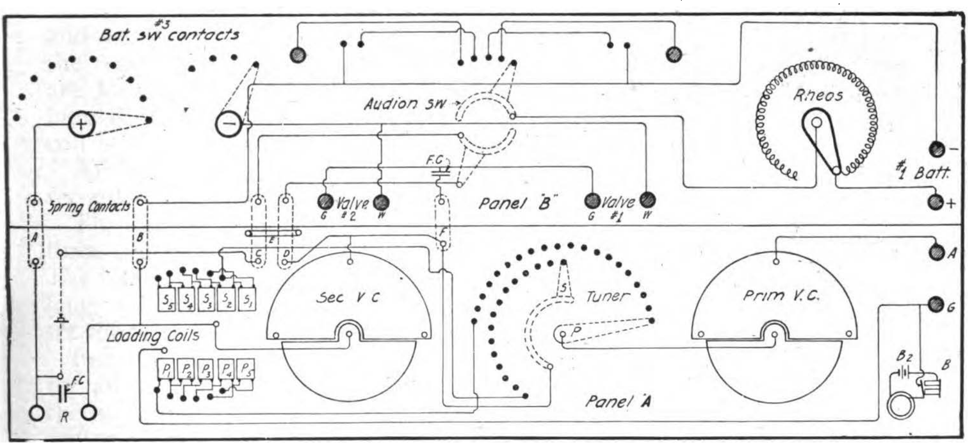



Figure 2—A rear view of cabinet showing wiring diagram

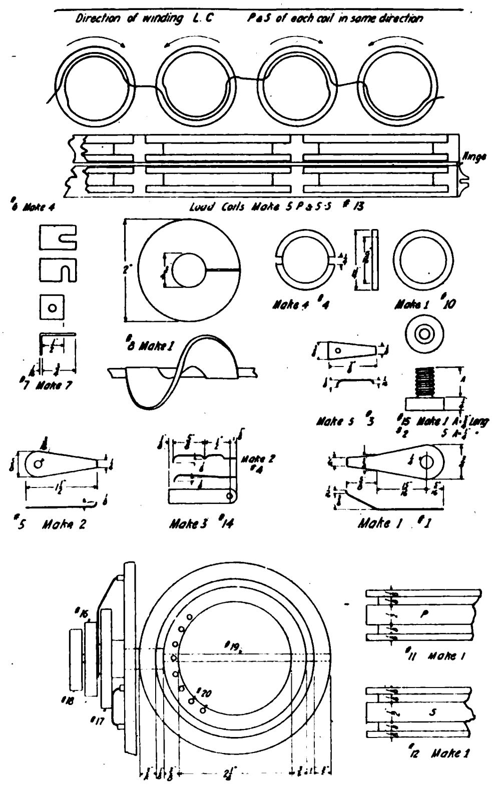
The switch for connecting in the loading coils also connects both the primary and secondary simultaneously in rather broad steps. Adjustments between the coils are made by changing the coupling of the tuner, which with a normal aerial will respond to a little over 2 thousand meters.

The coupling between the primary and secondary at the loading coils is varied by a small handle and brass rod running through the center of the switch handle (figure 1) to the rear of the set, where a cam made of a piece of one-sixteenth inch brass controls the primary. The author is fully aware that a loading coil and a tuner wound doughnut fashion such as is used in this set are condemned as inefficient but the author can truthfully state that by using the mineral detector (not the valve) he has heard South Wellfleet, using the spring of a couch bed for an aerial and the steam radiator for a ground! His station is on the second floor of an ordinary frame dwelling and about sixty miles from the station.

The mineral detector shown to the right of figure 1 is the universal type, first used by the Marconi Company. At the left of the panel, figure 1, will be seen the hard rubber binding posts for the aerial and ground connections, and on the right in the lower corner are the posts for the head telephones.

Connections between panels *A* and *B*, figure 2, are made with five one-thirty-second inch phosphor bronze springs *A, B, C, D,* and *F*. Removing panel *B* allows contact springs *C* and *D* to come toward the front of the set making contact with cross piece *E* and closing the detector circuit.

Since the batteries are mounted on a shelf in the back of the cabinet, in a box, panel *B* can be removed from the set by loosening four screws in brackets number 6 (figures 3 and 4) on the inside of the cabinet. It can then be pulled straight out.




**Figures 3 and 4—Constructional details**

The switch for the filaments of the two vacuum bulbs is built with a second blade or contact which automatically throws the mineral detector out when the valves are thrown in, thereby making unnecessary the use of a double throw switch.

The author has always found the ordinary switch for varying the battery current objectionable in that if the points were near enough to keep the blade or contact from sticking between them they would short circuit the set of batteries between these two particular points, and if the points were a greater distance apart than the width of the contact blade, the spring in the contact would force it down and it would hit or catch against the side of the next contact even though both the contact points and the contact spring were "rounded off."

For the above reason the author uses a dead point between each two live points making the width of the sliding contact a little less than the total distance between the live contacts.

The loading coils are wound on ten separate hard rubber discs three-

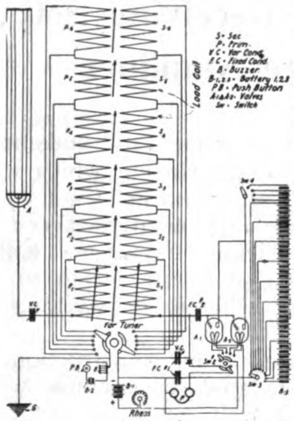


Figure 5—Connections for vacuum tubes

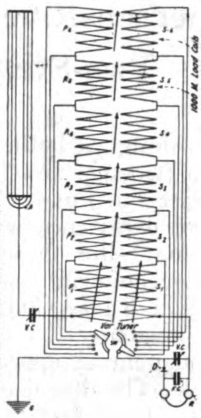


Figure 6—Crystal rectifier circuit

and-a-half inches in diameter. They are mounted five to a set, flat on the rear. Five coils are part of the secondary circuit and the other five are for the primaries. They are mounted on a thin piece of fibre sheet, hinged, and mounted face to face with the five secondaries. The first coil is wound clockwise, and the second counter clockwise.

All spring contacts are made of phosphor bronze about one-thirty-second of an inch in thickness.

The contact points are three-sixteenths of an inch in diameter and three-sixteenths of an inch in height. All metal parts are silver-plated. The binding posts are made from a six-thirty-second screw one-half inch long, a hexagon nut tapped to fit it, and a small rubber handle with a six-thirty-second tapped bushing made into it.

For the front panels the author uses one-quarter inch bakelite and for all handles one-quarter inch hard rubber except the handles on the rheostat, and battery switches which are standard knurled handles about one and one-quarter inch in diameter.

To connect the rod No. 19 (figures 3 and 4) to the hard rubber handle it is necessary to put a pin through the handle and rod, also through the rod and secondary coil. The bushing No. 15 is threaded and the primary tapped to fit. The hole through the panel has three-eighths inch clearance. and therefore the bushing holds the primary coil against the panel. This bushing has a one-quarter inch hole through it which is large enough to carry the tube connected to the primary handle. This tube is scratched on the end to make it rough and it is driven into the primary handle. The contact spring has a one-quarter inch hole and it is soldered onto the tube which extends an eighth of an inch beyond the face of the handle. This keeps the coupling handle far enough away to be easily manipulated.

The ring No. 8 is cut from one-sixteenth inch copper or brass and then cut to the center hole and pulled as shown in the drawing. This is soldered onto the one-quarter inch coupling rod.

# CHAPTER XXXIII

## A Supersensitive Receiving Set With Two-Stage Amplifier

THIS receiver is designed both for damped and undamped oscillations, and also has a two-step amplifier attachment which will increase the audibility to at least 150 times. The apparatus is not complicated; anybody who has had experience with undamped receivers can fully comprehend its working. For those lacking experience with the amplifier the author would recommend that they secure a copy of E. E. Bucher's "How to Conduct a Radio Club," wherein its workings are described especially for the amateur.

In figure 1, the general appearance and construction of the cabinet are given in detail. The dimensions apply to amateurs who cannot erect an aerial in excess of 300 feet in length, but will work exceedingly well on an aerial of 100 feet in length. The longer the aerial the better the results, but remarkable distances have been covered with a 100-foot aerial in connection with this set.

In figure 2 the circuits of the coils and coupler are given. The primary of the coupler may be wound on a tube 7 inches in diameter and 12 inches long, with No. 28 single silk. The first primary switch covers every ten turns. It has 15 taps. The secondary primary switch cuts in every 1 inch of winding and has ten taps. The secondary is wound with No. 30 single silk, and is tapped off every ½ inch. The twenty-four taps are divided between two 12-point switches, as shown in figure 1.

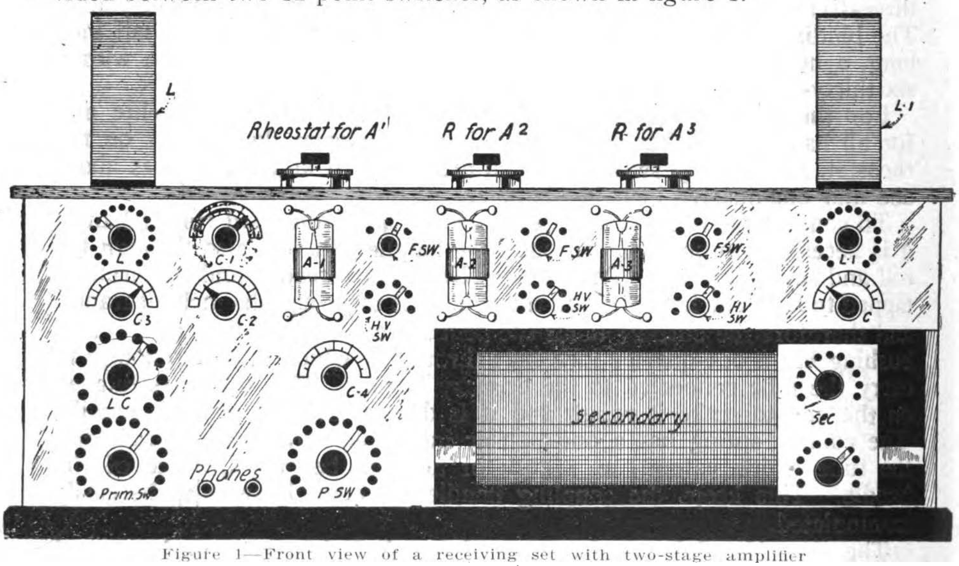



Figure 1—Front view of a receiving set with two-stage amplifier

The coils *L* and *L*-1 are each 30 inches long and 4 inches in diameter, wound with No. 30 single silk. They are tapped every 2 inches. A tubular bulb or present Marconi VT is suitable for continuous wave reception, but good results have been obtained with the old round bulbs.

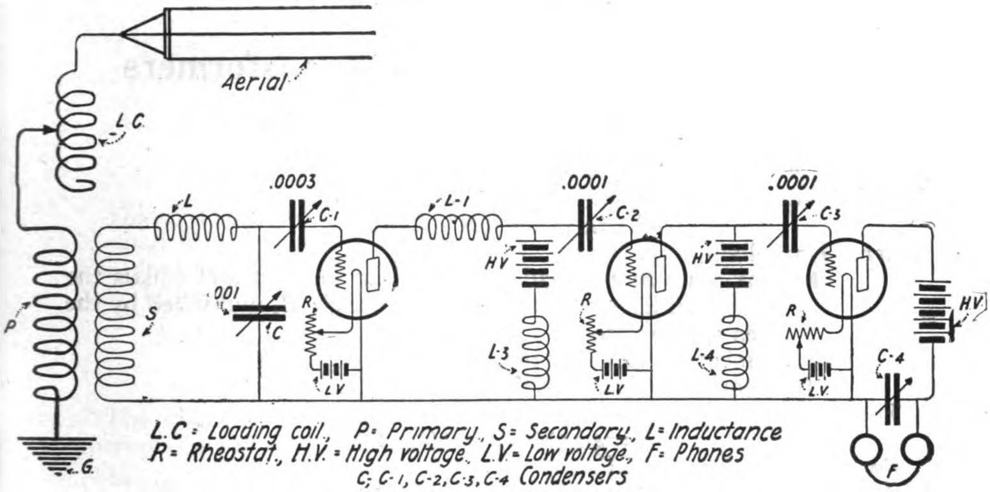



Figure 2—Wiring diagram for the receiving set incorporating a two-stage amplifier

The coils *L*-3 and *L*-4 are obtained from the secondary of a ½ inch spark coil, the primary being removed and the core replaced.

A loading coil may be inserted in series with the primary winding having the following dimensions: 4 inches in diameter and 12 inches long, wound with No. 26 single silk. No enameled wire should be used in a set of this kind, as experiments have proven it unsatisfactory for highly sensitive work.

Oak is recommended for the cabinet. This wood can be secured at nominal cost, and if it is treated with black stain, Johnson's Flemish Oak, and then rubbed down several times with wax, it fairly resembles hard rubber.

It should be mentioned also that if one does not care to use the amplifiers he should have no trouble in receiving 3,000 miles with this set. With the amplifier attachment and an aerial 100 feet in length no difficulty should be experienced in receiving stations as far as 7,000 miles, under favorable conditions.

The wood required for the construction of the cabinet is as follows: The base should be 36 inches in length, 12 inches in width and ¾ inch in thickness. The same dimensions apply to the top. The front should be 12 inches in height, 34 inches in length and ½ inch in thickness; the ends 10 inches wide, 12 inches in height and ½ inch in thickness, and the secondary front 4 inches wide, 6 inches in height and ¼ inch in thickness.

# CHAPTER XXXIV

## How to Design Sixty-Cycle Transformers For Amateur Transmitters

THE fundamental equation of the transformer is

$$E = 4.44 \times \Phi \times N \times f \times 10^{-8}$$

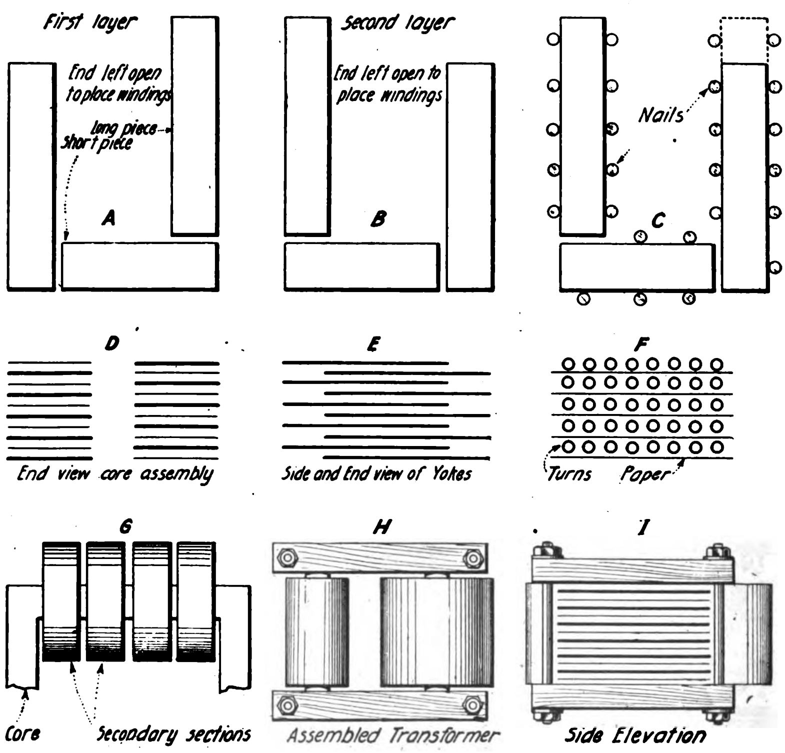
Where, E=voltage
$\Phi$=maximum flux threading the coil at no load and equals the density in lines of force per square inch, B, multiplied by the area of the core A.
N=number of turns in the winding
f=frequency of applied E.M.F.

For the primary E.M.F.

$$E = 4.44 \times \Phi_1 \times N_1 \times f \times 10^{-8}$$

For the secondary E.M.F.

$$E_2 = 4.44 \times \Phi_2 \times N_2 \times f \times 10^{-8}$$




Detailed design of the 60 cycle transformer for amateur transmitters

The ratio of primary E.M.F. to the secondary E.M.F. is,

$$\frac{E_2}{E_1}=\frac{4.44\,\Phi_2\,N_2\,f\,10^{-8}}{4.44\,\Phi_1\,N_1\,f\,10^{-8}}=\frac{\Phi_2\,N_2}{\Phi_1\,N_1}$$

If $\Phi_2=\Phi_1$, that is, if there is no magnetic leakage so that all of the flux produced by the primary cuts the secondary, this becomes

$$\frac{E_2}{E_1}=\frac{N_2}{N_1}$$

This is the ratio of the secondary E.M.F. to the primary E.M.F. and is equal to the ratio of the number of turns on the two coils. The relation does not hold for open core transformers as they have a large magnetic leakage.

## No Load Losses

The losses at no load are practically those due to hysteresis or eddy currents in the iron core.

The hysteresis loss is $W=K\ B^{1.6}\ f\ W$
The eddy current loss is $W=K_2B^2f^2t^2W$

Where, K=hysteresis constant[2] and varies with the grade of iron.
$=.0027\times 10^{-7}$ for alloyed iron
$=.0615\times 10^{-7}$ for ordinary iron
$K_2$=a constant inversely proportional to the electrical resistance of the iron
$=2.29\times 10^{-11}$ for ordinary iron
$=.792\times 10^{-11}$ for alloyed iron
B=maximum flux density in iron in lines per square inch
f=frequency cycles per second
t=thickness of laminations in inches
W=weight of iron in pounds

Iron .014" thick is suitable for transformers. At 60 cycles alloyed iron is preferable to ordinary iron.

## Losses Under Load

The losses when the secondary is connected to a load are those due to the resistance of the current in the primary winding, which equals $I_1^2\ R_1$

Where $I_1$=current
$R_1$=resistance of the primary winding

The resistance and current in the secondary winding is equal to $I_2^2\ R_2$ where $I_2$=current and $R_2$=resistance of the secondary winding. Added to this are the iron losses.

The $I^2R$ losses are know as the copper losses and vary with the load. The iron losses are practically constant at all loads. The total losses are simply the addition of the foregoing losses, viz.:
Iron loss $+I_1^2R+I_2^2R_2$

### Efficiency of Transformation

The efficiency

$$=\frac{\text{output}}{\text{input}} \text{ or}$$

$$\text{output} \div (\text{input} + \text{iron losses} + I_1^2 R_1 + I_2^2 R_2)$$

The efficiency of a transformer is maximum when the iron losses equal the copper losses.

A study of the fundamental formula shows that the number of turns of wire does not depend on the kw. rating of the transformer nor on the current the transformer will draw, but depends solely on the E.M.F., flux and frequency.

The only effect the load rating has is to fix the size of wire. The size of wire should be from 1,000 to 2,500 cir. mils per ampere for ½ kw. and about 500 cir. mils per ampere in 10 kw. sizes or larger. To illustrate the point let us change

$$E = 4.44 \text{ A B n f } 10^{-8} \text{ to}$$

$$An = \frac{E \times 10^8}{4.44 \text{ B} \cdot \text{f}}$$

Substituting E=110, B=60.000, f=60, we have

$$An = \frac{110 \times 10^8}{4.44 \times 60{,}000 \times 60} = 688$$

Now if A=1, n should equal 688
and if A=688, n should equal 1
if A=2, n should equal 344
and if A=344, n should equal 2, etc.

Any value can be chosen for A or n provided An=688.

### Number of Turns

The number of turns can be determined approximately as follows:

$$n_1 = \frac{E}{K \sqrt{W}}$$

Where E=coil voltage W=watts capacity of the transformer

K=.021 for small 60-cycle transformers and K=.03 for larger transformers.

If the formula above is used to find the primary turns, the secondary turns equal

$$E_1$$

In transformers for radio work, the current should be determined from the kilovolt-ampere rating rather than from the kw. rating as the power factor ($\cos\Phi$) is rather low.

*Example*

Let $W=500$ watts
$E_1=110$ volts (primary)
$f=60$ cycles
$E_2=13{,}500$ volts (secondary)
Power factor$=.8$ (assumed)$=\cos.\Phi$

The power $W=E_1 I_1 \cos\Phi$. Substituting the above values,

$$500=110\times I_1\times .8$$

$$I_1=\frac{500}{100\times .8}=5 \text{ amperes (approx.)}$$

$$\text{Secondary current } I_2=\frac{E_1\ I_1}{E_2}=\frac{110\times 5}{13{,}500}=.04 \text{ ampere (approx.)}$$

The area of the primary wire, allowing 1000 cir. mils per ampere$=5\times 1000=5000$ cir. mils. From a wire table we find that the wire nearest to this is No. 13 DCC wire. Its resistance is 2 ohms per 1000 ft. For the secondary, the area$=.04\times 2500=100$ cir. mils and from a wire table we find that this corresponds to No. 30 SSC wire. Its resistance is about 103 ohms per thousand feet.

To obtain the number of turns on the primary,

$$n=\frac{E}{.021\sqrt{W}}$$

$$=\frac{110}{.021\sqrt{500}}=238 \text{ turns}$$

At 60,000 lines per square inch. An should$=688$, so that

$$A=\frac{688}{n} \text{ or } \frac{688}{238}=2.89 \text{ sq. in.}$$

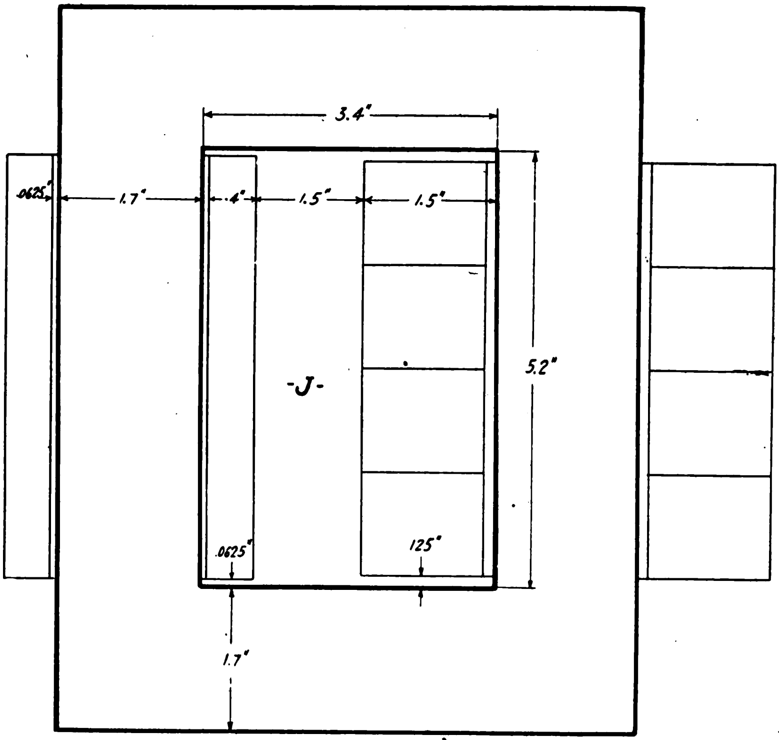
For economy of copper, the coil and core should be square in cross section; hence the core should be $\sqrt{2.09}=1.7''$ on side.

The secondary turns

$$n=\frac{E_2\times n_1}{E_1}=\frac{13{,}500\times 238}{110}=29{,}274 \text{ turns}$$

*Determining the Primary and Secondary Dimensions*

The voltage per section of the secondary should not exceed 4000 volts. Dividing 13,500 by 4 gives 3375 volts per coil, and dividing 29,274 by 4 gives 7319 turns per coil of the secondary. If we make each coil of the secondary square in cross section, we have $\sqrt{7319}$ or approximately 85 turns on a side. Allowing for pieces of insulation .05" thick between coils, and .125" micanite between the ends of the coils and the core, gives, allowing 4 mils insulation, $4\ (85 \times .014") + (3 \times .05) + (2 \times .125) = 5.2$ inches as the height of the transformer window. (See figure J). Since the diameter of No. 30 D.S.C. wire is .014", the thickness of the secondary




General plan with dimensions of the core, primary and secondary coils

coil$= (85 \times .014") + 0.125 +$ one layer of tape$= 1.5$ inches. The factor 0.125 is the thickness of the micanite tube.

Allowing .0625" as the thickness of the micanite tube between the primary coil and core, gives about 5 inch winding space. Dividing 5 by .078" gives about 64 turns per layer for primary coil. Dividing 64 into 238 gives 3 layers for the primary and calls for 46 additional turns to give the full 238 turns. The thickness of the primary coil is then $4 \times .078 + .0625$ or 0.4 inches approximately.

Mean length of secondary turn$= 4\ (1.7 + 1.4) = 12.5$ inches. And

$$\frac{12.5" \times 29{,}274}{12} = 30{,}494 \text{ ft. total length of secondary wire.}$$

At 103 ohms per thousand, the resistance of the secondary$= 30.5 \times 103 = 3141$ ohms. The copper loss of secondary$= I_2^2 \times R_2 = 3141 \times .04 \times .04 = 6.7$ or 7 watts.

The mean length of primary turn$= 4\ (1.7 + .4) = 8.4$ inches. This multiplied by 238=1999 inches and divided by 12 gives 166 feet as the length of the primary wire. The total resistance at 2 ohms per thousand=.166 ×2=.332 ohms. The primary copper loss=$I_1^2$. R=.332×5×5=8.36 watts. Total copper loss=8.36+7=15.36 watts.

The iron loss of good silicon steel is approximately .8 watt per pound. For the highest efficiency, the iron loss must equal the copper loss. Dividing 15.36 by .8 gives 19.2 pounds as the weight of iron in the core. Dividing 19.2 by .278 gives 69.4 as the total volume of the core. The length of the core with corners equals (5.2+1.7+1.7)=8.6 inches and for two cores=2×8.6=17.2 inches. The total volume of the cores therefore equals 1.7×1.7×17.2=49.7 cubic inches. Subtracting this from the total volume, 69.4—49.7=19.73 as the volume of the yokes. Dividing this by 2.89 gives 6.8 as the length of both yokes. Dividing this by 2 gives 3.4 inches as the width of the transformer window.

With steel laminations .014 thick, a core 1.7 inches will require 1.7× 59×4=404 pieces in all; 202 of these should be cut 1.7 inches wide and (5.2+1.7)=6.9 inches, say 7 inches, long. The other 202 pieces should be cut 1.7 inches wide and (3.4 inches+1.7 inches)=5.1 inches, say 5 inches. long. The builder may be able to get these cut to these dimensions by the manufacturers of the steel.

We may now determine the efficiency of the transformer from the foregoing formula. Summarizing,

| | | |
|---|---|---|
| Primary copper loss | = 8.36 | watts |
| Secondary copper loss | = 7. | watts |
| Iron loss | =15.36 | watts |

$$\text{Therefore, Efficiency}=\frac{500}{500+15.36+8.36+7}=94\%$$

## Assembly

Stack up the laminations as in figures *A* and *B* and be sure to stagger the joints. Drive nails in a board as in figure *C* and lay on sheets until the pile is 1.7 inches thick. The ends of the cores are shown in figure *D*. Figure *E* shows how the yokes will appear finally. After making up two cores and one yoke like figure *C*, bind them with one layer of friction tape.

Next put 1/16 inch washers on primary and ⅛ inch washers on the secondary. These should be made of micanite. Next place the micanite tubes on the primary and secondary cores. Make them about the same thickness as their respective washers.

The winding form for the primary is 1.8 inches on side and 5 inches long. Put on one layer of fishing twine, then one layer insulating paper, and finally 238 turns of No. 13 DCC wire. Now take off one end of the form, pull out fishing twine, whereupon the coil will come off very easily. Next solder on 1 foot of No. 12 machine cable to act as leads and then dip the coil in clear insulating varnish and bake for about 6 hours. Then wrap it with one layer linen tape, lapping the tape for half its width and then place the coil on the core. This completes the primary.

The form for the secondary will be 1.9 inches square and 1.2 inches long. First wind it with cord and paper as the primary, and put on 85 layers of 85 turns per layer of No. 30 D.S.C. wire. Place 1 layer of .007 inch oiled paper between the layers, then solder on leads of No. 20 silk covered lamp cord. Now remove the coil from form and wrap it with one layer of empire cloth. Construct the other three coils the same way.

The builder may be able to get these coils wound by some manufacturer of armature and field coils. The wire should be wound very carefully in even layers. It may be better to allow a little of the paper to extend beyond the ends of the winding as in figure *F*.

To finish the job, place the four coils on the core and connect up as in figure *G*. Be sure to connect the sections so the current travels around the core in the same direction. Place the remaining yoke in position, carefully watching the ends. Secure the core with oak clamps and bolts as in figures *H* and *I*.

The transformer should be placed in a tank and the leads brought out through suitable bushings. The secondary bushings should have an insulating value of at least 20,000 volts. Fill the tank with transil oil and put on a suitable cover.

The transformer has a leakage reactance suitable for a condenser of .008 mfd. using a quenched gap. When used with a non-synchronous gap the number of studs times the R.P.S. of the gap motor should not exceed 400.

# CHAPTER XXXV

## How to Make a Simple Hot-Wire Ammeter

ARTICLES have appeared in the various books and magazines describing the construction of a hot-wire ammeter for the wireless experimenter, but the main objections to these meters are the uncertainty of the zero position on the scale, and inaccuracies due to a change of the surrounding temperature. To overcome these disadvantages the meter shown in the diagram, figure 1, has been designed.

Two resistance wires *AB* and *CD*, each 4 inches long by .003 inches in diameter, are clamped between binding posts, using a paper washer to prevent slipping. *EF* is a silk thread 4 inches long. Another thread is tied at *G* and wound around the shaft on which the hair spring *H* is mounted. The hair spring tends to move the pointer to the right, but it is held on the zero position by the silk thread. The hair spring and its bearings were taken from an old alarm clock. *I* is a small spring, or

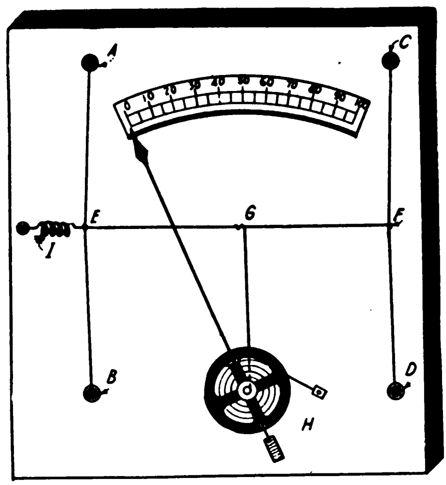



Figure 1—Design of the hot wire ammeter

rubber band, which should be very strong as compared with the hair spring. The pointer is cut along the band of a folded paper to give it stiffness. It is fastened to the shaft with a bit of sealing wax, by melting it off the point of a file.

If the wire *AB* expands, the spring *I* will pull up on *G* and move the pointer to the left. If the wire *CD* expands, it will slacken up on *G* and the hair spring will move the pointer to the right. It is evident then, that when both wires expand or contract alike, due to change of the surrounding temperature, the pointer will not move. The current to be measured should flow through the wire *CD*. The meter may then be calibrated by comparing it with a standard instrument.

Those who have a larger meter at hand, or who wish to make extremely small measurements, should note the diagram, figure 2. Here the wire *AB* has a shunt in parallel with it, and the instrument is connected in series with an adjustable rheostat, the large meter and a battery. The scale of the meter is also changed as shown.

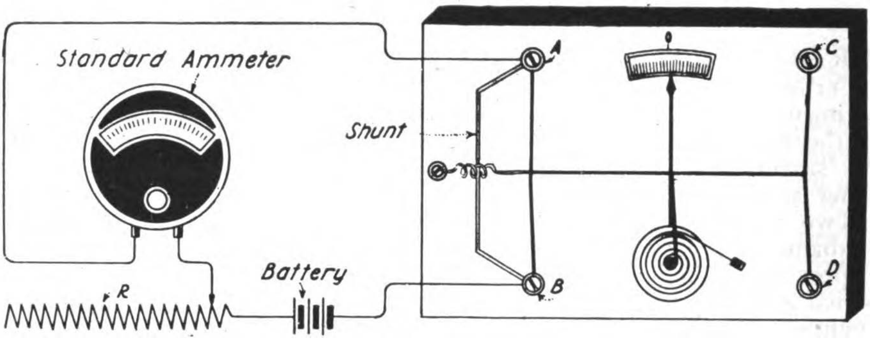



**Figure 2—Showing the hot wire ammeter connected up for calibration**

The current to be measured is passed through the wire *CD,* which moves the pointer to the right of the zero position. By adjusting the rheostat *R,* the value of the current flowing through the wire *AB* can be varied until it equals the current through *CD,* and the pointer will move back to zero. At this position the reading of the large meter should be taken and divided by the ratio of the shunt across *AB*. This result will be the value of the current through *CD*. For example, suppose the shunt has such a resistance as to allow 1/100 of the current to pass through *AB*. When .01 ampere flows through *CD,* to bring the pointer back to zero, .01 ampere should flow through *AB,* or 1 ampere through the large meter, which can be read more accurately. In this case a rheostat of 5 ohms maximum should be used, with a battery of two dry cells.

# CHAPTER XXXVI

## A Simple Design for a Self-Cooled, Quenched Spark Gap

ASSUME that the amateur desires to construct a quenched spark set to fit a 1 kw. 500 cycle transmitting set, so that the gap will be self-cooling. Also assume an 11,300 volt transformer and a condenser capacity of .008 mfd. Experience teaches that the gap current will be about 18 amperes. This is the root mean square and must be multiplied by $\sqrt{2}$ or 1.4 to obtain the maximum value, namely 18x1.4=25.2 amperes. In the design of quenched spark gaps, one square inch of sur-

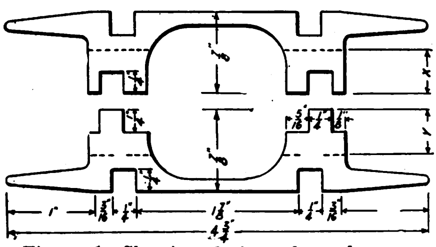


Figure 1—Showing design of spark gap

face should be allowed for every 10 amperes of current. Gaps of smaller dimensions will cause arcing, and plates of excessive size will cause a ragged spark tone.

In the particular example cited, 25÷10 gives 2.5 square inches as the area of the gap, keeping in mind that diameter $=\sqrt{\frac{\text{area}}{.7854}}$ and in this example $\sqrt{\frac{2.5}{.7854}}=1.8$ inches approx. We must allow 10 mils separation between the plates and a potential difference of 1,000 volts per gap; also we must allow .25 inches between the silver and the rim. If the rim is 3/16 of an inch in width, the total area of the rim will be approximately 1.4 square inches. We may now allow for the gap losses, 15 per cent of the power, which in this case equals 150 watts; and since for a potential difference of 1,000 volts we must have 11 gaps, we must allow 150÷11=13.6 watts to be dissipated per gap. Then assuming .2 watts per square inch for a 50 degree C. rise of temperature for continuous working, we have 13.6÷2=68 square inches, the surface required.

If we employ 2 cooling vanes per gap, then the approximate area will be equal to $68 \div 4$ (the number of sides of two vanes) $= 17$. The overall diameter $= \sqrt{\dfrac{17}{.7854}} = 4.7$.

It is now assumed that the completed gap is mounted in a metal frame and that the plates are pressed tightly together by means of a threaded bolt. We may then determine the leverage ratio with a 13 thread screw bolt and a 6 inch wrench; that is, ratio $= 2\pi\, 6 \times 13$ threads $\times 1$ lb. $= 489.84$, or approximately 490. If we allow 150 lbs. per square inch to make up for the tightness required with mica gaskets, we have $150 \times 1.4$ (area of rim) $= 210$ lbs.

Figuring $\dfrac{210}{490}$ gives about ½ lb. pressure to be placed on the end of a 6 inch wrench.

The sections marked *X* and *Y* of figure 1 are cut away to a depth of ½ inch for a space slightly less than ¼ circumference of the circle, so

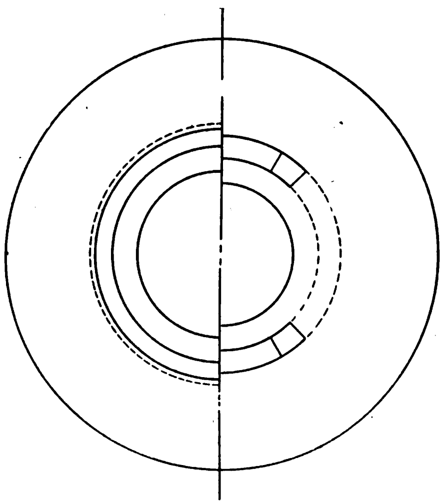


Figure 2—Gasket plates

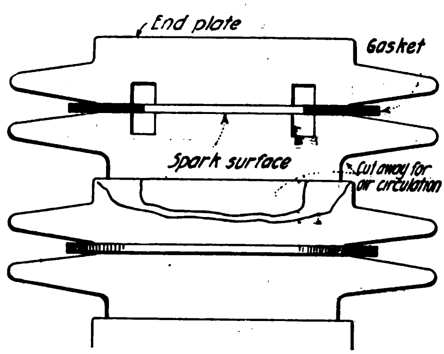



Figure 3—Spark surface of plate

that when the gaps are put together the air can circulate through the main body of the gap.

Figure 2 shows the plates of the gasket and figure 3 the sparking surface of a particular plate. It also shows a portion cut away for air circulation. If the gap is to be used intermittently, allow .4 watt cooling surface for a 50 degree C. rise in temperature.

# CHAPTER XXXVII

## How to Make a Simple Modulator for Continuous Oscillations

THE successful reception of signals from stations emitting undamped waves requires some means for reducing the radio frequency currents to audio frequency currents of less than 20,000 cycles per second. This can be accomplished in a number of ways, such as by the use of a tikker that breaks the circuit at a speed great enough to give an easily read note in the receivers, by utilizing an interfering current to produce "beats" or current peaks as in the heterodyne system, or by tuning and detuning the circuit at high speed to give an audible note.

The latter method has received little attention from experimenters and should be a fertile field for investigation. The revolving condenser method has been described previously but the instrument described in this paper uses an inductance to tune and detune the circuits. The device is nothing more than a small variometer so constructed that the inner coil can be revolved at a high speed.

In figure 1, is given a broken view of the device to show its assembly. The constructional details and dimensions are given in figure 2. A square wooden frame is used to support the stationary coils. This should be assembled with small brass screws, one end being left off till the rotor **is in place. Bearings for the rotor** are made from brass and mounted in the ends as shown.

The rotor is made from a two-inch length of shade roller or other wooden stick one inch in diameter. A slot one-quarter inch square is cut in opposite sides to take the winding. Holes are drilled in the ends to take one-quarter inch brass rods of the lengths given to form a shaft. Grooves are cut around the rotor for the fine silk or linen binders that hold the winding in place.

The rotor is wound with No. 28 B & S, S.C.C. copper wire. One end

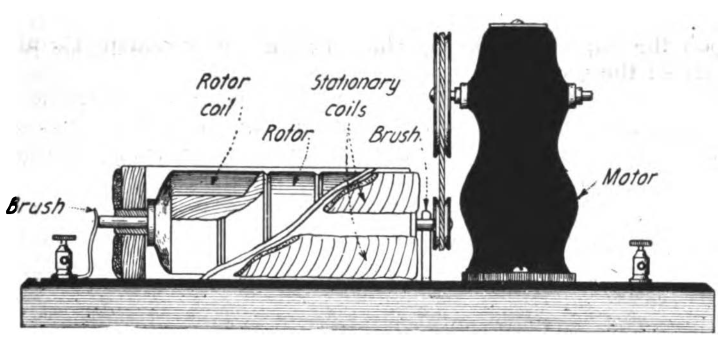



**Figure 1—Assembled view of device for modulating continuous oscillations**

of the wire is soldered to one shaft and the wire wound around in the slots similar to a telephone magneto. A little tape should be placed around the shaft where the wire touches. The winding is done in smooth layers, a slip of thin pasteboard being put between layers to

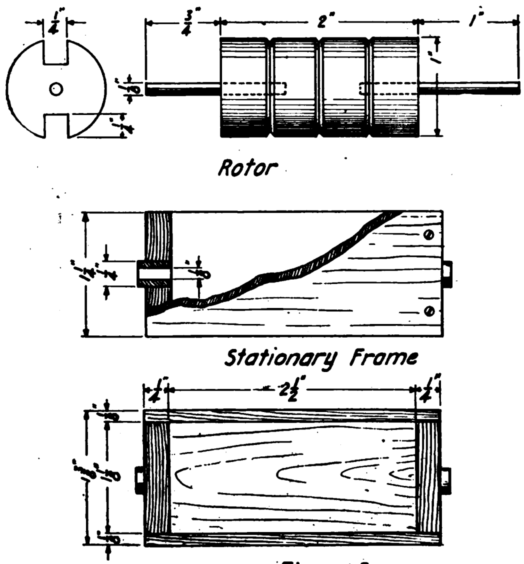



Figure 2

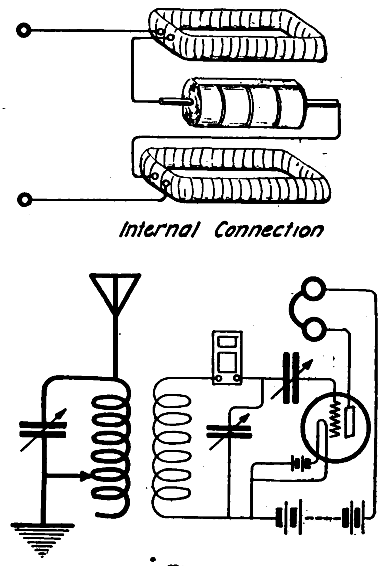



Figure 3

**Figure 2—Showing constructional details and dimensions**

**Figure 3—Showing method of wiring the device in the receiving circuit**

keep them smooth and reduce the capacity effect of the winding. When the slots are full the other end of the wire is soldered to the other shaft. A piece of cardboard is put in each slot over the winding and then bound in place with fine silk thread.

The stationary coils may be wound right on the square frame after the rotor has been put in place but it is preferable to make them so they can be easily removed. Each coil of the stationary winding should contain one-half the number of turns on the rotor, they being made of the same size wire. The form used for winding them should be a trifle larger than the square frame, a winding space three-eighths of an inch wide being used. Thin pasteboard should be placed between layers to stiffen the coils and also reduce capacity losses. After being removed from the form the coils are served with a layer of tape to keep them in shape.

The motor used for driving the rotor should be of the series type to give a high speed which can be controlled by a small rheostat. A heavy rubber band forms a very satisfactory belt for the device.

The usual method of wiring this instrument in the receiving circuit is shown in figure 3. By bringing out the leads from the rotor and stator to separate binding posts the experimental possibilities of the device are greatly increased.

# CHAPTER XXXVIII

## How to Make a High-Speed Key

MORE amateur dreams of a high-speed sending key have been wrecked upon the rocks of mechanical difficulties that were insurmountable, than any other device that we know of. The prohibitive price of the manufactured article places it beyond the reach of the average amateur's pocketbook, and the complicated nature of the instrument prevents its successful manufacture in the average workshop.

However, here is an automatic key operating by an electrical slow-acting relay instead of mechanical mechanism.

If we encircle an electromagnet with a closed copper ring of very low resistance, and if a current passing through the electromagnet is suddenly broken, there will be a secondary current induced in the copper ring which will in turn magnetize the core, thus tending to prolong the magnetic action.

This is precisely what is required for the electrical operation of our dot-making device in the high-speed key. In figure 1 is shown the circuit for the instrument, this consisting of a double contact key at *AB*, a battery and two electromagnets, number 1 being an ordinary magnet of about 20 ohms resistance, and number 2 being one of the slow-acting type just described. In order to give satisfactory results, the copper slug should be about ½ inch long and 1 inch in diameter, with a hole in the center of the diameter of the core.

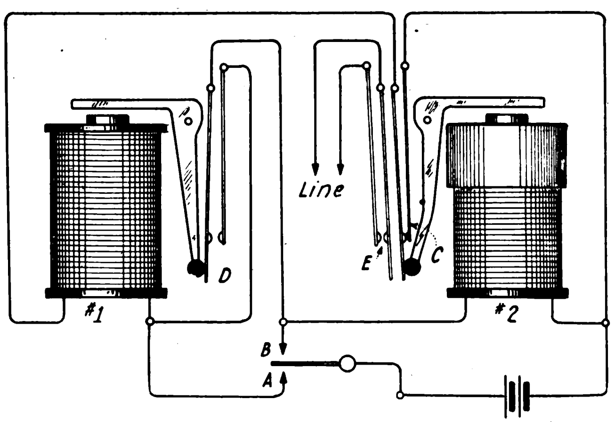



Figure 1—Showing the circuit of the high-speed key

The operation of the device is as follows: Closing the contact *A* allows the battery current to flow into coil number 1 through the contacts *C*. This pulls up the armature of number 1, closing contacts *D*, thus allowing current to flow into coil number 2, which in turn pulls up and opens contacts *C*, at the same time closing contacts *E*, which are connected to the main line. But the opening of contacts *C* releases coil number 1, thus opening contacts *D* and releasing coil number 2. This coil, however, requires an instant before releasing, which then starts the cycle over again.

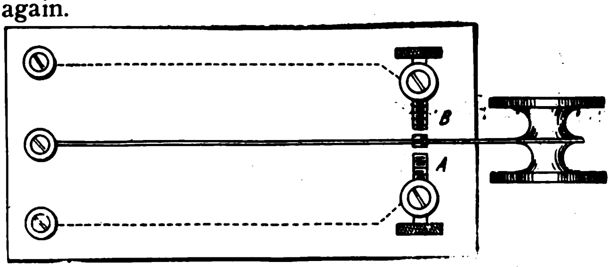
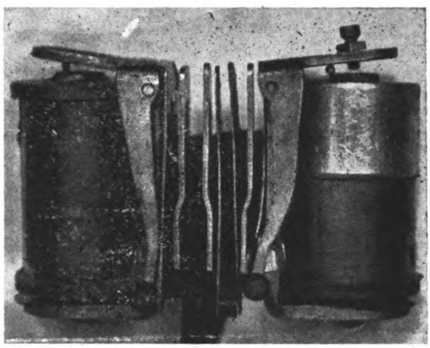



Figure 2—Simple form of the double contact key

The photograph shows such an arrangement as constructed by the author, using stock telephone relay parts, which was found to be entirely suitable. When sending at a speed of 20 words per minute, the speed of making dots varies from 8 to 12 per second; any variation of speed desired may be secured by adjusting the spring tension and the distance between the armatures and cores.

Figure 2 shows a simple form of double contact key to be used at



High-speed key apparatus constructed by using stock telephone relay parts

*AB*. It consists of a steel corset stay rigidly fixed at one end and making contact either with *A* for dots or with *B* for dashes. Two key knobs are screwed to the other end for its manipulation, and it is operated just like the ordinary high-speed key. In using a key of this type, practice is required to get just the correct number of dots in each letter, but a few weeks are sufficient to make one fairly adept.

# CHAPTER XXXIX

## How to Design a Five-Hundred Cycle Transformer

It has been shown that for maximum efficiency the iron losses in transformers should be approximately equal to the copper losses.

Assume for example that the design of a ¾ K.W. transformer is under consideration; with a loss of 6% and efficiency of 94%, the total loss will be 45 watts; one-half of this or 22½ watts will then be the iron loss.

The watt loss per lb. for good silicon steel .014 inches thick at 500 cycles is approximately 1.2 watts. Dividing this into 22½ gives 19 lb. as the weight of iron. Dividing 19 by .276 gives 68 cu. in. for the total amount of metal. For economy of copper, and to facilitate the cutting of the metal, the transformer should be square in form and in cross section.

Assume 1.7 inches for the side and 2.89 inches for the cross section; their product divided into 68 gives 23.5 inches as the mean length of the path. Dividing the result by 4 gives approximately 5.87 inches or 7.25 inches outside and 4 inches inside length.

With steel of the above dimensions we shall require about 59 pieces to the inch, or totally 400 pieces 1.7 inches wide by 5.9 inches long.

We may assume a primary voltage of 100 volts, current of 7.5 amperes; also a secondary voltage of 10,000 volts current of .075 ampere and the ratio of transformation to be 100. The formula:

$$V = \frac{4.44 \times a \times b \times n \times t}{10^8}$$

can be changed to

$$t = \frac{v \times 10^8}{4.44 \times a \times b \times n}$$

where,

v = voltage,
a = cross sectional area,
b = density in lines of force per sq. in.,
t = number turns of wire.

Allowing 15000 lines per sq. in. and solving for

$$t = \frac{100 \times 100\,000\,000}{4.44 \times 2.9 \times 15{,}000 \times 500} = 112$$ turns for primary, and since the ratio of transformation is 100 there will be 11,200 turns in the secondary.

For radio work 1000 circular mils should be allowed for current of 1 ampere. This calls for a conductor of 5700 cir. mils. for the primary coil and 75 cir. mils. for the secondary coil. Using the next larger size wire we employ No. 11 (8234 cir. mils) for the primary, and No. 31 (75 cir. mils) for the secondary.

If we use .25 inch Empire cloth to insulate the primary between the ends of the coil, and allow for the yoke between the coil and the core, the winding length will be 3.5 inches. In this space we can wind 3 layers of 35 turns each. An additional 7 turns can be placed in the middle of the coil to make up the 112 turns.

The secondary should be divided into 10 sections of 1000 volts, and 1120 turns each. Allowing the same thickness of insulation for the secondary as the primary, and 1/32 inch between coils we can wind 10 coils consisting of 59 layers of 19 turns per layer, for the secondary.

The overall efficiency may be determined as follows: The mean length of a primary turn is 8.5 inches and for 112 turns this equals 80 ft. At 1.3 ohms resistance per thousand ft.

$R = .1$ ohm

$I^2 R = 7.5^2 \times .1 = 5.6$ watts for the copper losses in the primary coil.

The mean length of the secondary turn is 10.6 inches, total 9900 ft. At 131 ohms per 1000 ft. $R = 1257$ ohms.

$I^2 R$ loss $= .075^2 \times 1297 = 7.2$ watts for the secondary losses. The total copper loss therefore equals 13 watts, the iron loss $= 22.5$ watts, and the efficiency $=$

$$\frac{750}{750 + 13 + 22.5} = 95\%$$

The primary and secondary inductances may be determined by a modification of the formula given by Messrs. Franklin and Williamson in their work on Alternating Currents as follows:

$$L = \frac{4 \times n^2 \times \lambda}{l} \left( \frac{X}{3} + \frac{Y}{3} + g \right) 10^{-9}$$

Where L = Inductance in Henries,
n = number turns
l = 2 times the height of the transformer window
λ = thickness of core
X = thickness of pri. coil,
Y = thickness of sec. coil,
g = distance between coils,

The above dimensions are in centimeters.

For this example

$$\frac{4 \times 3.14 \times 12{,}544 \times 4.3}{20.3} (3.3 + 7 + 6.9)\, 10^{-9} = .00069 \text{ Hy. pri. reactance.}$$

This may or may not be the correct value required. If not, the dimensions of the transformer will have to be changed.

# CHAPTER XL

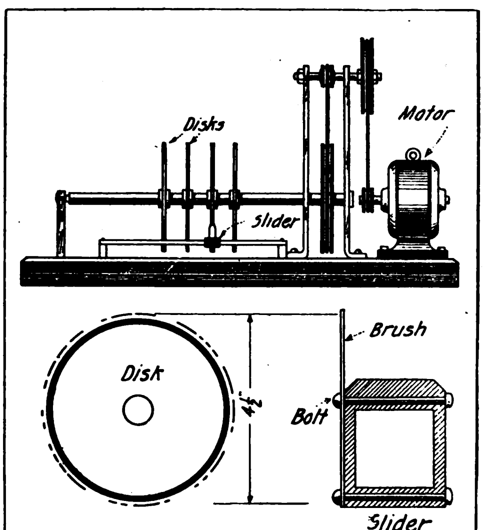
## An Instrument for Self Instruction in the Continental Code

THE ordinary buzzer gives only sending practice, but the device described herewith will give receiving practice, which, as is well known, is the harder of the two to master.

The apparatus can be cheaply constructed. The necessary parts can usually be found around the amateur's laboratory.

The assembled instrument is shown in figure 1, and the details of the cardboard discs are shown in figure 2. Figure 3 is a wiring diagram of the apparatus.

The disc shown in figure 2 is 4½ inches in diameter. Pieces are cut out of the circumference to form the dots and dashes of the International Code. The discs are then thoroughly shellacked and baked in an oven.




Figures 1 and 2—Instruments for self instruction in the Continental code

Strips of tin foil which are shown by the dotted lines in figure 2 are pasted on the cardboard disc, and connected to a copper washer in the middle. Care should be taken to cut the tinfoil exactly the same size as the dot or dash on which it is pasted, for otherwise, some dots and dashes will be longer than others. After this is done, the discs are clamped by means of bolts on a threaded shaft which is revolved by an electric motor as shown in figure 1.

The brush shown in figure 2 is made out of sheet brass and screwed onto an ordinary tuning coil slider. The brush may be pushed up and

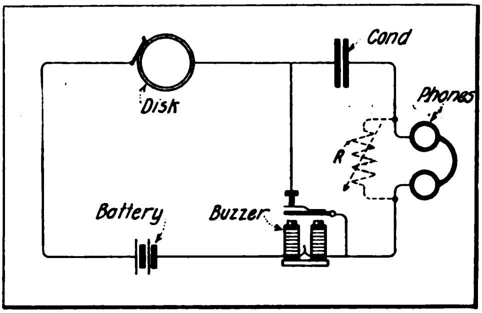
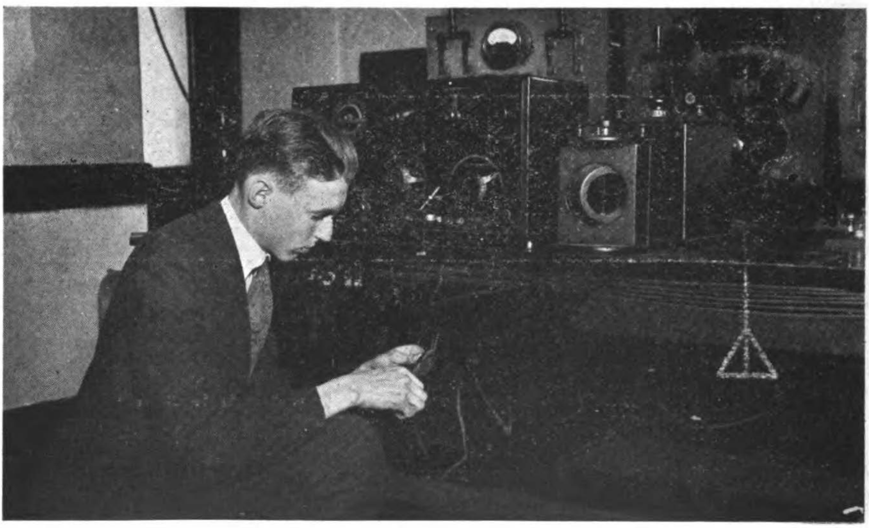



Figure 3—Wiring diagram for the code practice set

down the slider rod in contact with whatever disc the student desires to use. In this way he may receive practice from a large number of messages.

This device will work well as a flasher of lights on a 110-volt circuit, but a telegraphic relay must be employed because the high voltage would fuse the tinfoil.



The workmanlike appearance of this wireless set indicates the high type of construction achieved by the present-day amateur

# CHAPTER XLI

## Some Facts Regarding Quenched Spark Transmitters From the Amateur's Viewpoint

NO one who understands the principles of radio engineering doubts that the quenched spark discharger is the most efficient gap yet devised for low powered transmitters. The writer, however, will attempt to show that the amateur in the majority of cases is not in a position to take full advantage of the benefits thus to be obtained, and as a consequence a non-synchronous rotary spark gap is the one to be preferred for amateur use.

In the first place, many amateurs are of the opinion that simply to substitute a quenched gap for one of the plain rotary type will result in increased antenna current and range of transmission; but it is safe to say that those who have tried to experiment have been amazed at the degree of *inefficiency* which the quenched gap brought about! In all probability it will be found that such amateurs have never been told the requirements of a radio transmitter that gives good quenching. It is not alone the quenched spark that prevents the interchange of energy between the open and closed circuits with the consequent double wave emission, but it is the design of the whole transmitter which must be considered.

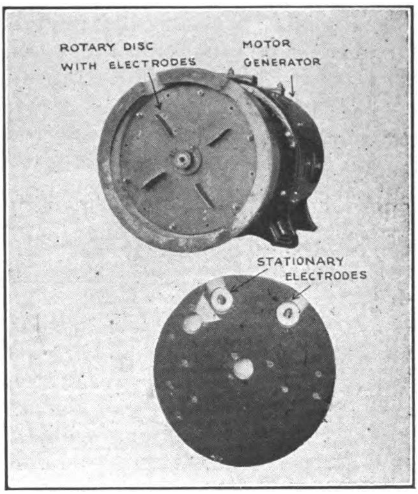
To begin with, there must be a certain amount of magnetic leakage in the power circuits of the transmitter, for otherwise when the condenser discharges across the spark gap, the transformer is short circuited and the resulting arc at the gap is too powerful to be quenched out. This permits the antenna circuit to react upon the spark gap circuit and results in a double wave emission. This is substantially what the amateur with the average 60 cycle transmitter will find.

A transformer fitted with a magnetic leakage gap will give some relief; even the insertion of a reactance coil in the primary circuit of the transformer will help some, but the best results will be obtained with a transformer having a magnetic leakage gap and utilizing the principles of resonance; that is, the transformer circuit with the secondary condenser should be tuned near to resonance with the frequency of the alternator.

The operation is then somewhat as follows: Due to resonance, the secondary voltage of the transformer rises to the point where the spark gap breaks down. The resistance of the spark gap is then reduced and the secondary of the transformer is short circuited. This throws the transformer circuits out of resonance with the alternator, resulting in a very marked drop in the secondary voltage. This drop in voltage combined with the heat dissipating qualities of the copper plates in the quenched gap permits the primary to oscillate only through two or three swings, whereupon the primary oscillations increase. The antenna circuit then oscillates at its own frequency at damping with a single wave emission.

Experiment has proven that it is difficult to maintain a clear spark note with a resonance transformer, hence, the natural frequency of the transformer circuit with its secondary condenser is designed to be 15 per cent or 20 per cent lower than that of the alternator. This prevents the breaking up of the spark note and still retains enough of the good effects of resonance to obtain the detuning results mentioned. In some types of transmitters like the Marconi quenched spark sets, the necessary magnetic leakage takes place at the alternator, the transformer being closely coupled; but since the amateur has no control over the source of power, he is required to obtain the necessary leakage at the transformer.

Suppose, for example, he possesses a transformer with a magnetic leakage gap and desires to operate near to the point of resonance. The necessary condenser capacity can be readily obtained in the following way: An ammeter is placed in the primary circuit, the key closed and the capacity of the secondary condenser varied until the primary ammeter reads the maximum. This indicates resonance. Then the capacity should be increased by 10 per cent to 15 per cent in order to slightly detune the circuit. With some types of transformers, the necessary capacity for resonance, or near resonance, may exceed .01 mfd. and as a consequence the amateur cannot operate on the wave length of 200 meters. If this is found to be the fact, he may obtain some relief by




**Synchronous rotary spark gap giving the high pitched note desired by amateurs**

placing a reactance coil in series with the primary circuit of the transformer, using it, as well as the secondary condenser, to tune the circuit. By giving proper attention to the foregoing suggestions, very good results can be obtained with the quenched gap. There is, however, one all important factor that has not yet been taken into account.

Some experimenters are of the opinion that a quenched gap will increase the frequency of the spark discharge. This is not true. The quenched gap has the effect of smoothing out the tone of the spark, but at best the resulting spark note will be relatively low and will hardly compare with the musical note of non-synchronous rotary spark gap which amateurs are accustomed to employ. The average 60 cycle transmitter gives, with a quenched gap, what is known as a "mush" note, which, while it may be pleasing to some ears, cannot be said to be the most desirable tone. There are no ready means available to increase the tone of the spark except the type of transmitter which involves both a rotary spark gap and quenched gap. Some experimenters have placed these gaps in series using the rotary gap to increase the tone, and the quenched gap to give the necessary quenching. Experiments in circuits of this type do not always give the desired results. In fact the writer has found that the system is not very efficient.

This discussion, of course, does not include the rotary quenched spark discharger which has been supplied to the amateur market, but the writer has observed that these transmitters have such a large capacity in the closed circuit that they cannot be operated efficiently on a wave length of 200 meters. Such a large capacity results from the use of a low voltage secondary, usually no more than 2500 volts, but if it were not for that disparaging feature, it is safe to say that it would be employed universally by amateurs; for it is well known that a set of this type now supplied to the amateur market produces a spark tone equivalent to a 500 cycle transmitter.

Another item which experimenters should take into account is the cost of the quenched spark discharger. It has been the writer's experience that the expense of milling, cutting and casting the plates for quenched gaps exceeds the cost of a good rotary gap; and moreover, unless the amateur is willing to put the best possible construction into the quenched gap, he will find that it will not operate over a considerable period of time without trouble.

The average wireless experimenter prefers a high pitched spark note, or at least a note equivalent to a non-synchronous rotary gap. The writer has yet to see the quenched gap operated on 60 cycle current that will give a note equivalent to the non-synchronous rotary gap.

This discussion, of course, doe not apply to 500 cycle transmitters, but since the amateur has not available a source of current of this frequency, the use of such frequencies need not be considered.

The writer firmly believes that in the future the approved transmitting set for amateur use will be one of the vacuum tube type because these transmitters are rugged, fairly efficient, can be connected up to generate radio and audio frequency currents simultaneously and thus produce musical tones so desirable for all-around wireless transmission. No one has yet put such a transmitter on the market, but it is safe to say that one of these types will appear in due time.

# CHAPTER XLII

## A One-Kilowatt Amateur Transmitting Panel Set

THE design of the transmitter should be given careful consideration, for whether one is able to transmit signals 1,000 miles, or only 100 miles, with a one kilowatt set, will depend upon the mounting of the component parts, as well as upon the electrical characteristics of the apparatus. The objects of this chapter are: To set forth methods of eliminating certain factors which tend to reduce the efficiency of a wireless station, and to show drawings of a transmitting set which will help to illustrate the fundamental points of this discussion.

### Ground Connection

The ground connection is a vital part of a wireless station. If it is poor, the effectiveness of the system is greatly diminished. The most efficient "ground" to be obtained by the amateur is a connection to the city water mains. The water pipes should not be used if the earth wire measured from the instruments to the water pipe exceeds 30 feet in a horizontal direction. In case it exceeds this length, it is advisable to construct a separate earth plate. The following table gives the resistance of different types of earth connections. The amateur should choose the best suited to his purpose, remembering that grounds of lowest resistance have the highest efficiency.

### Resistance of Different Types of Grounds

| | | |
|---|---|---|
| (1) | 10 lb. scrap copper set 6 feet—0 inches deep surrounded with 10 lb. coke | 14.2 ohms |
| (2) | Copper plate 5 feet x 3½ feet set 4 feet deep surrounded with 2 feet—0 inches crushed coke | 5.6 ohms |
| (3) | 9 feet length 1¼ inches black iron pipe driven 6 feet into solid earth | 25.1 ohms |
| (4) | 12 feet length black iron ditto | 14.8 ohms |
| (5) | Two 9 feet lengths ¾ inch pipe set 6 feet deep in coke | 15.2 ohms |
| (6) | Perforated metal cone 18 inches long filled with charcoal buried 6 feet in 2 feet of coke | 14.4 ohms |
| (7) | Connection to city water main | 0.44 ohms |
| (8) | 1 inch pipe in deposit of ashes 1 foot deep | 26. ohms |
| (9) | 1 inch pipe driven in 5 feet—0 inches, surrounded with 16 lb. salt mixed with earth, water poured around | 20. ohms |
| (10) | 1 inch pipe 5 feet—0 inches buried 12 inches horizontally, salted and watered after 4 days | 15. ohms |

The resistances given are for rich black soil.

The wire leading from the instrument panel to the ground connection should be short and run as nearly vertical as possible. A No. 4 B & S stranded, rubber covered wire serves the purpose.

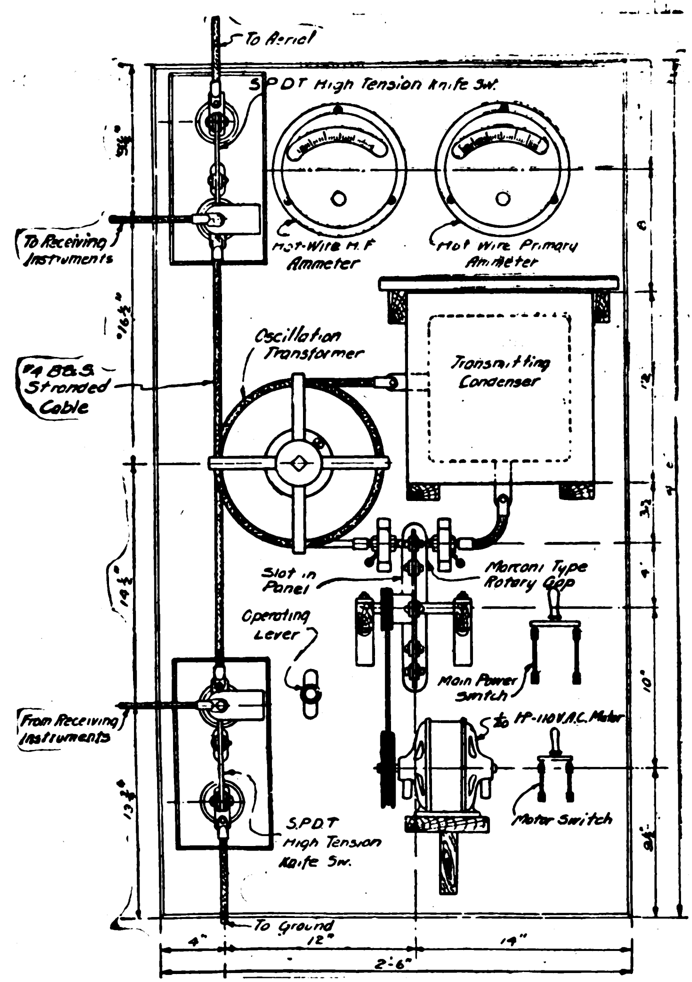



Figure 1—Front view of transmitting panel for an amateur radio station

## Operating Panel

The operating panel, shown in the accompanying figures 1, 2, 3 and 4, may be made of transite asbestos wood, from ½ inch to ¾ inch thick. This is the best kind of material to use, because it is cheaper than slate or marble, more easily worked and is fireproof. However, a panel of neat appearance may be built of 1 inch oak or pine boards and given two coats of floor varnish. The panel is mounted by means of wood screws on two 2" x 2" wooden uprights or on iron brackets and braced at a point 15 inches from the wall.

For switching from a transmitting to a receiving position, two single-pole double-throw high tension knife switches are employed. The blades as shown in the side elevations, figures 2 and 3, are interlocked by means of bell-cranks and levers, and are operated by a lever approximately 2 feet by 7 inches from the floor. This places it in a convenient position for a man sitting in a chair.

The wire used for the oscillation transformer shown in figure 3 should be in size no less than No. 4 B & S stranded bare or insulated cable. If none is available, the amateur may build up an equivalent cable by twisting together 27 No. 18 B & S bare wires, or 40 No. 20 B & S wires. The smaller the wires the better will be the conductivity for high frequency currents. The conductor for both primary and secondary of the oscillation transformer are wound on crosses made of pine boards impregnated with paraffin. Both coils are supported so that they may slide back and forth on a square brass rod set into the front of the panel. The coils are 10 inches in diameter.

The condenser in the primary circuit is built up of ¼ inch glass plates 12 inches square. Half the plates are coated with extra heavy tin foil 9 inches square, applied to both sides. Terminal lags are placed on the case, one on the lower edge, the other on the side. They are preferably made of thin sheet copper. In assembling the condenser a plain glass plate is placed between two coated plates to vary the capacity. This method avoids taking taps from the helix, as is usually done and is simpler.

The rotary gap is one of the Marconi type of dischargers. The disc is made from a piece of red fibre ¼ inch thick, 10 inches in diameter, impregnated with paraffin. It has eight ⅜ inch brass studs spaced equally around the circumference and fastened by means of a nut on each side. The nuts are thin, being made by cutting in two with a hack saw a ⅜ inch brass nut. The pulley should be about 3 inches in diameter. The disc and pulley are mounted on a piece of ⅜ inch drill-rod 6 inches long, which serves as a shaft. The rotary gap should be driven by a small induction motor and run about 1,800 R. P. M., giving 240 discharges per second. The size of the pulley on the motor depends on the motor speed. A leather belt serves as a driving medium.

The hot-wire ammeter on the left hand side of the panel should have flexible leads with spring clips so that it may be inserted in the aerial circuit when required. The other ammeter is placed permanently in the 110-volt supply line as shown in the wiring diagram, figure 4.

The special features of this transmitter are the short leads in the oscillating circuits and the lack of sharp bends or kinks which would cause leakage at high voltages. All sharp corners on both conductor and insulators should be rounded off with a file. The insulators shown on the high tension knife switches may be porcelain or electrose, or hard wood baked dry and then boiled in paraffin. High voltage insulation is necessary.

It will be noted that there are 5 turns on the secondary of the oscillation transformer. This may have to be modified for aerials of different heights and lengths. The inductance of such a coil is given by Nagaoka's formula:

$$L = \frac{4\pi^2 a^2 n^2}{b} \times K, \text{ cms.}$$

where a=means radius of coil=5″=12.7 cm.
b=overall length of coil=3.5″=7.89 cm.
n=number of turns=5
K=a constant depending on the ratio of 2a/b

Obtained from tables by Nagaoka which may be found in Bureau of Standards bulletin No. 74 or bulletin No. 169

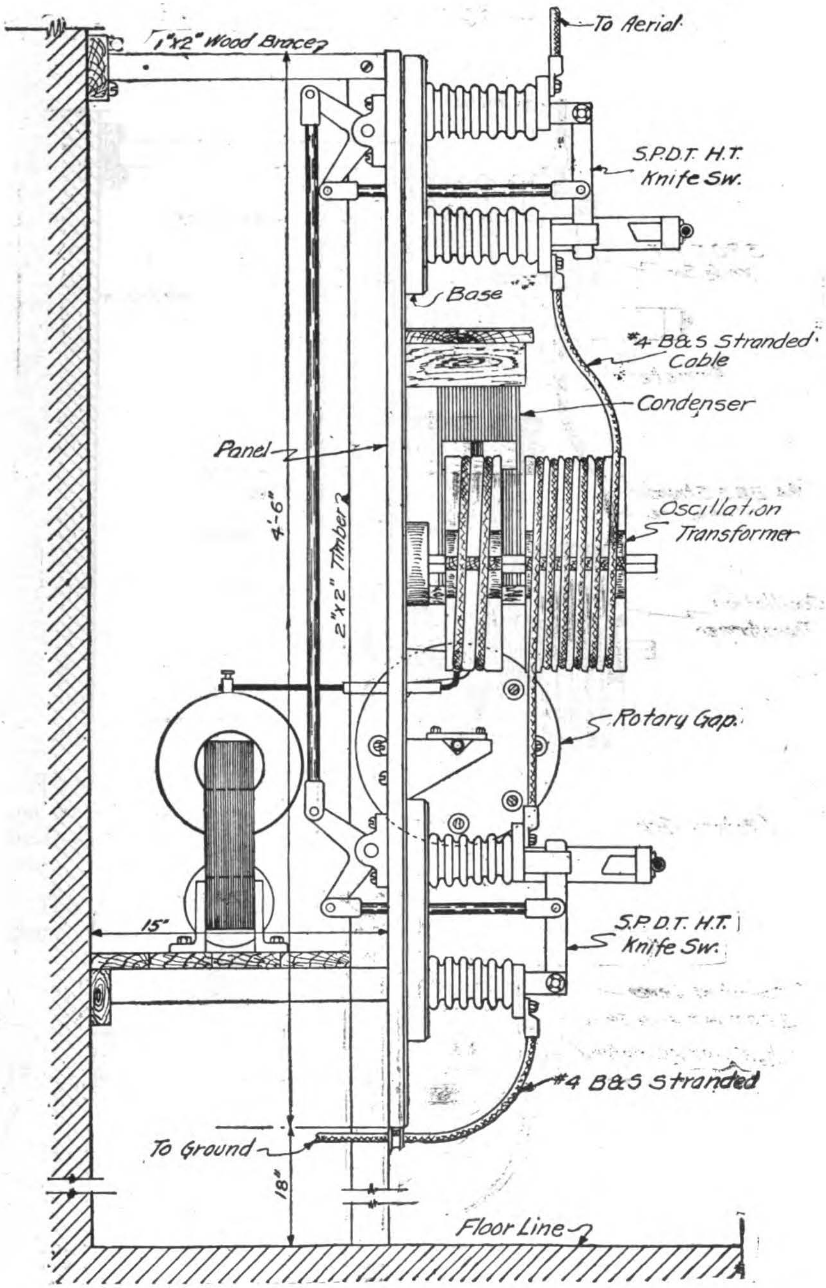



**Figure 2**—Left end view of transmitting panel showing single pole double throw high tension switches interlocked by means of bell-cranks and levers

For 2a/b=3.22, K=.412.
Substituting these values in the preceding formula we obtain,

$$L=8325 \text{ cms.}$$

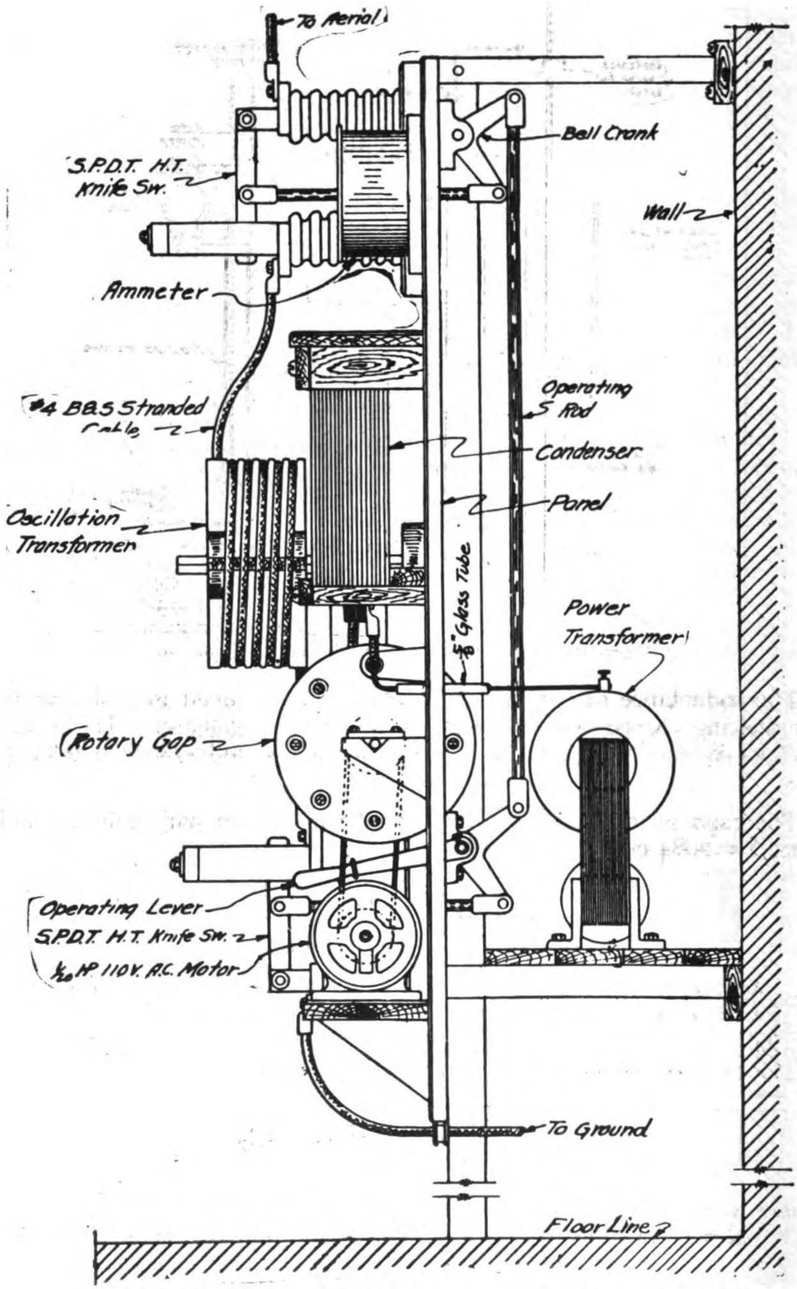



Figure 3—Right end view showing instruments and facilities for their operation

If we insert this inductance in a "T" aerial 120 feet long and 60 feet in height we obtain a wave length of $\lambda=203$ meters.

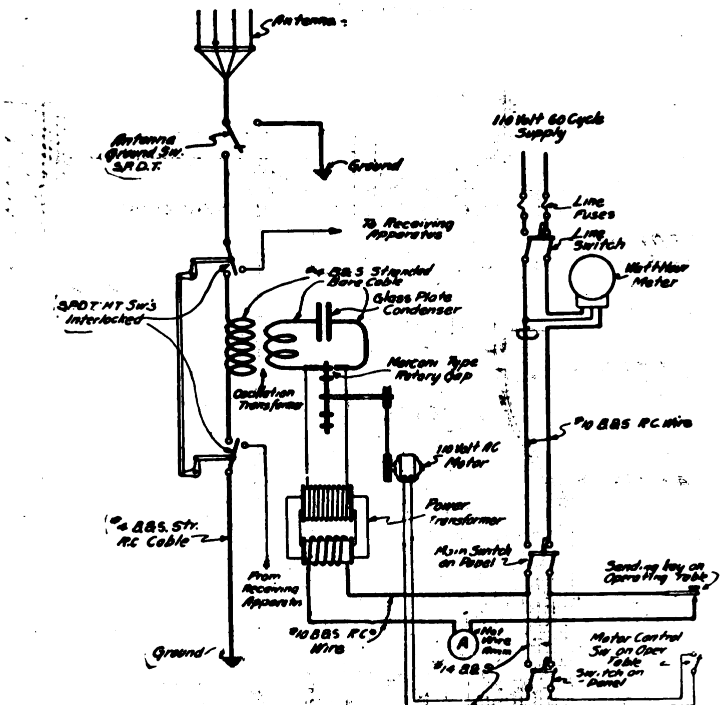



Figure 4—Diagram of connections for the panel set

The inductance of the primary coil may be obtained in a similar manner making corrections for the leads from the condenser. If the coil is built to dimensions given in the illustrations, its inductance will be 2084 cms.

The capacity of a condenser used in conjunction with primary inductance L=2084 cms. is given by

$$C(\text{mfd})=\frac{\lambda^2\ (\text{meters})}{3550\ L\ (\text{cm})}$$

If $\lambda=200$ meters
$C=.0054$ mfd.

The capacity of a glass plate condenser is given by,

$$C=\frac{n\ K\ A}{4\pi d}\times 1/9\times 10^{-5}\ \text{mfds}$$

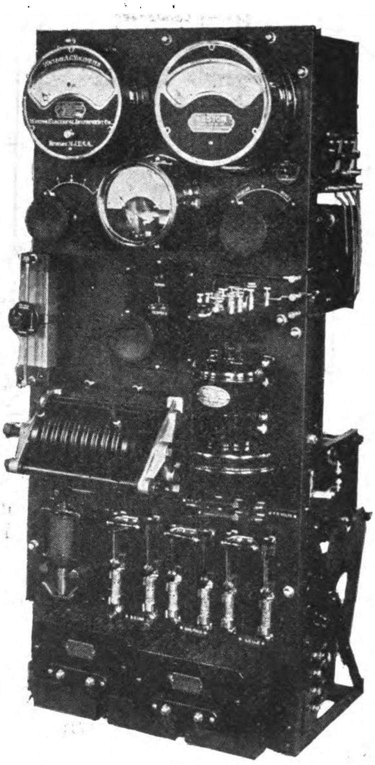
where n=number of plates required,
K=a constant which for plate glass may be taken as approximately 6.
A=area of the metal foil=81 sq. in.=253 sq. cm.
d=thickness of the glass=.25″=.635 cm.

The number of plates required then is,

$$n=\frac{4\pi\ d\ C}{K\ A}=12.35$$

We shall therefore use 13 plates and adjust the capacity by varying the distance between the plates. For the wave length of 250 meters, it will be necessary to use 20 plates.

The diagram, figure 4, does not show protective condensers. A protective unit consists of two 2 microfarad condensers connected in series. The central wire is connected to earth and the two outside wires across the power line close to the meter. A protective spark gap might also be connected across the secondary of the high voltage transformer.



**A commercial panel type transmitter, illustrating the ideal design for amateurs to imitate**

# CHAPTER XLIII

## How to Make a Simple Wireless Telephone Transmitter Using a Vacuum Tube

LOW-powered radio telephone transmitters soon will be the order of the day, but few amateurs know just exactly how to get started in this branch of radio. The books "Radio Telephony" by Goldsmith and "Vacuum Tubes in Wireless Communication" by Bucher, are excellent for obtaining an understanding of the operating characteristics of continuous wave generators for speech transmission. This chapter aims only to give constructional details.

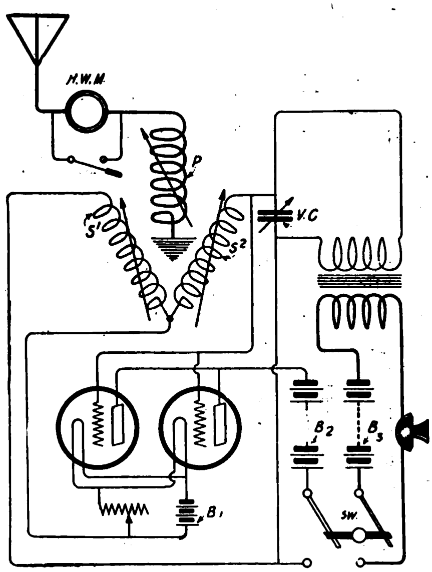



Figure 1—Hook-up of instruments for a small amateur radiophone transmitter

Directions for assembling a small radio telephone, which should have a transmitting range of at least six miles, follow. Prior to the war, a similar but cruder set was constructed, using but one ordinary vacuum tube with a speaking range of three miles.

In constructing a radio telephone, there are three primary obstacles which confront the experimenter. He must find:

(1) A very simple and easily understood hookup, containing inexpensive and easily procured instruments.

(2) A source of direct current of fairly high voltage.

(3) A continuous wave generator.

The three element vacuum tube will be the only type considered. Figure 1 gives a hookup which seems an adequate answer to problem (1).

If the amateur has access to a source of 110 volt AC and a sufficient amount of money to expend, he may either obtain a 500 volt DC motor generator or a kenotron rectifier, patterned after the Fleming valve. and obtainable from the General Electric Company. Either the DC generator or the kenotron with 500 volts AC, may be employed to supply the plate current. With such sources of current, quite a respectable transmitting range may be obtained. However, few amateurs will care to begin their radiophone experiments on such a large scale. The experimental set herein described uses from fifty to ninety volts of the large size tubular flashlight batteries or No. 6 dry cells. In wholesale lots the price is not as high as one might imagine from retail com-

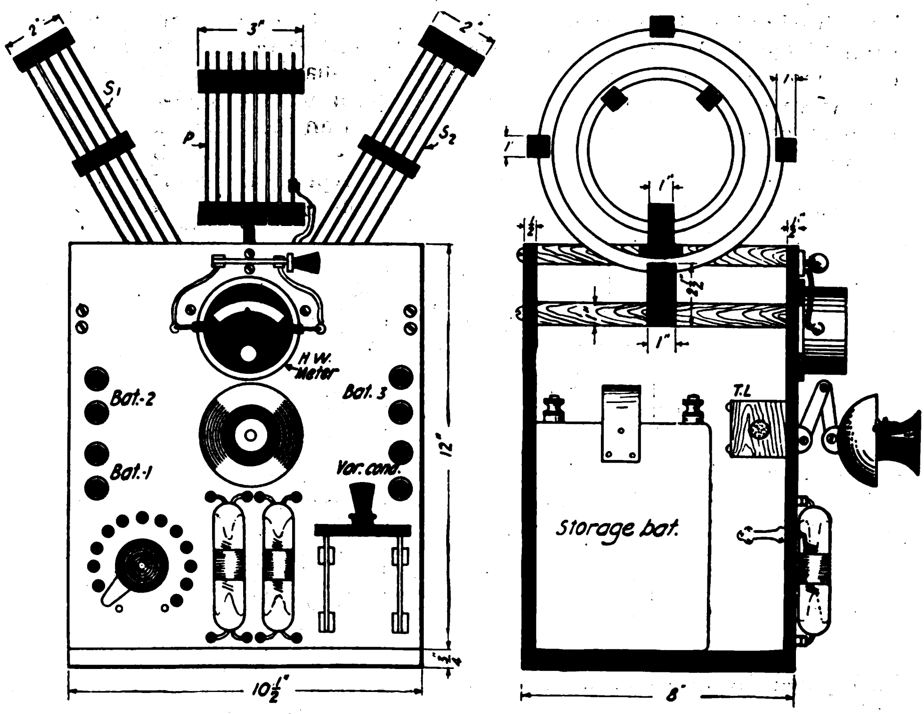



Figure 2—Front and side view of assembled radiophone transmitter

parison. Under favorable circumstances a discount as high as 50 per cent may be had on quantity lots.

Problem 3 as in problem 2 resolves itself into a question of financial resources. The continuous wave generator in the outfit described here consists of two small, three-element vacuum tubes such as tubular bulbs or electron relays with the members connected in parallel. Additional bulbs may be added to increase the range, which should be from two to six miles per bulb, depending on the tuning of the circuit and the efficiency of the antenna and ground.

After the experimenter has gained a working knowledge of radio telephony and has access to a source of high voltage, he should get possession of a "power bulb" such as the pliotron or one of the Marconi bulbs. Large bulbs of this type, fed by 500 volts DC often give a speaking range of a hundred miles or more.

Figure 2 gives the front and side view of the assembled outfit. The front panel should be made of some good insulating material such as bakelite. The base and back may be of hard wood treated with asphaltum varnish or a mixture of lamp-black and shellac as they are touched by no current carrying connections. On each side of the panel, about 9 inches up from base, two wooden strips 7 inches long should be placed between the back and front, to strengthen the construction. These are not shown in the side view as they would cover up the wooden, inch square strips which support the two secondaries. These hinge from the primary with these strips as axes.

Each of the two secondaries, *S*1 and *S*2, is composed of five turns of edgewise wound copper strip spiral 7½ inches in diameter, ½ inch wide and 1-16 of an inch thick. Each turn is held ⅜ inch apart from the adjoining turn by strips of bakelite, 1 inch square and 2 inches long, except at the bottom. The coil is fastened to the axis upon which the secondary pivots by a piece of bakelite shaped as in figure 3-A. The primary, *P*, is composed of copper, spiral wound edgewise as the secondaries and is 5 inches in diameter, 5-16 of an inch wide and 1-16 of an inch thick. Each adjoining turn is held ⅜ inch apart by bakelite strips, ¾ inch square and 5 inches long, except at the bottom, where the primary is supported by a piece of bakelite as in figure 3-B. This piece is to be fastened to a strip of wood, held between the front and

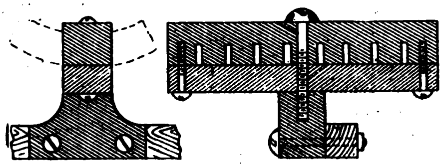


Figure 3A—Detail of fastening coils

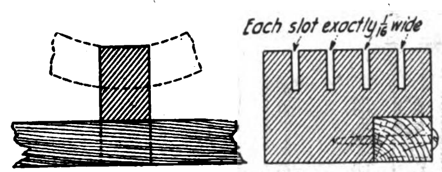



Figure 3B—Primary supported by a piece of Bakelite

back panels by wood-screws as in the side view of figure 2. The copper strip for the "oscillation transformer" may be purchased from wireless supply houses.

The transformer is designed considerably heavier than necessary for the current derived from the high voltage battery as suggested here, for the experimenter sooner or later may find himself in a position to use power bulbs and a commercial form of high voltage supply.

In most radiophone circuits a radiation indicator (such as a hot-wire ammeter) is essential, for successful operation depends mainly on careful tuning. The meter suggested is one of the small "junior" patterns. It should be short circuited by the switch at top of panel when not in use.

The battery *B*3 in the transmitter circuit may be from six to ten volts of storage or No. 6 dry cells. The transmitter is taken from one of the common long-distance telephones. If it happens that the carbon grains become fused, replace them with larger grains. The induction coil *I* is nothing more than the ordinary telephone transformer. A type that will operate from a ten-volt dry battery may be purchased from any electrical supply house. Both the high voltage battery $B2$ and battery $B3$ are cut into the circuit by the switch at the bottom of the panel. One rated at 30 amperes, 250 volts is about the right size to use.

Battery $B1$ is a six volt storage battery and is mounted behind the panel to prevent the outfit from overturning. There are sixteen points of variation of one-half ohm each. A good radius for the switch points is 1½ inches.

Better results will be obtained if the bulbs are purchased from reliable companies which standardizes its products, that is, all bulbs are supposed to be alike.

The variable condenser $VC$ is one of the 43 plate receiving type, filled with castor oil, or a good grade of motor oil to give a capacity of .005 mfd.

The design of the three coupling coils herein described permits a range of 180 to 350 meters with the average antenna. If permission can be obtained to use a longer wave length, either a loading coil or a longer aerial may be used, the latter is preferable.

The variation for the high voltage battery is obtained by a clip and flexible lead at the battery box as it would be impractical to take a large number of leads up to the panel from the batteries.

It is of even more importance in radio telephony than in wireless telegraphy that the various leads and connections should be of litzendraht or stranded wire, and well soldered. No. 12 rubber covered stranded wire, is a practical size for the outfit described.

An early type of experimental wireless telephone using a vacuum tube

# CHAPTER XLIV

## Arranging the Apparatus in an Ideal Wireless Station

SOME amateurs will undoubtedly state at length the technical requirements of the ideal amateur station, but in this chapter we discuss the matter from the view-point of accessibility of apparatus and ease of operation. Amateurs frequently are at a loss how to go about installing their apparatus in a manner that will fulfill these conditions, and while all of us have other ideas on this subject, years of experience in radio work leads the writer to believe that the accompanying drawing gives a plan of an amateur station of the detached instrument type that will work towards all-around efficiency and permit the greatest ease of manipulation.

The reader will note that on the top of the pigeon holes which is to retain the message blanks and other stationery, the author has mounted the principal elements of the transmitting set, the high voltage transformer, the spark gap and an inductively coupled high frequency oscillation transformer. Immediately to the left of the table is placed an inductively-coupled receiving tuner which in the up-to-date station will be fitted with a vacuum tube detector, and at the right the transmitting key in a place convenient to the operator. The switchboard to the extreme right of the table should contain the volt-meter and amme-

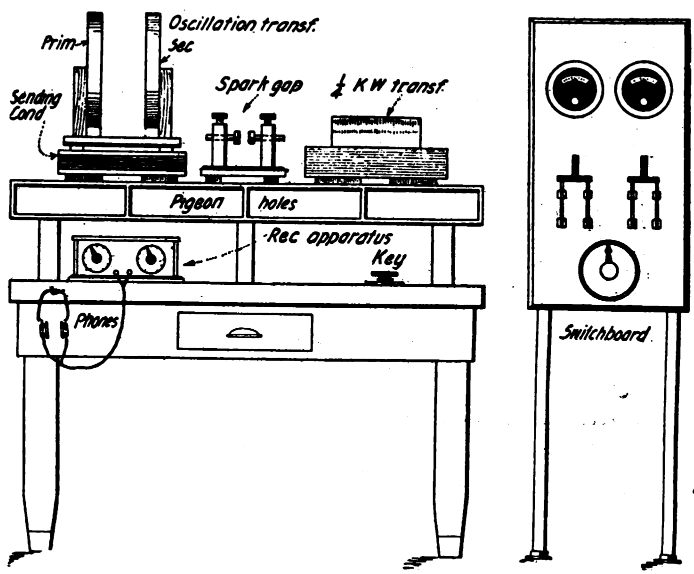



Figure 1—Plan of an amateur station of the detached instrument type

ter, a switch for turning off the power, and a reactance regulator for controlling the primary current.

This lay-out in addition to presenting a neat appearance permits the shortest possible connections between the elements of the closed oscillation circuit.

The general specifications of the spark transmitter are so well known to the amateur field that we need not enter into a discussion of the problems here. It is believed that if the plan presented is adopted by the rising experimenter, it will prove of great advantage to successful operation.


A jeweler's amateur outfit used for receiving the time signals sent out daily from the high power naval stations

# CHAPTER XLV

## Some Ideas for the Experimenter's Workshop

THE construction of a carbon amplifier for radio signals is as follows: Two magnets from a 1,000 ohm receiver are mounted as shown in figure 1 and suitable connections thereto are provided by the binding posts 3 and 4.

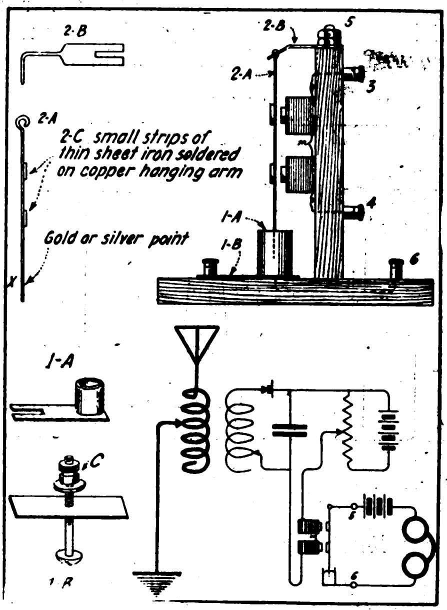



**Figure 1—Detailed plan of construction and circuit of the carbon amplifier**

On the base is mounted the cup which holds the carbon granules. It is made adjustable by providing a slotted strip of brass as shown at 1-*a* which slides over and makes contact with the brass strip 1-*b* and is held or clamped when the desired adjustment is obtained by the locknut *c*. The dipping arm 2-*a* is made of copper wire about No. 24 preferably gold pointed (at *x* the part which dips into the granules can be gold-plated or a small piece of gold wire soldered thereon). The top of this No. 24 wire is bent so as to form a circle and fits on the arm support 2-*b* which allows it to move freely. The end of this dipping arm is allowed to rest in the cup, 1-*a* of carbon granules. The arm support 2-*b* is fastened to the same support which holds the magnets, and a binding post is supplied to furnish a connection from the dipping arm through the cup. The detail 2-*c* is made of two strips of iron which act as armatures for the telephone magnets. They are soldered on the copper hanging arm which dips into the carbon granules.

This amplifier when properly constructed works exceedingly well, and owing to the fact that it is simple in construction there is no reason why pains should not be taken to make as good a job as is possible with the material at hand.

Under actual working conditions the amplifier functioned with a signal whose audibility was a little more than 100. The dipping needle if not provided with a silver or gold point will not work as well, and will have to be constantly cleaned. Better results were obtained by inserting another receiver of 1,000 ohms in series with the two mounted magnets making in all 2,000 ohms. The carbon granules should be of the finest grade and the inside of the cup or retainer should be kept clean. From time to time it is well to remove the granules and clean them. If it is possible to get several of these amplifiers to function efficiently, the cascade connection can be resorted to for further amplification. As an experimental instrument this is a good one but there is plenty of room for improvements in connection therewith.

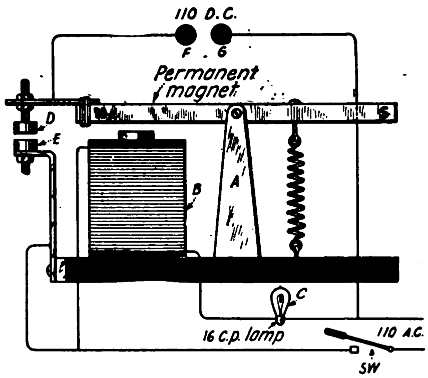



Figure 2—Construction of magnetic rectifier for alternating currents

## A Magnetic Rectifier for Alternating Currents

A magnetic apparatus for A.C. rectification is shown in figure 2. A permanent bar magnet (marked *N* and *S*) is pivoted at the center by drilling a hole through the bar and passing an 8-32 screw through same. Both ends rest in the holes made in support *A*. The magnet *B* is taken from any old sounder or constructed along that size throughout. This is in turn put in series with the 16 C. P. carbon lamp *C* so as to prevent the windings from burning out and at the same time perform its duty. Two contacts are furnished which are insulated from other parts of the mechanism *D* and *E*.

The apparatus works on the fundamental law of magnetism: LIKE POLES REPEL and UNLIKE POLES ATTRACT. The alternating current flowing through the magnet *B* changes the poles of its core according to the frequency of the current entering its windings, but at the same time the steel bar magnet retains its poles. The result is that when the current entering the magnet produces a north pole at the top end of the electro-magnet there is no attraction, since like poles repel, but on the other half of the cycle the poles of the electro-magnet are reversed and the top end is made a south pole. Then the law holds good that unlike poles attract thereby drawing the two contacts *D* and *E* together causing current to flow through the contacts *F* and *G* as direct current. This performance continues so long as the current is turned on.

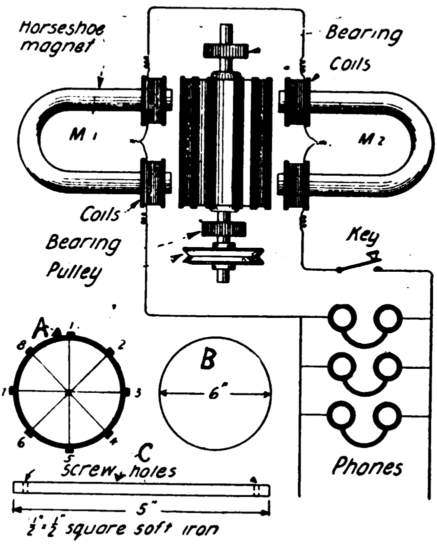



Figure 3—Diagram of construction and circuit of the high frequency generator

## An Economical and Efficient High Frequency Generator for Code Practice

Having had the pleasure all these years of experimenting with several types of buzzers the author has found that the contact points always burn out after considerable use, and numerous other troubles present themselves. A form of high frequency generator which gives a clear note of constant amplitude in the telephones and has many advantages which are only to be appreciated under operation is described below. Means should be provided to regulate the strength of signals in the head telephones according to the number of head sets on the line.

It is also possible to take off parallel wires and run them to the various tables in series with the ordinary telegraph key for each table.

The apparatus completed is shown in figure 3 where a drum as in detail *B* is constructed of two round ends of wood 6 inches in diameter and about 1 inch thick upon which are mounted bars of soft iron ½x½ inch in thickness and 5 inches long. A suitable shaft is run through the center and two bearing supports are provided together with means for oiling. As is seen in detail *A,* eight iron bars spaced evenly apart are screwed to the wood ends. This drum is rotated between the two horseshoe magnets *M*-1 and *M*-2 upon which have been wound coils consisting each of 200 turns of No. 28 D.C.C. wire. Magnet *M*-1 is adjusted to have its magnetic circuit completed by the movable iron bar just after magnet *M*-2 has had its magnetic circuit broken. This gives double the frequency to be obtained with one horseshoe magnet. A suitable pulley about two inches in diameter is mounted on the drum and a five inch pulley on the motor turning 1,500 R. P. M.

In practice considerable frictional losses were experienced owing to the fact that the writer did not have good bearings and means for oiling them continuously. Therefore, it is wise to benefit from his experience and secure good bearings and an adequate oiling system. As a whole the apparatus is very interesting under operation and provides a means for demonstrating the principles of alternating currents to students during lecture periods.

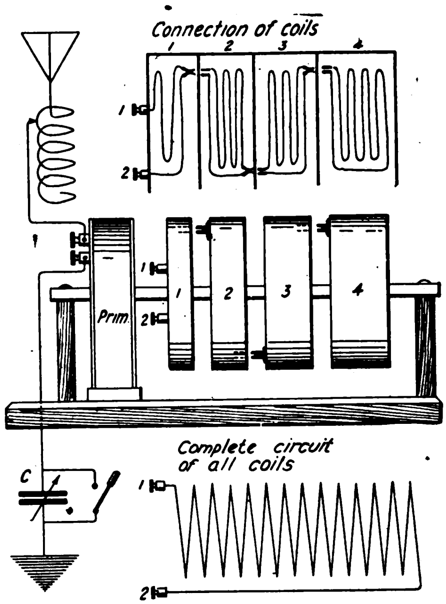



Figure 4—Design and connections of the complete receiving transformer

## An Up-to-Date Receiving Transformer

A receiving transformer of the design shown in figures 4, 5 and 6, 7 will be a valuable adjunct to any station. This tuner is fitted with a primary coil consisting of thirty turns of wire, this number being sufficient for general practice. Further variation of wave length in the antenna circuit is secured by the loading coil, external to the transformer. Response from short waves can be secured by means of the series variable condenser *C*.

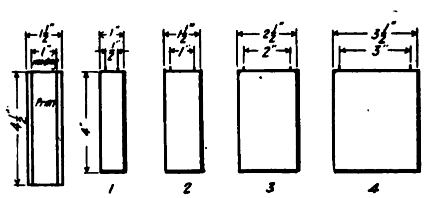
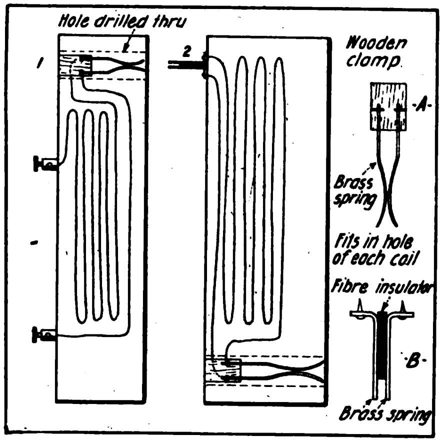



Figure 5—Showing dimensions of primary and secondary coils and their windings

It is to be especially observed that the secondary winding is broken into four units and means are provided whereby they can be connected together by means of a special plug. The primary winding is made on a form, 4½ inches in diameter, 1½ inches in length, wound for 1 inch with 30 turns of No. 22 DCC wire. Approximately 35 feet are required.

The first coil in the secondary is 4 inches in diameter and 1 inch in length, wound for ½ inch with 22 turns of No. 28 DCC wire. Twenty-four feet are required. Secondary unit No. 2 is 4 inches in diameter, 1½ inches in length, wound for 1 inch with 45 turns of No. 28 DCC wire.




Figures 6 and 7—Detailed construction of the plug switch

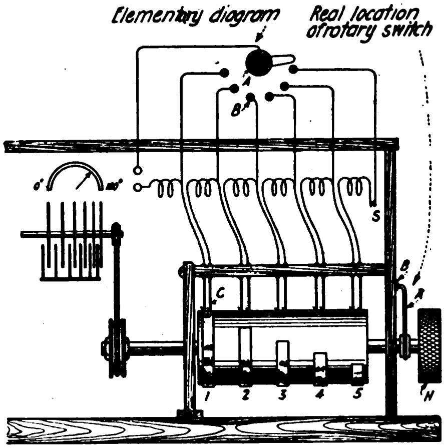
Forty-seven feet will be required. Secondary unit No. 3 is 4 inches in diameter, 2½ inches in length, wound for 2 inches with 90 turns of No. 28 DCC wire. Ninety-four feet are required. Secondary unit No. 4 is 4 inches in diameter, 3½ inches in length, wound for 3 inches with 135 turns of No. 28 DCC wire. One hundred forty-one feet will be required. The total secondary therefore will consist of 292 turns or 306 feet of No. 28 DCC wire. The measurement of all parts are shown fully in figure 5 and the details of the plug switch at *A* and *B* in figures 6.

If desired additional secondary units can be provided. Each successive coil should be larger than the preceding one, as in the design already shown.

A suitable shunt condenser must be connected across the secondary. In this way, a closeness of adjustment not possible with the secondary inductance alone, can be obtained. The principal advantage of this design is that the unused turns for a small range of wave lengths are disconnected from the used turns which, as is well known, increases the efficiency to a remarkable degree.

The sketch, figures 8 and 9, gives the details of a mechanism for changing the secondary inductance of a receiving tuner from one tap to the next, which at the same time causes the shunt secondary variable condenser to rotate throughout its range of capacities before another secondary coil is connected into the circuit. The whole adjustment is brought about by the rotation of a single control handle. This arrangement eliminates the necessity for using both hands in changing the inductance and capacity while tuning and leaves one hand free for writing down the message.

The objects of this design are brought about by arranging the strips of brass 1, 2, 3, 4 and 5 of the end-turn switch figure 2, so that when coil No. 2 is cut in, the condenser has revolved from zero to maximum capacity, and so on throughout the series of taps. The condenser is rotated by attaching a pulley to the shaft of the end-turn switch and a smaller pulley on the shaft of the condenser. By a partial turn of the control handle the secondary variable condenser is shifted through its entire scale. It is clear to the reader that a certain relation must exist




Figures 8 and 9—Detailed sketch of mechanism for changing the secondary inductance of a receiving tuner

between the diameter of the pulley on the condenser and that on the main shaft; also the taps on the secondary inductance must be of sufficient width to permit the variable condenser to rotate over its scale before the switch reaches the next contact point.

The switch *A, B,* is of the rotary type and connects each coil in the circuit only when the last end is brought into the circuit by the end-turn switch. The rotary type of switch is necessary because the contact must be maintained while the switch is rotating and it should only make connection with the next strip in the circle when additional inductance is desired.

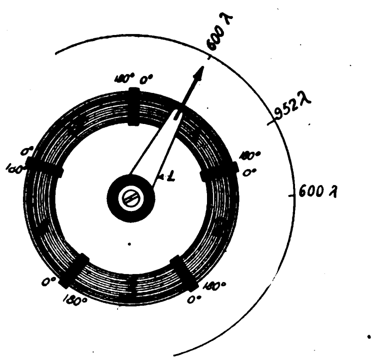



Figure 10—Rotary switch used to connect the coils

In figures 8 and 9, the location of the switch is indicated at the lower right hand part of the drawing and an elementary diagram of connections at the upper part showing how the coils are connected in circuit.

The rotary switch to be used in conjunction with this apparatus is shown in figure 10 where a contact lever coil makes connection with copper segments 1, 2, 3, 4 and 5. These may be made of brass if desired.

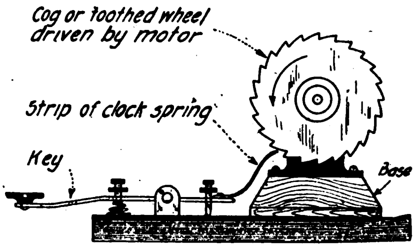



Figure 11—Mechanical code practice device

The diameter of the switch must be chosen so that an individual segment will be long enough to permit the variable condenser to be rotated over its scale while the blade is on one tap.

The experimenter will observe that as the inductance switch leaves one tap and makes connection with the second tap, the wave length at the

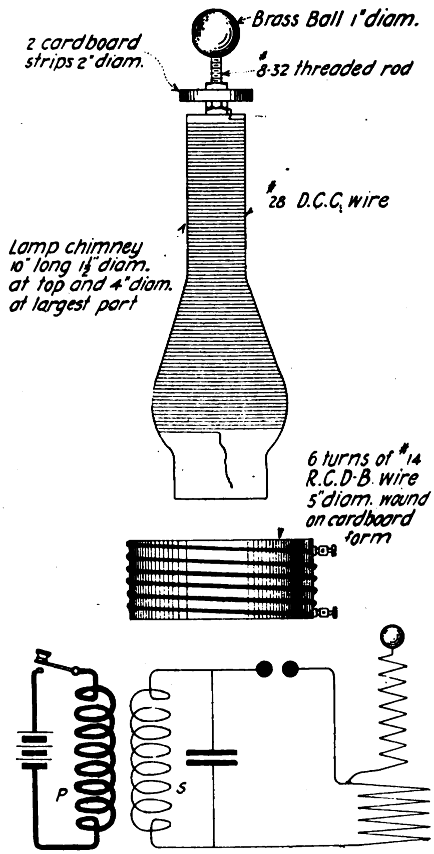



Figure 12—Diagram of detailed construction of the Oudin resonator

first part of the scale of the second tap will be shorter than the maximum wave length of the preceding tap. But as the switch is moved on and the variable condenser is rotated over the scale, the longest wave will be considerably in excess of the wave obtained from the preceding coil.

As indicated in the drawing a wave length scale may be attached to the inductance switch, to indicate the wave length of the secondary circuit for various positions of the shunt variable condenser.

## Code Practice Device

A very serviceable set for use in code practice is shown in figure 11. The object of it is to generate a buzzing signal without the use of a buzzer. The telephone current is interrupted by a cog wheel which may be taken from an old clock.

No current is utilized other than that which turns the motor to which is attached a toothed or cogged wheel. The key is situated so that upon pressing same it raises a strip of clock spring which barely touches the revolving cog wheel. This produces a very clear note when adjusted correctly. The motor should rotate away from the operator to protect his eyes from the flying filings which are liable to be thrown from the steel spring or the brass or iron cog wheel.

A very precise adjustment can be arrived at by making tight all screws on the key after adjustment, the spring being arranged to barely touch the wheel in order to preserve its life. This, as a whole makes a very cheap practice set giving loud signals. A small Ajax motor and a cog wheel 4 inches in diameter by 1/8 inch thick, connected in series with four good dry cells, gives good results.

A pulsating note of a frequency depending upon the number of teeth on the wheel and the speed at which it rotates is obtained.

## A Small Oudin Resonator

The Oudin resonator in figure 12 will give a good three-inch spark with a 1/2 to 3/4 inch spark coil.

The secondary circuit is wound on a lamp chimney, making an excellent insulator. To place the wire, start from the end with the smallest diameter and wind upwards. It is impossible to wind from the other end owing to the slope of the chimney, but it is an easy matter to wind the opposite way. A globe ten inches long is covered with No. 28 D.C.C. wire closely wound (not spaced) 1/2 inch from the top and 2 1/2 inches from the bottom as shown. The primary is composed of 6 turns of No. 14 R.C.D.B. copper wire spaced about 1/2 inch apart, wound on a cardboard form 5 inches in diameter. The connections are shown just below the constructional drawing. This type of resonator will be found to be of exceptional interest and can be constructed at a small initial expense.

All kinds of high frequency phenomena can be demonstrated such as drawing sparks to your hand or to an iron instrument in your hand. Standing on an insulated form, matches can be lit from any part of your body by some one standing on the ground. Drop a piece of tinfoil inside the globe and a great quantity of ozone, a great germ killer and sure cure for colds, etc., will be generated and can be inhaled from the top of the globe.

Stand another small coil such as the primary or secondary of a "loose coupler" about 6 inches away from the resonator when in operation and without any connection whatsoever, a spark will appear at both ends of the winding, the forerunner of the wireless transmission of power.

Hang a small light or lamp into the globe and a beautiful blue light will fill the globe. By bringing a piece of glass 1/8 inch thick close to

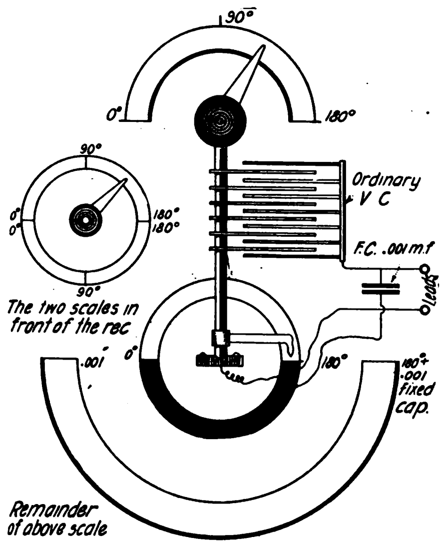



Figure 13—Sketch of a fixed condenser and variable condenser combined by means of a special switch to double the capacity

the ball and a piece of wire held in the hand close to the other side, the current will jump from the ball to the wire as if the glass were not there. The field for experimenting is great, and it is my personal opinion that if it ever becomes possible to intercept such waves that the whole world could be communicated with by the use of a small Oudin coil. The frequency of the currents being generated are so great that they are ab-

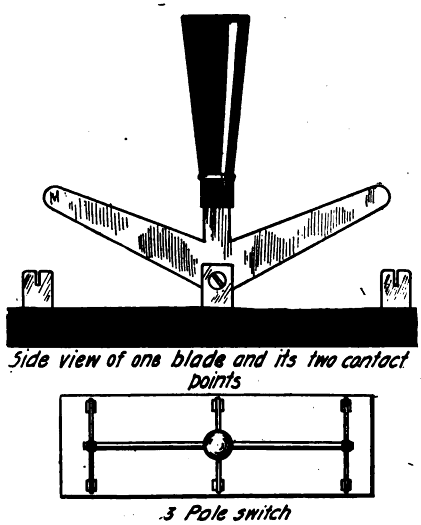



Figure 14—Sketch of switch used for starting small A. C. motors

solutely inaudible—but who can tell what will take place in this wonderful new field in a space of ten years.

### Means for Doubling the Capacity of a Variable Condenser

The combination of a fixed condenser, a variable condenser and special switch, as in figure 13 will double its range of capacity.

It is clear from the diagram that when the ordinary condenser is at 180 degrees the maximum amount of capacity is in use, but if the condenser is brought back to zero and rotated toward the left instead of toward the right, a fixed condenser having the same amount of capacity as the variable condenser at maximum is connected in parallel. Therefore by rotating the condenser in the opposite direction, we can progressively double its capacity in the same manner as it is built up to its maximum capacity in the ordinary way. The scale on the outside of the condenser will be a complete circle instead of the usual half circle, or 180 degrees. An insulated circle is provided and half of it is made conductive by means of a strip of brass which cuts in the other fixed condenser. A switch arm protrudes from the shaft of the condenser and makes contact with the switch (brass semi-circle) cutting in the extra capacity.

This is a very convenient arrangement and is easily added to the ordinary receiver.

### Special Switch for Starting Small A. C. Motors

Ordinary types of switches furnished for this purpose are of the three-pole double-throw type, reactance coils being thrown in on one side in the motor line circuit and the other side cutting in the full line voltage. This is an awkward arrangement owing to the fact that one is liable to throw his arm across the line when pulling the switch from one position to the other in a hurry. For that reason, the writer has constructed the switch shown in figure 14. It works on the rocking principle, passing through an arc of about 25 degrees, thereby making it much easier to shift the connections.

# CHAPTER XLVI

## The Vacuum-Tube Generator for the Radio Laboratory

A VACUUM tube connected up as a high frequency generator and mounted with auxiliary instruments will be found a very useful piece of apparatus around an experimental radio laboratory. It may be employed in several ways such as calibrating wave meters, inductances, condensers, measuring the decrement of decremeters and high frequency resistance; also as a source of radio frequency oscillations for beat reception, and in many other ways.

The amount of energy obtained from such a device will, of course, depend upon the size of the tube, its operating characteristics, and upon the E. M. F. of the plate battery. One hundred and ten to 250 volts D.C. can be safely applied to most bulbs, and in some cases more, without undue heating of the grid and plate, but it is best to consult the manufacturer of the tube for potentials above 250 volts.

Several circuits may be employed. That shown in figure 1 is very simple and will do the work of more complicated connections.

The size of the coil $L_1$ and condenser $C_1$ will depend upon the range of frequencies desired. It will be found that if a variable condenser $C_1$ having a maximum capacity of .0005 mfd. is used, the coil described below will be correct for a frequency of 120,000 cycles or above, which corresponds to the wave length of 2,500 meters at the maximum value. The coil should consist of a single layer of No. 26 S. C. C. wire wound on a tube 4 inches in diameter and 4 inches long. One hundred and seventy-five turns will be necessary, which will occupy a winding length of 3.5 inches. With a condenser $C$, having a capacity of .005 mfd., 50 turns of the same wire, on the same size cylinder with a winding length one inch long are needed. Three taps should be brought out from the coil, one at each end and one in the center.

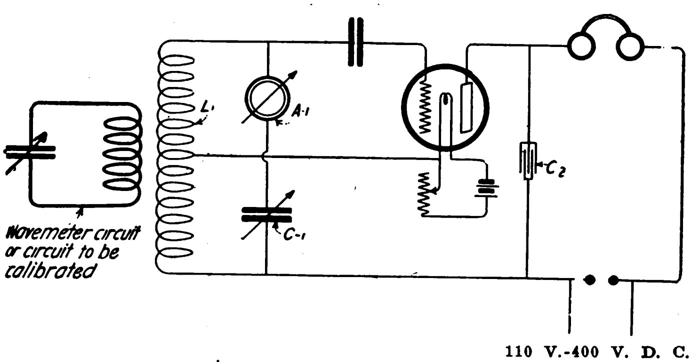



Figure 1—A simple circuit having a vacuum tube connected up as a high frequency generator

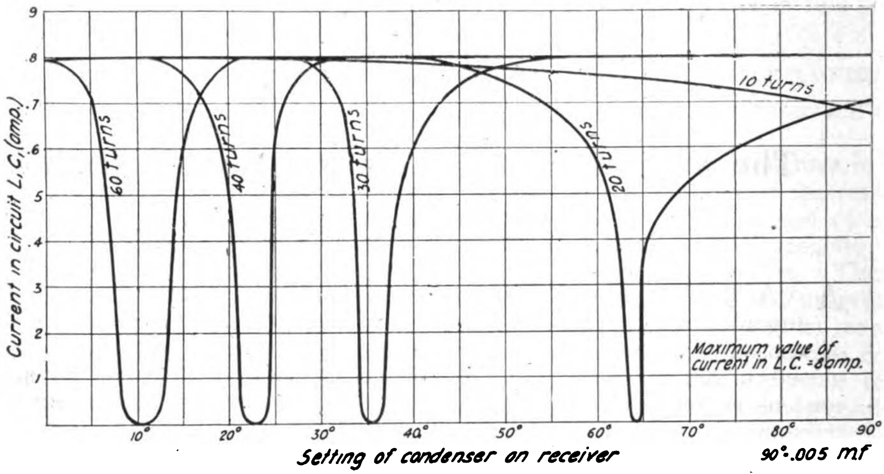



Figure 2—Graphic curves taken while calibrating a receiving set

The circuit should be calibrated against a standard wave meter. The distributed capacity of the coil, the effect of the leads and of the internal capacity of the bulb itself will change any theoretical determinations of the oscillation constant. A hot-wire ammeter $A1$ will indicate when the tube is oscillating properly. It should have a range of not over .5 amperes maximum except when large bulbs and high voltages are used. The condenser $C2$ should have a capacity of 2 mfd. The telephone receivers and the grid condenser should both have a short circuiting switch plug to cut them out of the circuit when they are not in use.

The whole apparatus should be mounted on one base or in a case with the inductance $L1$ in such a position that it may be readily placed near another circuit.

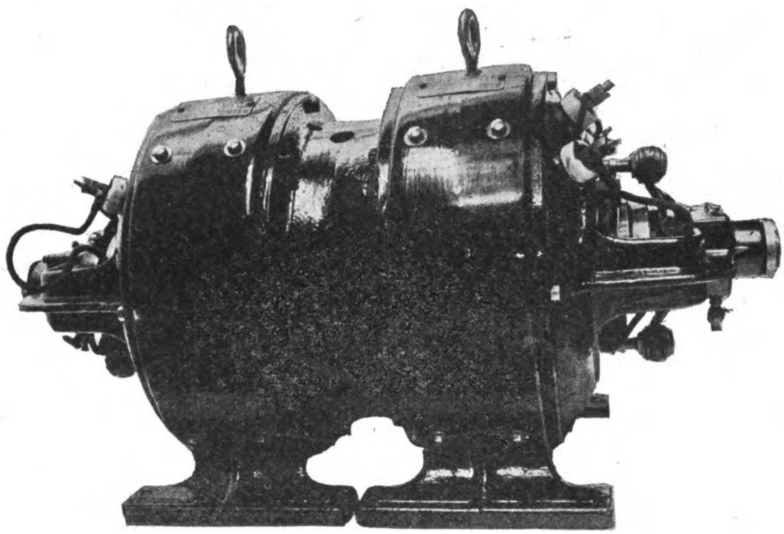
To calibrate a wave meter with this apparatus place the inductance coil of the wave meter to be tested near the coil $L1$ as indicated in the diagram, and set the condenser of this wave meter at some desired point. Note the reading of the ammeter $A1$ in the oscillating circuit. By varying the condenser $C1$ it will be found that as the condition of resonance between the two circuits is reached the current indicated by $A1$ will fall off, often dropping to zero if the coupling between the two circuits is close. When the resonance point is passed the ammeter will again read the normal value. It is necessary to note the point on the condenser $C1$ when the current in $A1$ is at a minimum, and refer to the calibration curve for the circuit $L1$, $C1$ to find the wave length at this point. It is not necessary to have the two circuits coupled so tightly that the current in $A1$, drops to zero, as a slight decrease is all that is necessary. Otherwise two waves will be in evidence if the coupling is too tight.

The advantage of this method is that no connections need be made to the wave meter under test. It is a very rapid method of making a calibration. It is understood that with the standard condensers and inductances on hand the calibration of coils and condensers may be done in the same manner.

Curves taken while calibrating a receiving set are shown in figure 2. These show distinctly how the energy is "drained" from the valve circuit when resonance between the two circuits is reached. In these determinations the frequency of $L1$ $C1$ was left constant and the condenser of the receiving set was varied, its values forming the abscissa on the curve sheet. Each curve represents one value of inductance on the receiving transformer.

There is another method in which a very interesting phenomena is made use of. It will be found that under certain conditions that a beat note will be heard in the telephones when the circuit $L1$ $C1$ is nearly in resonance with the wave meter circuit. A shrill note is first heard as $C1$ is rotated which drops to a low tone and then rises to inaudibility as the resonance point is passed. Anyone who is acquainted with beats will easily recognize the point when resonance occurs. It is necessary to have a correct value of the grid condenser, and sometimes a grid leak in order to have this action occur.

The telephone receivers and the grid condenser are not needed for other tests and may be omitted, if desired.



A Commercial 1 k.w., 60 Cycle Motor-Generator

# CHAPTER XLVII

## Finding the Distance Between Wireless Stations

THERE is only one practical method of accurately finding the distance between any two points on the earth's surface, such as two wireless stations, and that is by means of spherical trigonometry. Recourse is had to this method in navigation, astronomy, and other scientific pursuits; also, maps are plotted from certain calculations obtained in this way. All maps based on Mercator's projection become increasingly inaccurate as the poles are approached, and hence are of no value in finding distances near the poles, or those which span any great part of the earth's circumference.

The actual details connected with the method herein described are usually taught in advanced trigonometry classes in colleges, but since

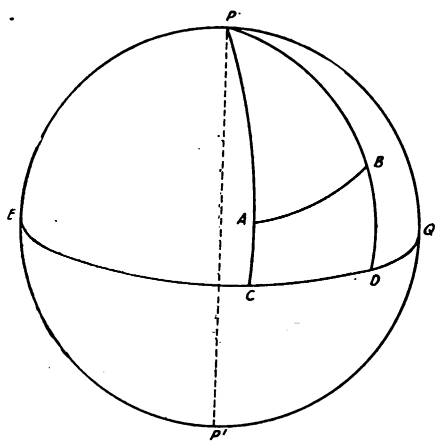



Figure 1—Diagram showing method of determining the distance between two wireless stations

only a few formulas are needed, along with a table of the various trigonometric functions, it is presented in the hope that those who have not had the advantage of such training, or else have forgotten the work, may avail themselves of the method. The use of the tables does not necessarily require a knowledge of trigonometry, but a working knowledge of common logarithms will greatly simplify the labor incident to these calculations.

The tables should give the values of the sine, cosine, tangent, and cotangent to within 12 feet. Greater accuracy is not required, as it is usually impossible to obtain the latitude and longitude with much more exactitude than this, and since 1 foot is only equal to 1.1516 miles, the error is inappreciable.

To apply this method, it is only necessary to know the latitude and longitude of each of the two places concerned, which can be found on any map, and by use of the formulas which will follow, the distance between them can readily be found. A brief discussion, however, will be of value to anyone making use of these formulas. In figure 1 is depicted the earth's globe, *P* and *P'* representing the poles, *EQ* the equator, and *A* and *B* any two points on the earth's surface whose separation it is desired to find. It is evident that *AC* is the latitude of *A, BD* the latitude of *B*. By subtracting each of these values from 90 degrees we will obtain *AP* and *BP* respectively, the two known sides of the spherical triangle *ABP*. It is to be noted that these values are in degrees and minutes, as in the case of spherical triangles the sides are given as parts of an arc or a circumference.

Also, *A* has a given longitude, and *B* has a given longitude, and the difference between these two values will be the separation of *A* and *B* in degrees of longitude along the equator, or the value of the angle *APB*. In case either *A* or *B* are on opposite sides of the prime meridian, or of the 180th meridian, a different procedure must be followed, as is explained later.

We have now determined the two sides *AP* and *BP*, and the included angle *APB*, of the spherical triangle *ABP*. For the sake of convenience, we shall refer to the angles shown by the capital letters which designate those extremities, as angles *A, B* and *P*. The sides of the triangle shall be referred to as *AP, BP*, and *AB*, the latter being the unknown side whose length we are to find.

The following formulas are then applicable, the first two being Napier's Analogies:

$$\text{Tangent } \tfrac{1}{2}\ (A+B) = \frac{\cos \tfrac{1}{2}\ (BP-AP)}{\cos \tfrac{1}{2}\ (BP+AP)} \cot \tfrac{1}{2} P$$

$$\text{Tangent } \tfrac{1}{2}\ (A-B) = \frac{\sin \tfrac{1}{2}\ (BP-AP)}{\sin \tfrac{1}{2}\ (BP+AP)} \cot \tfrac{1}{2} P$$

Also, tan ½ (A+B)+tan ½ (A—B)=greater unknown angle, and tan ½ (A+B)—tan ½ (A—B)=smaller unknown angle. Which angle is *A* and which is *B* can be found by applying the rule from geometry, that the greater angle is opposite the greater side, and vice versa.

Having found the unknown angles *A* and *B* of our triangle, we now apply the law of sines in spherical triangles, namely:

$$\sin AB = \frac{\sin P}{\sin B} \sin AP$$

Looking up the value for the anti-sine of *AB*, gives the distance between these two points in degrees and minutes. This value (in degrees and decimals of a degree) is then multiplied by 69.117 to obtain the distance in statute miles.

Let us now examine the results of an actual calculation to fully fix in our mind the use of these formulas. Supposing it is desired to find the distance from Arlington, Va., to Kahuku, Hawaii. The latitude and longitude of the former are 38 degrees 50 minutes N., 77 degrees W., respectively; of the latter, 21 degrees 40 minutes N., 158 degrees W. Subtracting the two latitudes from 90 degrees, we have 51 degrees 10 minutes and 68 degrees 20 minutes for the sides *BP* and *AP* of the triangle, respectively. Also, the angle *P*, being equal to the difference in longitude of the two places, is 158 degrees—77 degrees=81 degrees. Applying the formulas:

$$\tan \tfrac{1}{2}\ (A+B) = \frac{\cos \tfrac{1}{2}\ \ 17 \text{ degrees } 10 \text{ min.}}{\cos \tfrac{1}{2}\ 119 \text{ degrees } 30 \text{ min.}}$$

cot ½ 81 degrees=2.298

$$\tan \tfrac{1}{2}\ (A-B) = \frac{\sin \tfrac{1}{2}\ \ 17 \text{ degrees } 10 \text{ min.}}{\sin \tfrac{1}{2}\ 119 \text{ degrees } 30 \text{ min.}}$$

cot ½ 81 degrees=0.2023

Looking up these values, we have, tan ½ (A+B)=tan 66 degrees 30 minutes, and tan ½ (A—B)=tan 11 degrees 26 minutes. Therefore, applying our rule for finding the unknown angles, and noting that the angle at Arlington is the larger of the two, we have:

Angle *A*=66 degrees 30 min—11 degrees 26 min=55 degrees 4 min.
and
angle *B*=66 degrees 30 min.+11 degrees 26 min.=77 degrees 56 min.

Also, we have

$$\sin AB = \frac{\sin 81 \text{ degrees}}{\sin 77 \text{ degrees } 56 \text{ min.}}$$

sin 68 degrees 20 min.=0.9386

From which *AB*=69 degrees 50 min., or 69.8 degrees. This is then multiplied by 69.117, giving the value 4825 statute miles as the distance between Arlington and Kahuku.

It has been stated that in case the stations are located on opposite sides of the prime meridian, or of the 180th meridian, a different procedure is necessary for finding the angle *P*. In the first case just mentioned, the longitudes are added instead of subtracted, in the second case both values are subtracted from 180 degrees and the results added together. A little consideration will show the necessity of such methods.

In case the two points are almost of the same latitude, a simpler method will give the same results. It consists in finding the difference in longitude of the two places, and multiplying this by the value of a degree of longitude in miles, at the mean latitude. For example, Funabashi, Japan, is at latitude 35 degrees 40 minutes N. and Los Angeles, California, is at latitude 34 degrees N. The mean latitude is 34 degrees 50 minutes, and at this latitude a degree is equal to 56.95 miles. Hence the distance is equal to 101.67 degrees (the difference in longitude) times 56.95= 5790 miles. Tables of this sort are called spheroidal tables, giving the length of a degree longitude at various values of latitude, in nautical and statute miles. The student is referred to the Year Book of Wireless Telegraphy for the complete values.

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