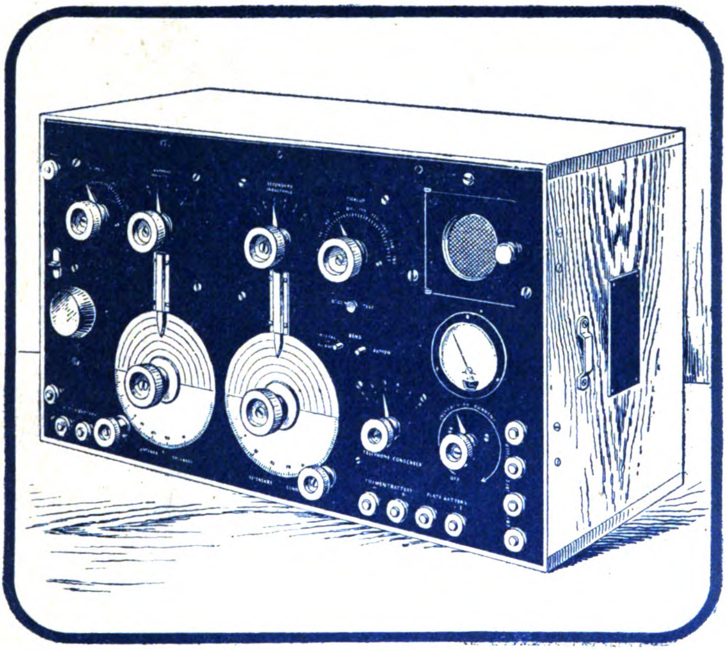
HOW TO MAKE COMMERCIAL TYPE RADIO APPARATUS



By M. B. SLEEPER

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THE NORMAN W. HENLEY PUBLISHING CO.
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HOW TO MAKE COMMERCIAL TYPE RADIO APPARATUS

A GUIDE BOOK FOR THOSE WHO DESIRE TO MAKE THEIR EQUIPMENT THE EQUAL, IN APPEARANCE AS WELL AS PERFORMANCE, OF THE COMMERCIAL APPARATUS

THIS BOOK GIVES IN COMPACT FORM A WORLD OF DATA ON HOW TO MAKE YOUR STATION THE EQUIVALENT OF GOVERNMENT AND COMMERCIAL STATIONS. THE LARGE NUMBER OF ILLUSTRATIONS SHOW, MUCH BETTER THAN DESCRIPTIONS, MANY OF THE NICETIES OF DESIGN DEVELOPED THROUGH YEARS OF EXPERIENCE BY THE COMMERCIAL COMPANIES

BY

M. B. SLEEPER

Former Radio Editor of *Everyday Engineering Magazine*
Author of *Design Data, Radio Hook-Ups*

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PREFACE

After many sets in experimental form, with the maze of necessary wiring, the experimenter will desire finished equipment of permanent form for his station.

Commercial companies, through years of experience in both electrical and mechanical design, have learned just how to build transmitting and receiving equipment, which will be efficient, rugged and neat in appearance.

This book is written and illustrated with the idea that the experimenter will benefit and get many ideas, which will help him in the perfecting of his own equipment.

M. B. SLEEPER.

April, 1922.

INTERNATIONAL MORSE CODE AND CONVENTIONAL SIGNALS

TO BE USED FOR ALL GENERAL PUBLIC SERVICE RADIO COMMUNICATION

1. A dash is equal to three dots.
2. The space between parts of the same letter is equal to one dot.
3. The space between two letters is equal to three dots.
4. The space between two words is equal to five dots.

A	• —
B	— • • •
C	— • — •
D	— • •
E	•
F	• • — •
G	— — •
H	• • • •
I	• •
J	• — — —
K	— • —
L	• — • •
M	— —
N	— •
O	— — —
P	• — — •
Q	— — • —
R	• — •
S	• • •
T	—
U	• • —
V	• • • —
W	• — —
X	— • • —
Y	— • — —
Z	— — • •
Ä (German)	• — • —
Á or Å (Spanish-Scandinavian)	• — — • —
CH (German-Spanish)	— — — —
É (French)	• • — • •
Ñ (Spanish)	— — • — —
Ö (German)	— — — •
Ü (German)	• • — —
1	• — — — —
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8	— — — • •
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0	— — — — —

Period	• • • • • •
Semicolon	— • — • — •
Comma	• — • — • —
Colon	— — — • • •
Interrogation	• • — — • •
Exclamation point	— — • • — —
Apostrophe	• — — — — •
Hyphen	— • • • • —
Bar indicating fraction	— • • — •
Parenthesis	— • — — • —
Inverted commas	• — • • — •
Underline	• • — — • —
Double dash	— • • • —
Distress Call	• • • — — — • • •
Attention call to precede every transmission	— • — • —
General inquiry call	— • — • — — • —
From (de)	— • • •
Invitation to transmit (go ahead)	— • —
Warning—high power	— — • • — —
Question (please repeat after ......)—interrupting long messages	• • — — • •
Wait	• — • • •
Break (Bk.) (double dash)	— • • • —
Understand	• • • — •
Error	• • • • • • • •
Received (O. K.)	• — •
Position report (to precede all position messages)	— • — •
End of each message (cross)	• — • — •
Transmission finished (end of work) (conclusion of correspondence)	• • • — • —

INTERNATIONAL RADIOTELEGRAPHIC CONVENTION

LIST OF ABBREVIATIONS TO BE USED IN RADIO COMMUNICATION

ABBREVIATION.	QUESTION.	ANSWER OR NOTICE.
PRB	Do you wish to communicate by means of the International Signal Code?	I wish to communicate by means of the International Signal Code.
QRA	What ship or coast station is that?..........	This is......
QRB	What is your distance?....................	My distance is ......
QRC	What is your true bearing?................	My true bearing is........degrees.
QRD	Where are you bound for?..................	I am bound for ......
QRF	Where are you bound from?.................	I am bound from.......
QRG	What line do you belong to?...............	I belong to the.......Line.
QRH	What is your wave length in meters?........	My wave length is.......meters.
QRJ	How many words have you to send?...........	I have...... words to send.
QRK	How do you receive me?....................	I am receiving well.
QRL	Are you receiving badly? Shall I send 20? ..... • • • ▬ • for adjustment?............	I am receiving badly. Please send 20. • • • ▬ • for adjustment.
QRM	Are you being interfered with?.............	I am being interfered with.
QRN	Are the atmospherics strong?................	Atmospherics are very strong.
QRO	Shall I increase power?....................	Increase power.
QRP	Shall I decrease power?....................	Decrease power.
QRQ	Shall I send faster?.......................	Send faster.
QRS	Shall I send slower?.......................	Send slower.
QRT	Shall I stop sending?......................	Stop sending.
QRU	Have you anything for me?..................	I have nothing for you.
QRV	Are you ready?.............................	I am ready. All right now.
QRW	Are you busy?..............................	I am busy (or: I am busy with......). Please do not interfere.
QRX	Shall I stand by?..........................	Stand by. I will call you when required.
QRY	When will be my turn?......................	Your turn will be No. ....
QRZ	Are my signals weak?.......................	Your signals are weak.
QSA	Are my signals strong?.....................	Your signals are strong
QSB	Is my tone bad?............................. Is my spark bad?............................	The tone is bad. The spark is bad.
QSC	Is my spacing bad?.........................	Your spacing is bad.
QSD	What is your time?.........................	My time is......
QSF	Is transmission to be in alternate order or in series?	Transmission will be in alternate order.
QSG	....	Transmission will be in series of 5 messages.
QSH	....	Transmission will be in series of 10 messages.
QSJ	What rate shall I collect for..............	Collect... ....
QSK	Is the last radiogram canceled?............	The last radiogram is canceled.
QSL	Did you get my receipt?....................	Please acknowledge.
QSM	What is your true course?..................	My true course is... ... degrees.
QSN	Are you in communication with land?........	I am not in communication with land.
QSO	Are you in communication with any ship or station (or: with........)?	I am in communication with.......(through.........).
QSP	Shall I inform........that you are calling him?	Inform.......that I am calling him.
QSQ	Is........calling me?......................	You are being called by ....
QSR	Will you forward the radiogram?............	I will forward the radiogram.
QST	Have you received the general call?........	General call to all stations.
QSU	Please call me when you have finished (or: at ....o'clock)?	Will call when I have finished.
*QSV	Is public correspondence being handled?.......	Public correspondence is being handled. Please do not interfere.
QSW	Shall I increase my spark frequency?..........	Increase your spark frequency.
QSX	Shall I decrease my spark frequency?..........	Decrease your spark frequency.
QSY	Shall I send on a wave length of......meters?	Let us change to the wave length of.. ...... meters.
QSZ	....	Send each word twice. I have difficulty in receiving you.
QTA	....	Repeat the last radiogram.

*Public correspondence is any radio work, official or private, handled on commercial wave lengths.

When an abbreviation is followed by a mark of interrogation, it refers to the question indicated for that abbreviation.

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HOW TO MAKE COMMERCIAL TYPE RADIO APPARATUS

PART I

RECEIVING EQUIPMENT

CHAPTER I

AUDION-CRYSTAL RECEIVER

The radio equipment designed by the Bureau of Steam Engineering of the U. S. Navy Department, and such designs as have been accepted by it, can be properly called the highest developments in efficient and substantial radio equipment. Dependability sums up, in a word, the construction and operation of Navy apparatus.

A typical example is the Destroyer type receiver described in this chapter. Fig. 1 shows the outward appearance of the set. It is intended to operate on 250 to 8,000 meters using a crystal or audion for damped wave reception, and a feed-back coupling with the audion for undamped waves.

The circuits are of the usual loosely coupled type, having a 6-step antenna inductance and series condenser for the primary, and a secondary coupling coil, 6-step inductance, and shunt tuning condenser in the secondary circuit. One-half of the condenser dials are divided into 180° scales, while the remainders are used for wavelength calibrations. As the inductance switch is turned, the pointer moves to a corresponding arc on the dial. Vernier adjust-

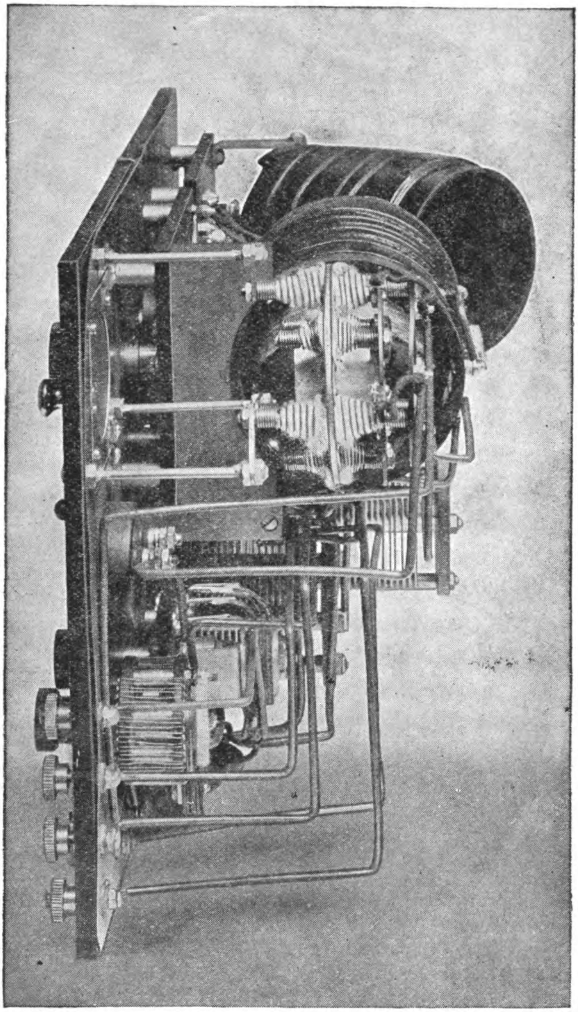


Fig. 3. A side view of the set, showing particularly the audion, mounting.

ments of the condensers are provided by the handles which can be seen at the lower part of the panel near the dials.

At the left-hand side are the coupling control, safety spark gap, buzzer, and buzzer press button. On the right, the tickler

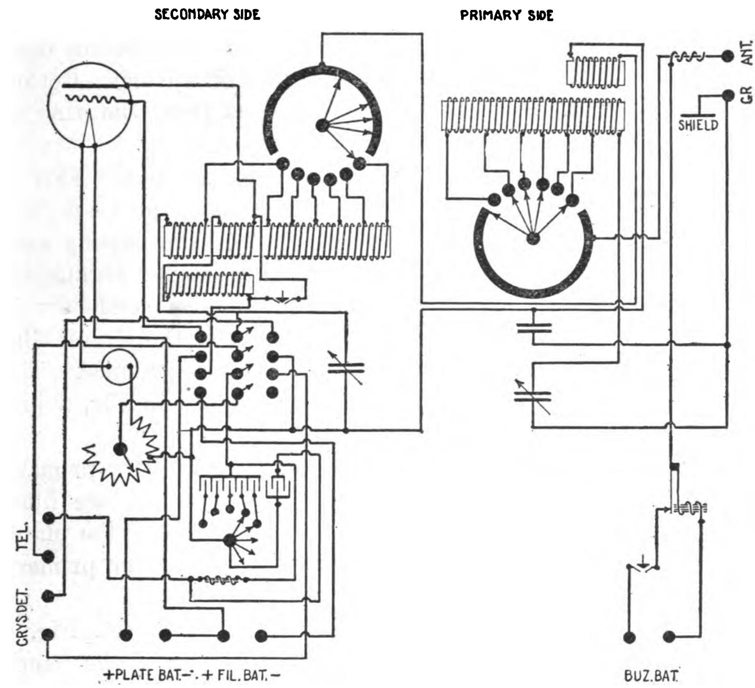


Fig. 4. Connections for the instruments as they appear from the back of the panel.

coupling adjustment, oscillation test, crystal-audion switch, and telephone shunt condenser are mounted. There are also an audion mounting, filament current ammeter and rheostat.

The instruments themselves can be seen in Figs. 2 and 3. A metal shield covers the rear of the panel, to reduce interference from the body of the operator and to prevent any capacity coupling between the primary and secondary circuits.

The audion socket is of a design which absorbs vibrations, an important consideration, for vibration during operation causes a noise in the telephones and also reduces the life of the tube. Six sets of expansion-compression springs are fastened alternately to the three panel supports and the bakelite socket mounting disc, while a bakelite ring is held at the middle of all six springs. Cotton is packed lightly in the springs to prevent them from vibrating at their natural period.

Below the audion mounting is the filament rheostat. This is made up of resistance wire wound between brass pins set into the peripheries of two bakelite discs. A switch arm, passing over the set of pins next to the panel, gives the resistance regulation.

At the side of the rheostat, an adjustable mica condenser is secured to the panel. This condenser is shown in the circuit diagram between the filament side and the plate impedance. The impedance is of the closed core type; it can be seen in Fig. 2 just below the mica condenser.

The secondary inductance and tickler coil, as well as the primary and secondary coupling coil, with their 45° mounting, are illustrated in Fig. 2. Balanced condensers, with one-half of the plates at one side, and half at the other, are used in tuning the primary and secondary circuits.

Figs. 4 and 5 show the circuits employed in this set. Fig. 4 indicates the arrangement as viewed from the rear of the panel, while Fig. 5 gives the connections when the crystal-audion switch is at the audion position.

The antenna circuit is made up of a tuning condenser of 0.0015 mfd. and a six-step inductance. Instead of disconnecting the unused parts of the coil, they are simply shortcircuited by the four contact fingers. Connections are made to the first active section by the last contact and the metal segment to which the antenna is attached. Both primary and secondary switches are mounted on panels located behind the main instrument panel. A

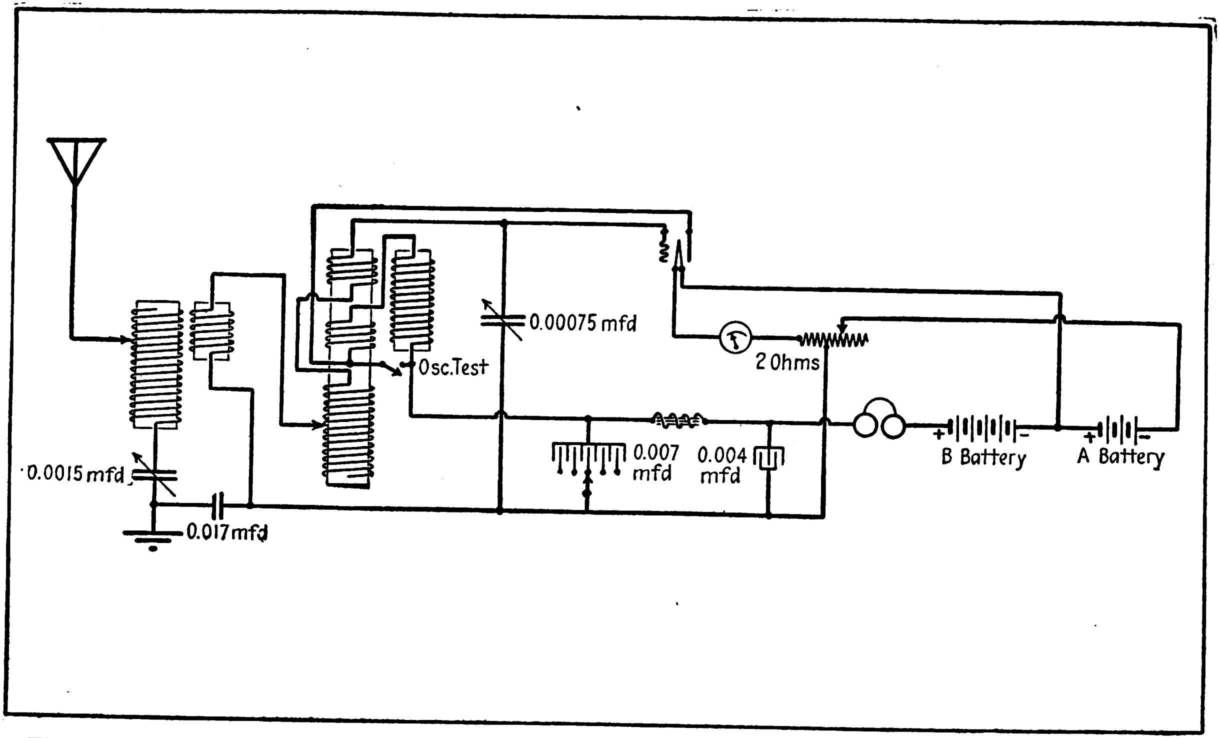


Fig. 5. An unusual arrangement is used for the secondary and tickler. The inductance of the tickler is varied by the variometer method as the coupling to the secondary is changed.

small coil, put around the antenna lead, is joined at one end to the armature of the buzzer. Excitation is obtained in this way for the buzzer test. The shield which covers the rear of the panel is wired to the ground, to prevent interference from the hands of the operator.

Fig. 5 shows that there is a small coil, in series with the secondary tuning inductance, coupled to the primary. At the end of the secondary is a rather unusual arrangement for tickler coupling in which a part of the tickler inductance is wound on the secondary tube, and the remainder on a separate form. A short circuiting switch is provided around the tickler to test for oscillating.

Negative grid voltage is obtained by means of a tap taken from the filament rheostat so that 2 ohms resistance are always in the circuit to the grid. Since the positive terminal of the filament battery goes directly to the filament, the grid tap from the rheostat is more negative than the filament by an amount depending upon the current through the filament circuit. In other words, the difference in potential across the 2 ohms is where

$$E = I \times R,$$

E = difference in potential,
I = current through resistance,
and R = resistance.

If, therefore, 1.3 amperes is flowing in the circuit, the negative grid potential will be

$$E = 1.3 \times 2$$

or grid potential—2.6 volts.

In the plate circuit there is a small impedance and two condensers, one fixed, of 0.0004 mfd. and one variable in six-step up to 0.007 mfd. The latter is shunted across the battery and telephones.

When the set is connected for the use of a crystal detector, the detector impedance, and telephones are in series around the secondary tuning condenser, with the fixed condenser around the phones, and the adjustable condenser across detector and tuning condenser.

At the detector adjustment, if no crystal detector is used, a radio frequency amplifier and detector can be connected to the adjacent crystal and phone posts. These posts lead directly to the secondary condenser, so that the tickler and all the local audion circuits are not connected.

This set offers a number of features which should suggest new ideas to those who are building their own apparatus.

CHAPTER II

AN AMERICAN RECEIVER FOR FRENCH SHIPS

American radio men, when they come in contact with French equipment, are often caught at a disadvantage because of a lack of familiarity with the lettering on the apparatus and the meaning of the technical words even though they have a working knowledge of the language. For the benefit of these men, and the experimenters who may at any time be called upon for this information, an explanation of the most important French radio terms is given in this chapter.

In the first place, T. S. F. is the abbreviation for télégraphie sans fils, or telegraphy without wires. The primary tuning circuit of a receiver might have an antenna, an antenne, inductance, self, in series, en série, with a variable air condenser, condensateur diélectrique variable à air and the ground, terre. Perhaps the antenna inductance would be controlled by two switches, commutateurs, one having large steps, grands gradins, and one with small steps, petits gradins. There may be small wire, fin fil, or large wire, gros fil, wound in the form of a solenoid, solénoide. The unused turns may be short-circuited, mis en court-circuit, to prevent, empêcher, absorption in that part of the coil, partie de la bobine.

The secondary circuit, secondaire or C. S., may be connected with a crystal detector, detectur cristol, or an audion, lampe. The plate, plaque, requires a set of dry batteries, piles seches, and perhaps a graphite potentiometer, potentiometre en graphite, which would be turned from left, ganche, to right, droite, to increase the voltage, pour augmenter le voltage.

With these words and ondes continues, undamped waves, interrupteur, switch, panneau, panel the other words can be guessed at with sufficient accuracy to get the sense of a French description of

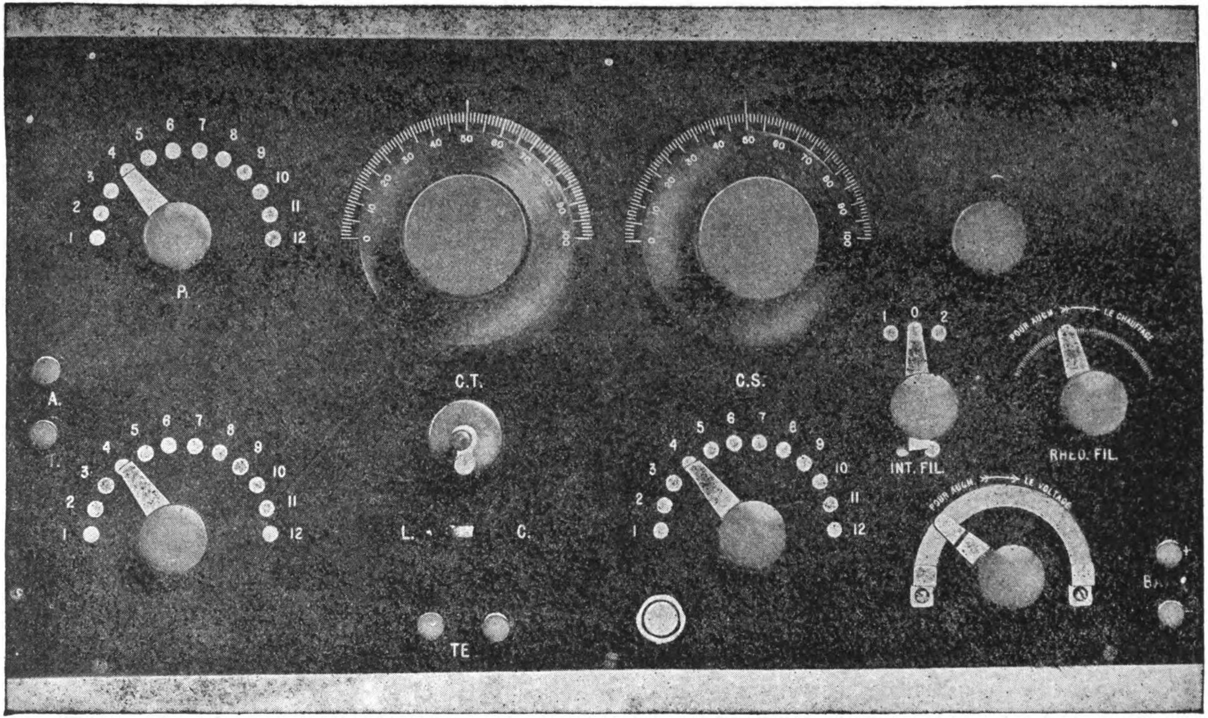


Fig. 6. This set, built in America, has been used on French ships during the war. Several interesting features are described in this article.

a receiving set. Fortunately, many of our terms are the same or very similar in French.

Several views of an audion receiver, built by the Emil J. Simon Company for the French Government, are shown in the accompanying illustrations. At the left of the panel are two switches which control the primary inductance. It will be seen from the rear view that the large steps of the coil are wound with fine wire, and the small steps with large wire. Toward the center, are the coupling condenser, C.T., crystal detector, and audion-crystal switch. At the left are mounted the secondary tuning condenser, secondary inductance switch, and the plate and filament batteries controls. A small shutter near the upper corner allows an observation of the audion bulb.

The circuit, Fig. 10, used with this set is rather unusual. In the first place, there is no magnetic coupling between the primary and secondary. Condenser C.T. acts as a coupling condenser, although it has an effect upon the secondary wavelength, and on the local oscillations which, by a proper adjustment of this condenser, can be started for undamped wave reception.

Condenser C.S. and the inductance give the principal adjustment of secondary wavelength. The operation of this circuit is not as simple as that of the usual loosely coupled circuit with a tickler, but, when the knack of using the condenser is mastered, it gives excellent results.

In actual use, damped signals are tuned in by a rough adjustment of the two primary inductance switches. As the primary large step switch is moved the secondary switch is put on corresponding points. C.T. is kept at 0° until the final adjustments are made. When the small step, primary switch is adjusted, a slight tuning of C.T. and C.S. will bring the signals to maximum.

For the reception of undamped waves, the set can be made to generate oscillations by a slightly different method. The large step antenna inductance switch and secondary inductance switch are moved together as before, while condenser marked C.S. is adjusted with the small step switch. C.T. is kept at about 15° during the

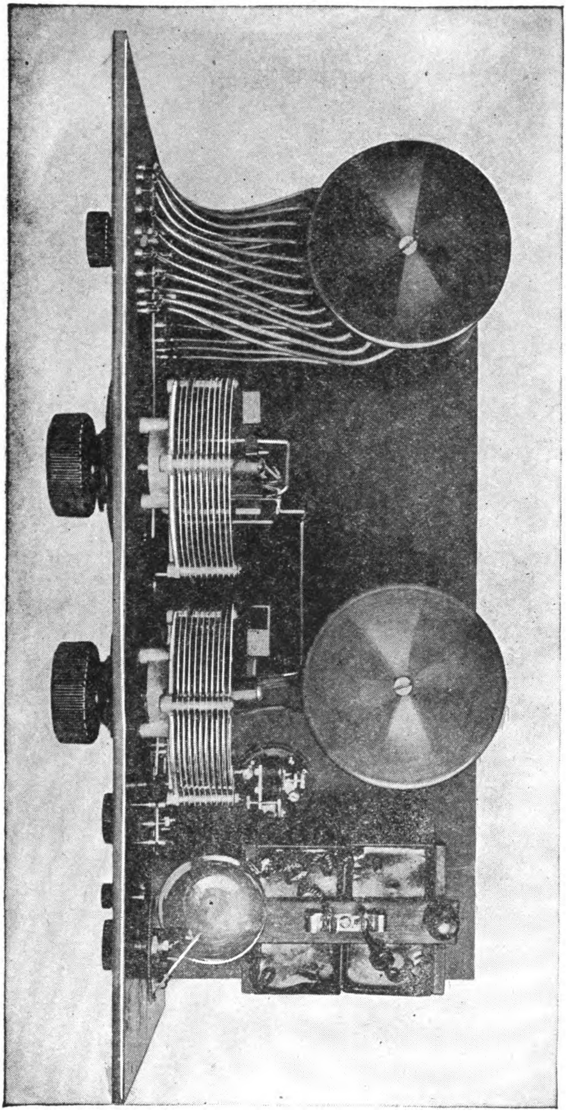


Fig. 7. A top view of the receiver. It will be seen that there is practically no magnetic coupling between the two coils designated as primary and secondary. Standard American B batteries are used with the French vacuum tube, though unlike most American receivers, a potentiometer control is employed to regulate the plate voltage.

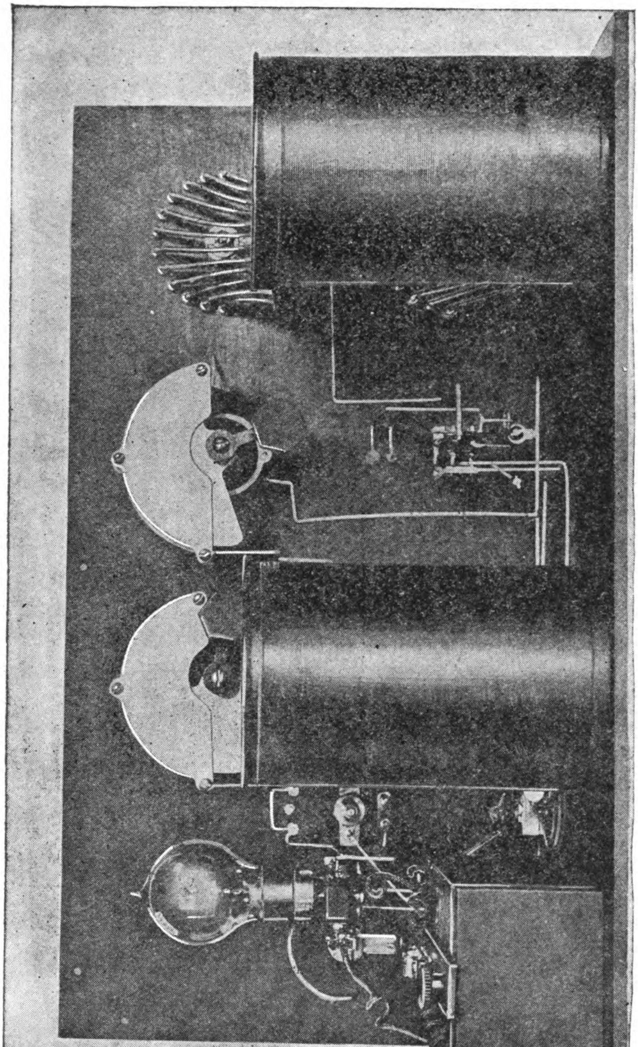


Fig. 8. This rear view shows clearly the type of vacuum tube used by the French. Instead of the socket and contacts used with American tubes, there are four plugs which fit into brass tubes set in the bakelite bracket. It is interesting to compare the design details and general appearance of this set with our American apparatus. In general our equipment has a more rugged construction, though it is often more complicated since we require wider limits in operating characteristics.

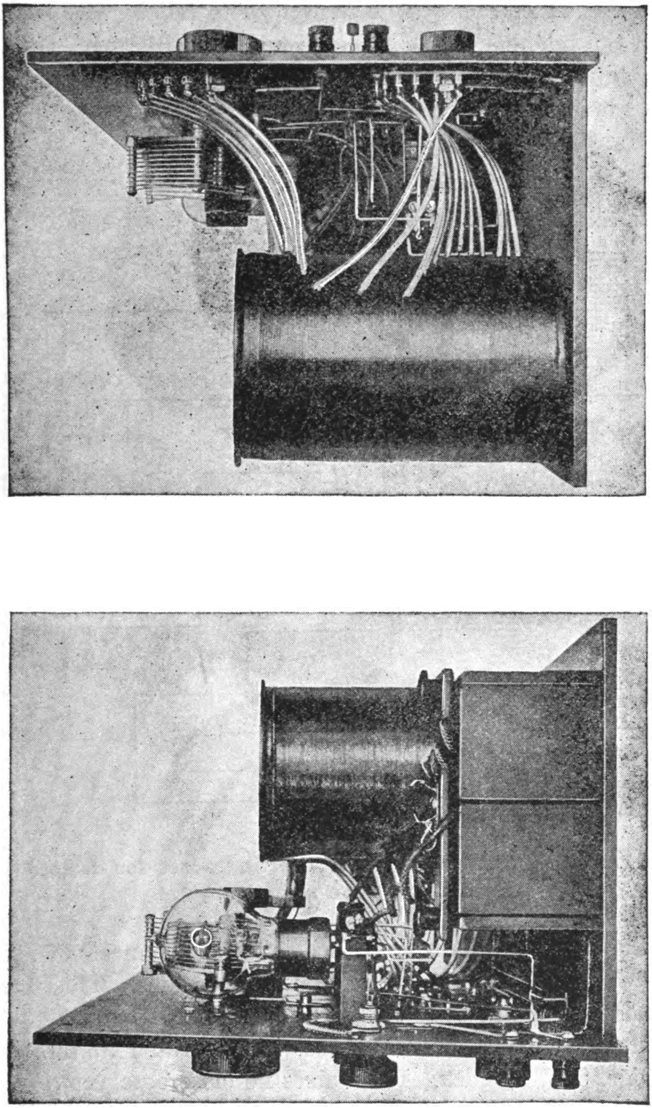


Fig. 9. End views, showing some of the constructional details. The tube mounting and filament rheostat, set in a curved slot in the panel, are interesting.

rough tuning. Experience will show how to tell by means of the sounds in the telephones when the circuit is oscillating. One sure test is to touch the secondary switch. If the set is oscillating, a plucking sound will be produced.

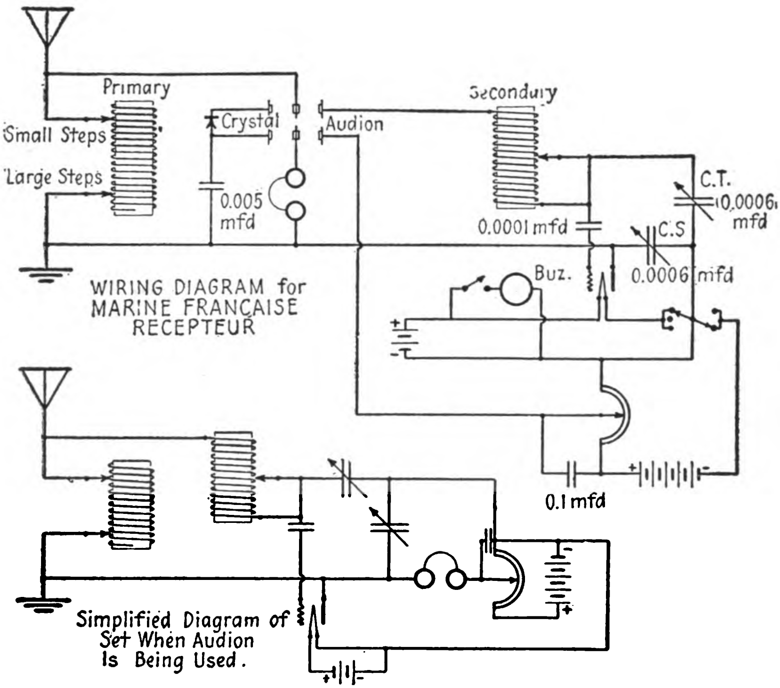


Fig. 10. A rather unusual way of connecting a set for damped or undamped wave reception.

When the crystal detector is used, it is simply connected in series with the telephones around the primary inductance. This is good for a standby adjustment, but it will not give sharp tuning.

The general construction of this set is illustrated in the photographs, Figs. 6, 7, 8 and 9. It requires no close observer to recognize American, French or English radio apparatus. While there is some similarity between the last two, American equipment is as different as American people. Even this Americanized French bears the original ear marks. Various comparative criticisms have been made, but a single statement cannot be all inclusive.

The outstanding feature of French and English instruments, is the amount of hand work on them—beautifully made. The trouble is, however, that there is so often the same delicacy in design. American equipment, on the other hand, gains in many cases because due allowances are made for quantity production and the ruggedness required, particularly of equipment for the Army and Navy. Although foreign apparatus often calls for commendation of workmanship, it seldom equalled our own recent developments under the severe test of war conditions.

In the illustrations of the details of this French set, the standard French tube, also used by the English, can be seen. The plate is a horizontal cylinder, bent so that the support is integral with the plate itself. Inside is the filament, surrounded by a helical wire grid, resembling an open spring. This tube requires only 40 volts, though transmitting tubes of this type of construction operate at as high as 750 volts. Either sort, however, do not come up to the VT1 or VT2 of the Signal Corps.

CHAPTER III

LONG WAVE RECEIVER

The CR-7 set from the A. H. Grebe Company is one of a very few long wave receivers which have been offered to radio experimenters. In fact, long wave sets have not been prominent in the great number of new radio catalogs, principally because, with the long single-layer inductances tabooed, the problems of large inductance in small space have not been solved satisfactorily by many companies.

Electrical circuits of mechanical design have been carried out on the CR-7 set in a way which will meet the unqualified approval of the most exacting experimenter. The design of the primary and secondary inductances, described farther on, is an unusually clever piece of work, representing an amount of thought seldom shown by other apparatus.

Fig. 1 illustrates the bakelite panel, 12 by 21¼ ins., with the various controls. An oak cabinet carries the panel on which all the instruments are mounted. A hinged cover permits the examination of the set.

Across the top, from left to right, are the primary-secondary coupling, primary inductance switch, opening for the insertion of the audion bulb, secondary inductance switch, and tickler coupling, while at the bottom are the primary condenser, antenna compensating inductance switch, rheostat, bridging condenser, secondary condenser, and telephone jack.

In the rear view, Fig. 12, the primary condenser and inductance are at the right hand end of the panel. The tube at the center carries the audion socket. Dust is, in this way, kept out of the set.

Three small bridging condensers are located at the left of the socket tube, any one of which can be cut in by the three-point switch.

Fig. 13 shows, in the primary circuit, four concentrated inductances and a divided tubular coil wound with two banks of high

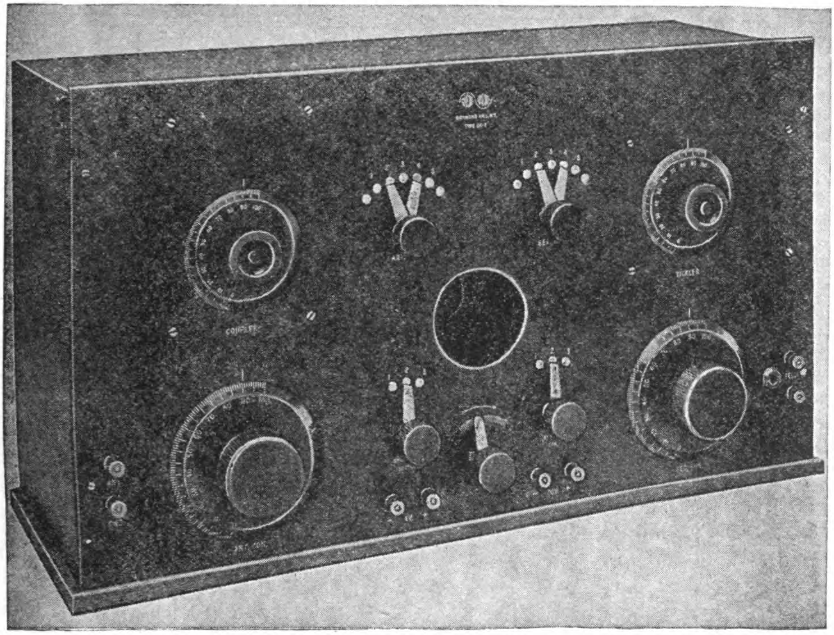


Fig. 11. The arrangement of the controls makes possible very rapid adjustment.

frequency cable. The appearance of the assembled coils can be seen in Fig. 12.

The concentrated coils, instead of having the same inside diameters, have the same outside diameters, so that they fit snugly inside a tube on the end of which are the divided coils. The purpose of dividing the coils is to allow for the shaft of the secondary coupling coil.

The end section of the banked coil is tapped at three points, and is used to compensate for variations in the capacities of different antennas. By setting this switch at the proper point, determined

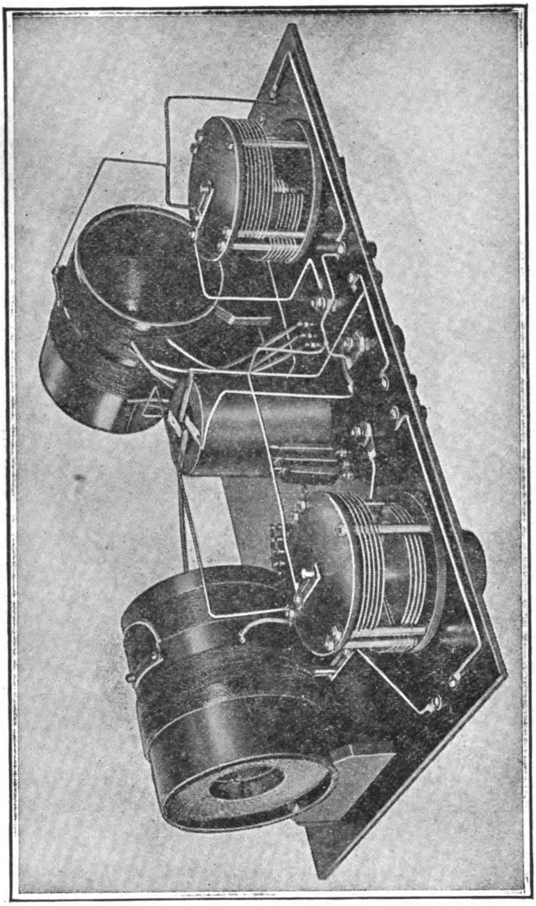


Fig. 12. The wiring of this set is a prominent feature.

experimentally, corresponding adjustments of the primary and secondary condensers and inductances give very nearly the same wavelengths in both circuits.

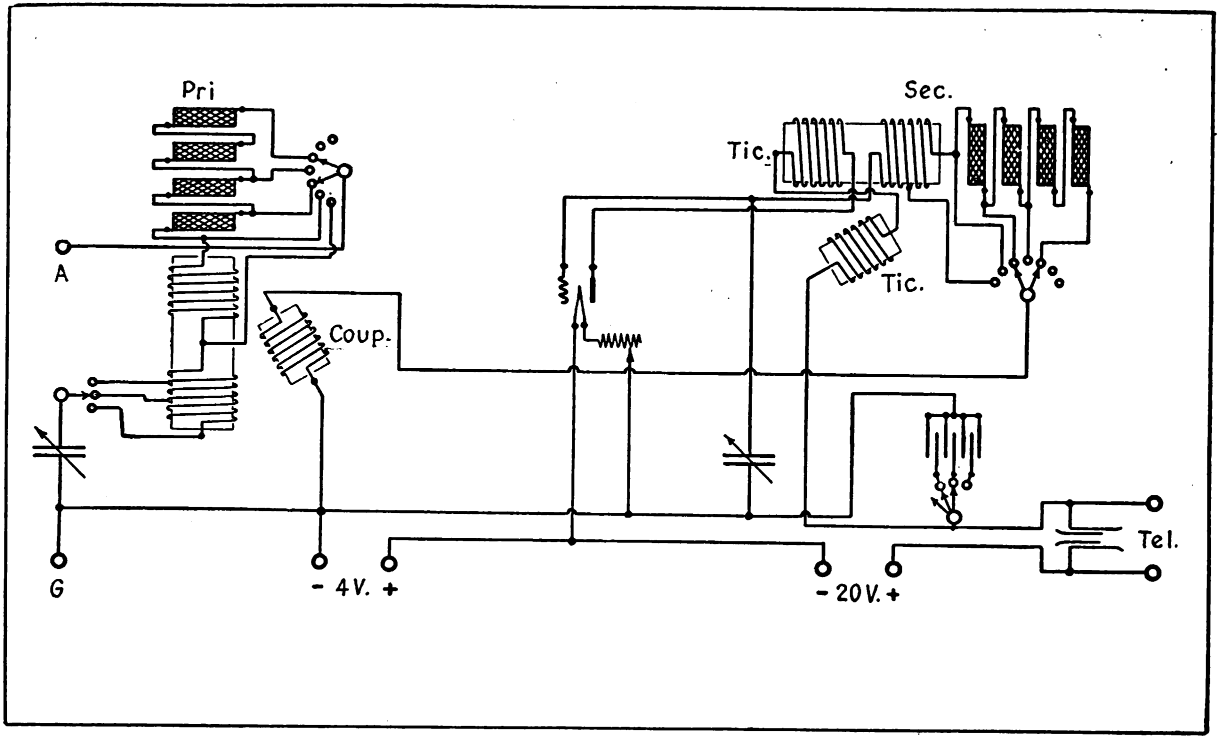


Fig. 13. Circuit for the Grebe CR-7 receiver.

Two contacts, are employed on the inductance switch to short circuit the two sections ahead of the last one in use, a method of cutting down dead-end losses which is quite effective.

A 26-plate balanced condenser, having a maximum capacity of 0.0008 mfd., is connected in series with the ground. The method of establishing connection to the rotating plates is interesting. A short strip of brass, drilled and slotted at one end, clamps the end of the shaft tightly enough to give a low resistance contact.

Fig. 12 shows clearly the coil assembly, similar to that of the primary. It is mounted at right angles to the other, to prevent any coupling effect. Here the tickler coil is mounted at the end of the tube. One part of the tickler is wound on the tube, and the other on the variometer ball. The coupling from the straight part of the tickler is not great enough, however, to cause any noticeable feed-back when the adjustable section is at 0.

In Fig. 3 this coil is marked COUP. It can be seen at the end of the primary coils. The ends of the coil are soldered to the shaft, which is made in two pieces. Slotted brass strips are fastened to the tube and one to the panel, clamp on the shafts and make connections. These can be seen more readily on the tickler coil.

An 18-plate balanced condenser is provided for tuning the secondary circuit. At maximum, the capacity is 0.0004 mfd. Tuning is made sharper when a small condenser is employed in the secondary circuit.

Fig. 4 shows the wavelength of the secondary circuit at various settings. These curves are approximately correct for the primary circuit when the compensating coil is adjusted according to the antenna capacity.

Energy from the plate circuit is fed back to the grid by means of a tickler coil. This method gives the best control, particularly on a long wave set.

At 0 coupling, park stations come in the usual manner. As the coupling is increased, regenerative and finally oscillating effects occur. The table on page 36 shows the dial settings.

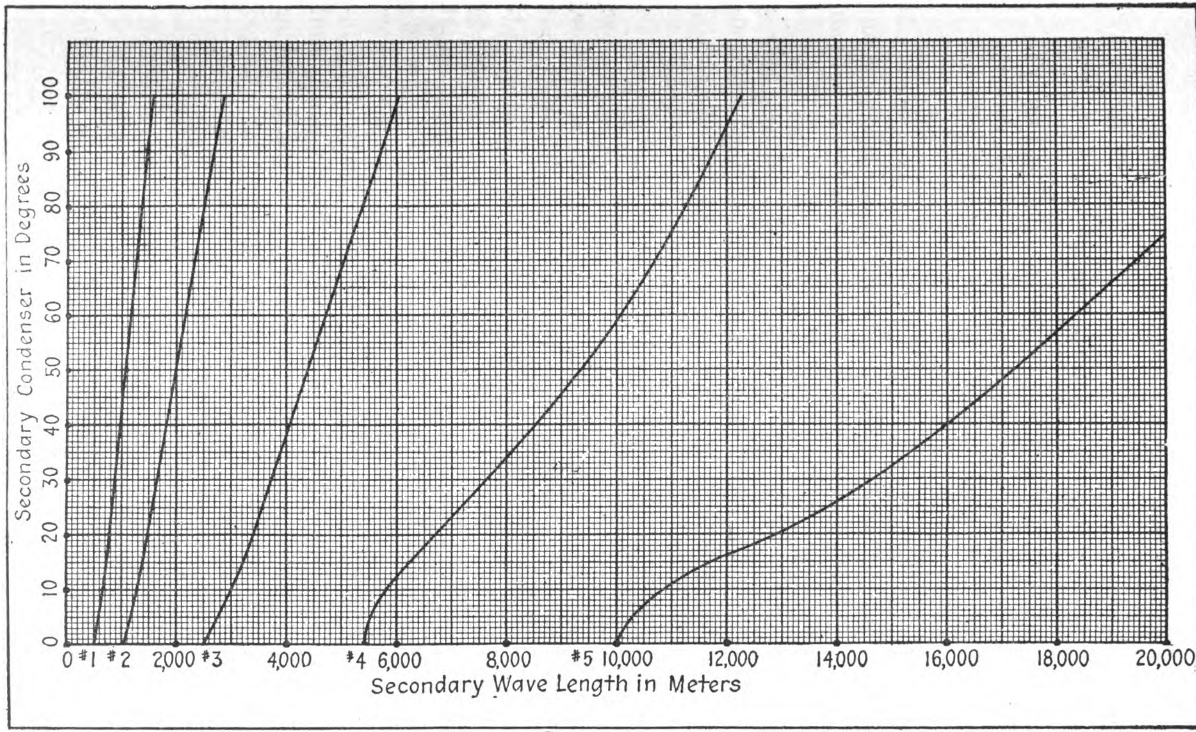


Fig. 14. Wavelength calibration for the secondary circuit. The numbers refer to the points on the secondary inductance switch.

Dial Setting	*Reception*
0	Undamped waves (set oscillating locally).
0—40	Damped waves (amplified by regeneration).
40—100	Damped waves (not amplified).

No grid leak or condenser is used with this set, as provision is made for a constant negative grid potential. Particularly on undamped waves, this is an advantage, as reception is better without a grid condenser.

Fig. 3 shows the connections of the by-pass condenser which shunts the telephones and batteries. The adjustment of this condenser has quite an appreciable effect on long wave signals.

A 4-volt battery is required for the audion filament, and a 20- or 22.5-volt battery for the plate.

The CR-7 is extremely simple to operate and, as the elements are all connected with heavy bus wire, the circuits are easy to follow.

To tune to a given wavelength, consult the wavelength curve and set the secondary condenser and switch to the positions corresponding to the desired wavelength. Next adjust the primary circuit to the same settings, making final adjustment for maximum signal strength when the signals are received.

For regeneration or amplification of spark signals, the tickler dial is turned towards the 100 mark until the signals have increased to the maximum, just below the point where a mushy and distorted note is obtained; for continuous wave reception, the tickler is increased to the oscillating point, and the proper beat obtained by adjustment of either the primary or secondary condensers.

CHAPTER IV

UNI-CONTROL RECEIVER

There is an inherent disadvantage in the usual type of radio receiving apparatus in that, while listening in, only such stations are heard as may be transmitting on the wavelength to which the receiving is tuned. To overcome this difficulty, Mr. Roy E. Thompson of the Wireless Improvement Co. designed the uni-control set described in this chapter.

As may be implied from the name the uni-control receiver is designed to be operated by the adjustment of a single handle, shown in Fig. 15 at the lower left-hand corner of the panel. For listening in, this handle is continuously revolved by a motor connected thru a worm gear and flexible shaft to the single adjustment. When the motor is started the set is slowly tuned over a range of 300 to 3,000 meters. When a station is heard, the operator merely switches off the motor and makes a close adjustment of the tuning by means of the handle.

This summarizes the operation of the uni-control receiver.

There are several distinct advantages in the use of a set of this type. In the first place, it assures the reception of any call which is transmitted at a wavelength in the range of the receiver. If equipment of this sort were generally adopted, the disadvantage of a single calling wave would be overcome, with the result that interference would be greatly reduced, as a station could call on a wave which another station, also sending, was not using and the calling operator could depend upon the reception of his signals. While it may not be advantageous to reduce the responsibility of the radio operator to too great an extent, it is certain that this type of set would increase the effectiveness of an operator inclined to be indifferent in carrying out his duties.

Detailed views of the uni-control receiver are shown in Figs. 16,

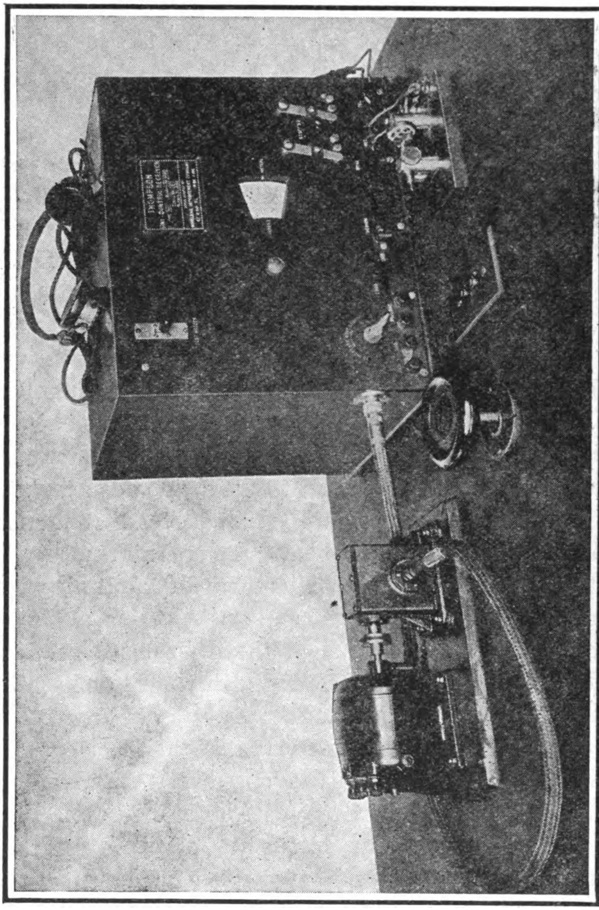


Fig. 15. A complete Uni-Control Receiver installation, with motor switch and speed control.

17 and 18. Fig. 16 shows the front of the set with panes removed; Fig. 17 is a top view, and Fig. 18, the front, with the wavelength indicating dial removed.

The circuit employed with the set is of the untuned secondary type. The primary inductance is divided into two sections, one with twenty-six taps brought off at short intervals and the other with nine larger steps. The latter coil is broken by four dead-end

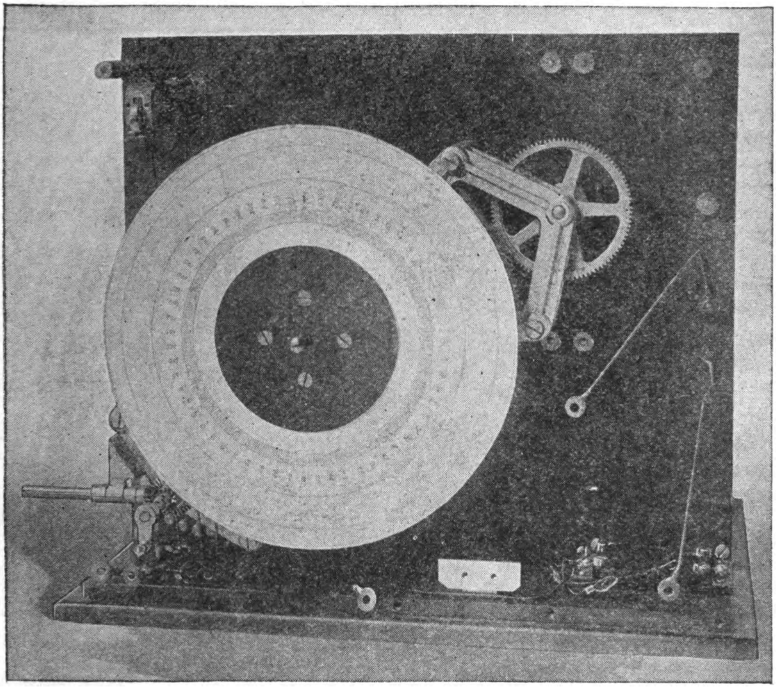


Fig. 16. The main panel removed, showing the arrangement on the sub-panel.

switches. A coupling control is provided between the secondary and the primary coils, so that the signal's strength can be varied.

On the shaft which carries the wavelength indicating dial there is a switch which moves over two concentric sets of segments which are connected to the large steps on the inductance. A small sector of the inner circle goes to the variable condenser and on to the small step switch mounted at the rear lower left-hand corner of the sub-panel. Both the condenser and small step switch are continuously rotated as long as the wavelength indicated dial shaft is being turned. The condenser, however, is only used for short wave reception when the switches are in a position for

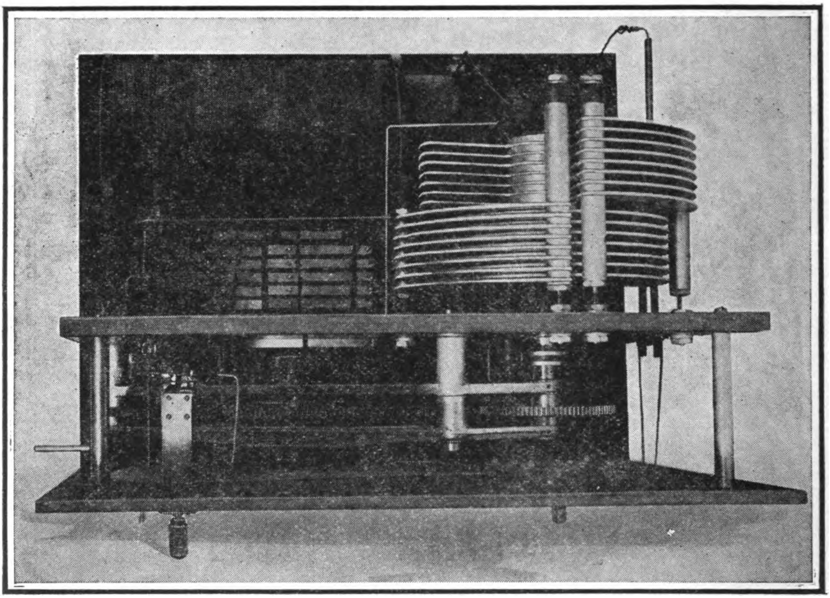


Fig. 17. Looking down on the top of the set, the inductance, dead-end switch, and condenser can be seen.

minimum inductance. When this point has been passed—that is, the wavelength increased from the minimum to the maximum value obtainable with the full capacity of the condenser—the inductance is increased by cutting in more turns of the small section. The wavelength is still further increased until the end of the small step switch is reached. At this point it moves on to zero, but the first large step of inductance is cut in. Again the small step switch is rotated until it passes from maximum to minimum as another large section of the coil is brought into circuit. In this way a continual variation from the low length obtained by the use of the series condenser is slowly accomplished until all of the small steps and all the large steps of inductance are in use.

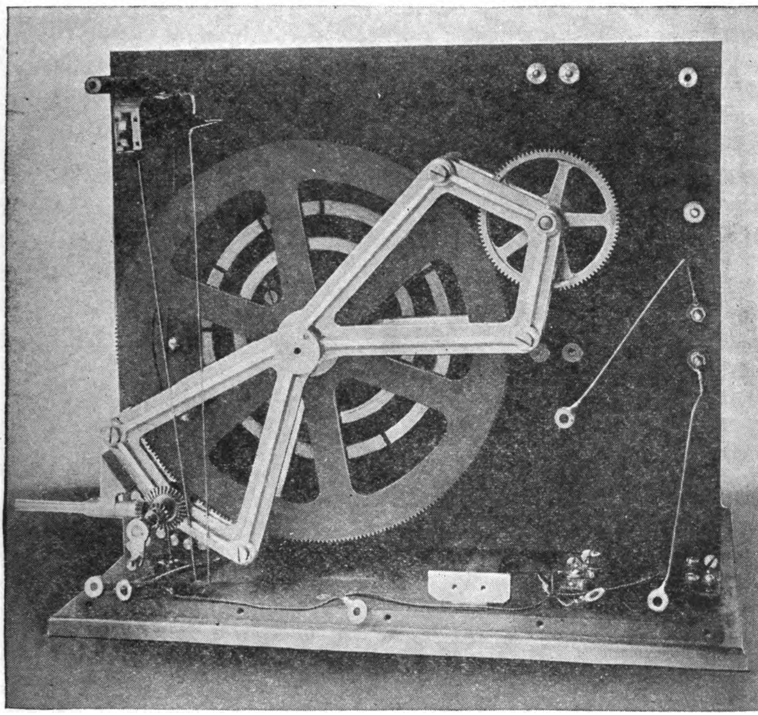


Fig. 18. With the indicating dial removed, the switch segments are visible.

In Fig. 18 the large gear is clearly shown. At the upper right-hand corner is the gear which rotates the variable condenser. Down in the left-hand corner there is a set of beveled gears, to one of which is secured the flexible shaft from the motor. The other beveled gear is on the shaft which drives, thru a spur gear, the large controlling gear. On this shaft, also, is the switch arm for the small step switch, the points of which are just visible below the beveled gear.

Fig. 17 illustrates the tuning inductance and dead-end switches; it also makes more clear the relation of the driving gears.

Fitted to the shaft carrying the large gear is a dial divided into 300 sections, opposite which a calibration can be made after the receiving is set up with a particular antenna.

The manual control of the wavelength adjustment is rather interesting; by pushing in the handle, the beveled gear is disengaged from that on the flexible shaft, so that the motor is not rotated when the adjustment is controlled by hand.

CHAPTER V

AUDION CONTROL BOX

The influence of manufacturing apparatus for the Government can be plainly seen in the new experimental equipment, an effect of advantage and credit to both the builders and users of the instruments. This audion control box, illustrated in Figs. 19, 20, 21 and 22, is of the regular Navy type with adaptations which made it quite versatile in respect to the important problem of plate voltage supply.

Beginning with the panel mounting, it can be seen that hinges are used, at the bottom, having the pin secured to one-half of the hinge. Therefore, when the panel is down, it can be slipped to one side and the pins pulled out of the other half of the hinges. In the closed position, however, the sides of the case hold the panel in position.

Fig. 19 shows a small thumb screw at the top center of the panel and at Fig. 22 a threaded block inside the case. To lock the panel, the thumb screw is turned tightly into the block. Supports are fastened rigidly onto the panel, Fig. 22, to keep it from falling down. These strips catch on angle pieces inside the case. A little inward pressure releases them so that the panel can be lowered further or removed.

At the rear, Fig. 20, the impedance, audion socket, fixed condenser, ammeter and grid leak are shown. The impedance, of the closed core type, is in the direct current plate supply circuit to smooth out current ripples. The paper condenser is put across the line. The method of supporting the impedance and audion should be studied, as it may present suggestions for designing other equipment.

Fig. 22 shows the rheostat under the socket. This is of the regular Navy design, made up of resistance wire wound back and forth on pins set into two bakelite discs. The carbon sector potentiometer

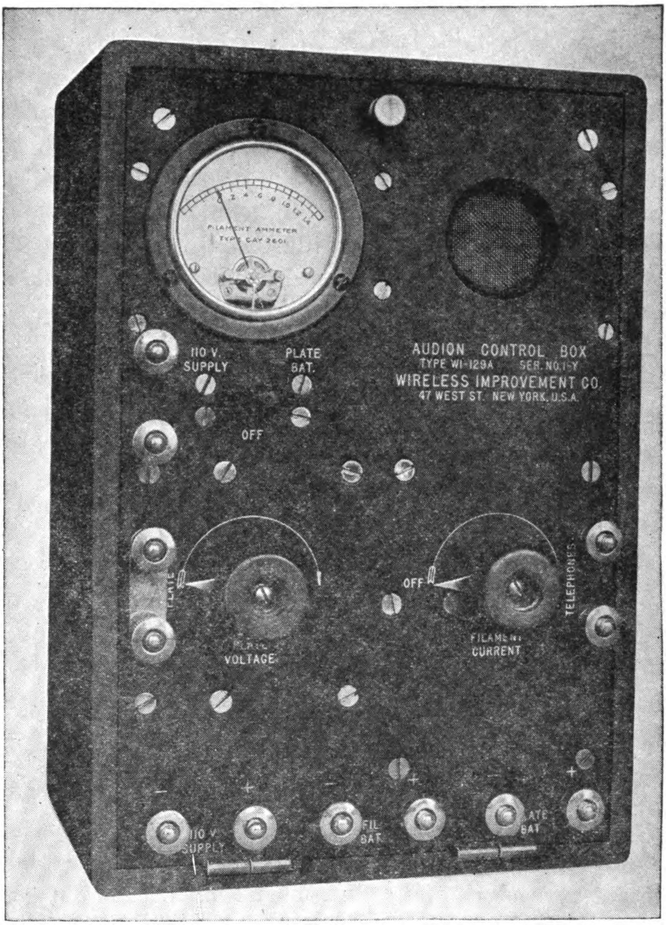


Fig. 19. The change from batteries to 110 volts is accomplished by a switch just below the ammeter.

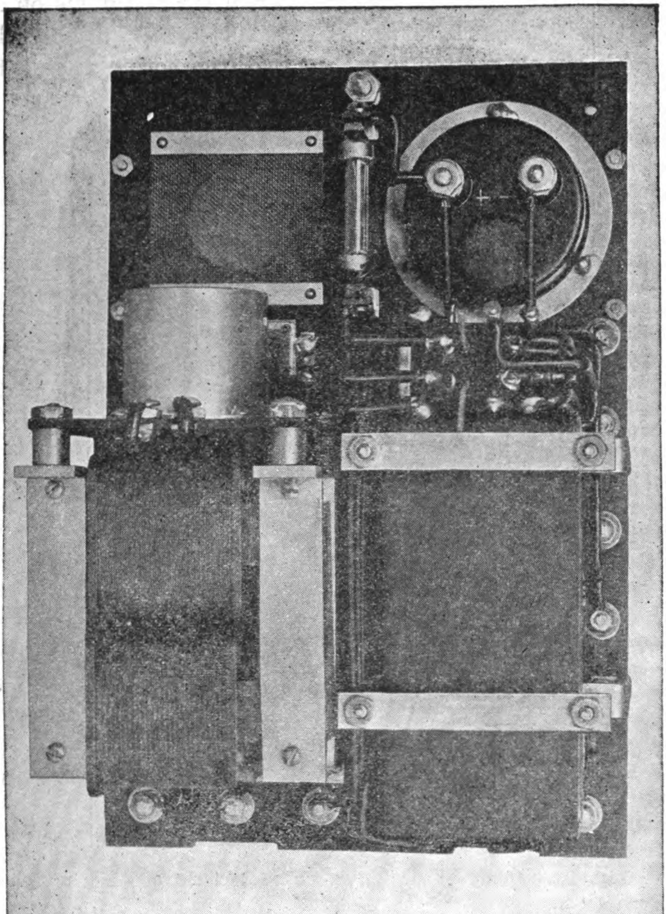


Fig. 20. A closed core impedance is used to smooth out the 110 volts.

is hidden under the condenser. It controls the voltage from the plate battery or 110-volt supply.

Other details can be seen from illustrations. The circuit employed is of the usual type. Change from the battery to 110 volts is accomplished by an anti-capacity, double-pole, double-throw switch. Experimenters who try to run their audions on 110 volts should benefit by the experience of the author at the laboratory. It was a simple matter to set up two iron core chokes with a con-

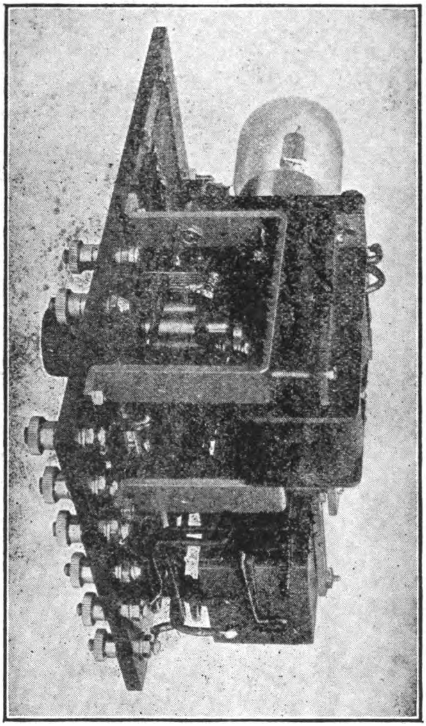


Fig. 21. Compact design is characteristic of this equipment.

denser across them. To prevent any accident, fuses were put in front of the choke coils. When the circuit was closed the fuses blew out. Everything was all right, but the fuses blew a second time. Finally it was suggested that we had a two-phase line in the building and that this circuit must be on the wrong side. It appeared that that must be the trouble, for the polarity of the 110-volt circuit leads were carefully tested, yet the fuses blew when the negative side was grounded.

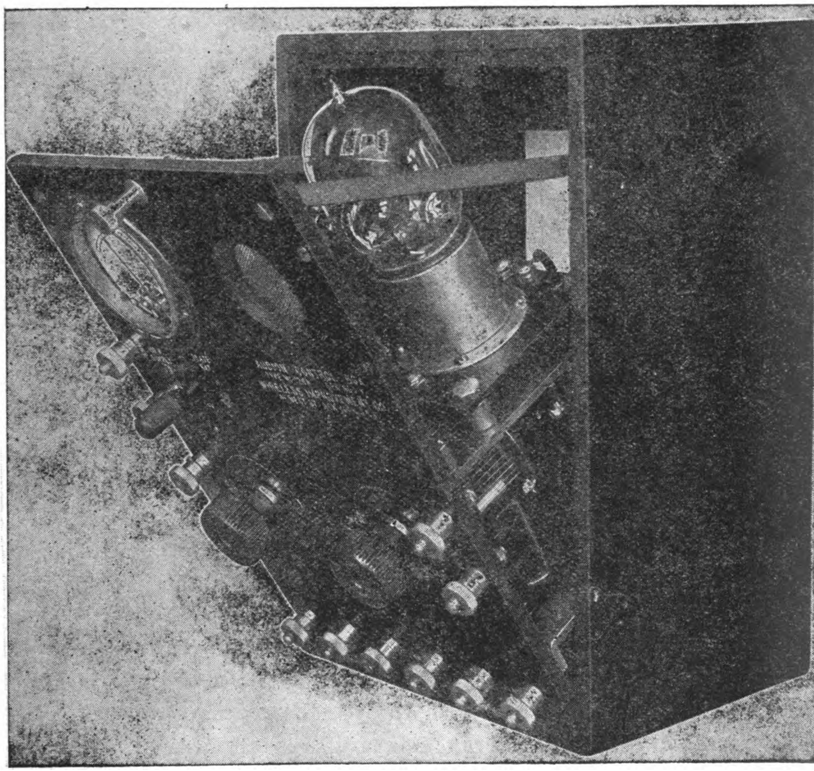


Fig. 22. The box partly open to show the interior construction of the audion control set.

Finally we called the electric light company and were informed that the installation was an old one and that the positive side was grounded. This will seldom happen at other places, but serves as a suggestion for those who experience any difficulties on this score.

CHAPTER VI

TWO-STEP AMPLIFIER

Although, from the point of view of the experimenter, construction following what has become known as standard Navy design is expensive, it gives to purchased or home-made equipment a dependability which inspires a consistent faith and pride in the instruments.

The amplifier illustrated here, Fig. 23, is carried in a case 9½ in. high, 4½ in. deep, and 6½ in. wide. All the instruments are carried on the removable panel.

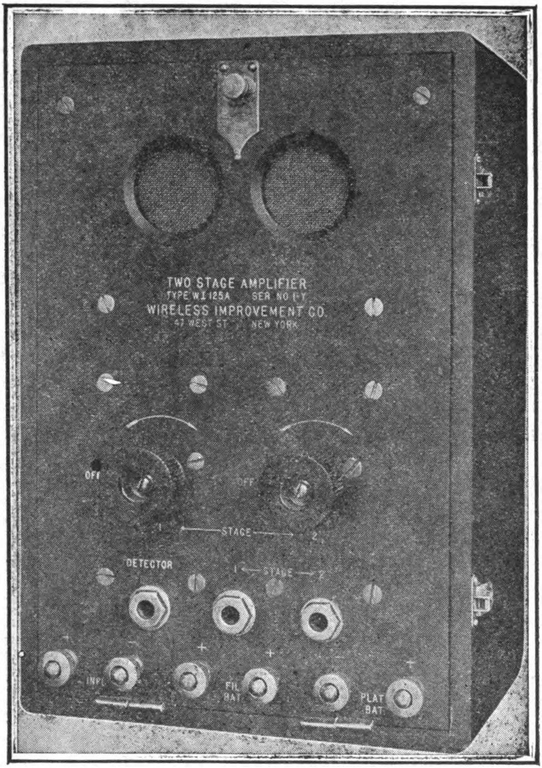
At the front are the tube observation windows, closed to dust by a fine mesh screen, filament rheostats, telephone jacks, and binding posts. Connections from the detector are run to the posts marked INPUT. When signals are of such strength that no amplification is required, the telephone plug is simply inserted at the jack marked DETECTOR.

For one or two stages, the filaments are lighted by turning up the rheostats, and the phone plug put in the one- or two-stage jacks.

The rear views, Fig. 24, with the panel removed from the case, show the very compact arrangement of the apparatus. Four U-shaped brackets hold the transformers and tube sockets. This type of mounting has not been used extensively by experimeters, although it is readily adaptable to the compact design of all kinds of instruments. A bakelite plate on the upper legs of the brackets carry the sockets.

Between the upright parts are two Navy type rheostats, just visible in the side view. A dead point is left on each rheostat so that the corresponding tube circuit can be opened. This is accomplished by connecting the tubes in parallel, with a rheostat in series with each tube.

Small biasing resistances, to give negative grid potentials. are mounted just above the socket plate.



23. **Front View of a two-stage amplifier.**

The phone jacks are clearly shown. The first is of the open circuit type. Therefore, as long as the plug is not inserted, the plate circuit of the detector goes directly to the grid or input circuit of the first stage. The second and third, however, are of the closed circuit type. The plate circuits are closed through the jacks, when

PART II

TRANSMITTING EQUIPMENT

CHAPTER I

DUPLEX RADIO TELEPHONE

The question of two-way radio telephony in which two speakers may carry on conversation without the necessity of changing the circuit connections from the receiving to the sending condition or the reverse, and which for brevity will be spoken of as "duplex radio telephony," is one which has been of considerable interest to radio engineers for sometime and while a number of attempts have been made to obtain such communication it has not come into general use. This is, no doubt, due largely to the enormous ratio between the power developed for transmitting purposes and the power of the received energy at a given station which makes it exceedingly difficult to prevent an overwhelming amount of side tone during the transmitting period, that is, the presence in the operator's receiver of the message which he is endeavoring to transmit. This condition has made necessary thus far the use of a circuit in which a switch or key of some kind is employed for throwing from the receiving to the sending condition, the set normally being in the condition for reception and being thrown into the other condition only during the actual transmitting period, during which time the local receiving circuit is entirely disconnected for its own protection.

The Western Electric Company has recently designed and built duplex radio telephone sets for the United States Navy which, in accordance with the definition of the term, permit two people at remote stations to converse with one another by radio without the

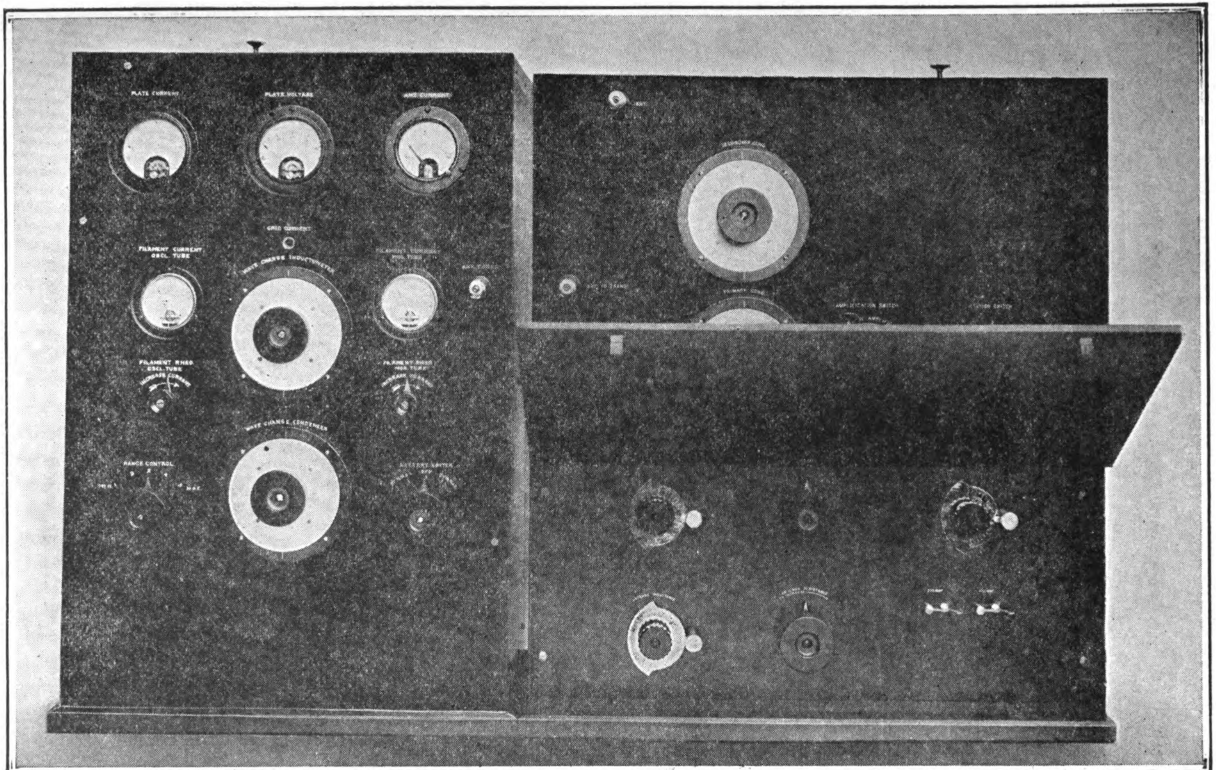


Fig. 25. The complete duplex radio telephone system, comprising a transmitter, receiver and dummy antenna.

necessity of throwing switches and with no more thought to the question of whether one is transmitting or receiving or both than is done in the case of an ordinary wire telephone conversation.

There are a number of different arrangements which might be used for successful duplex radio signalling. One method would ob-

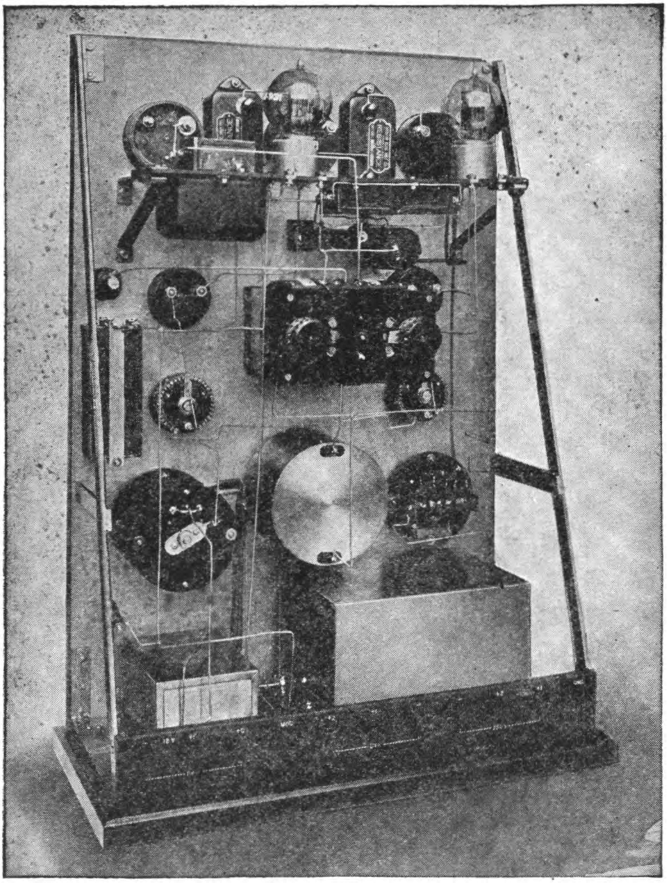


Fig. 26. Interior of the transmitter. The rear of the panel is shielded, and the set, when in use, is fitted into a metal case.

viously be to have two separate antennae, one for transmitting and one for receiving, the two antennae being tuned for different frequencies or being so related by form or position that the receiving antenna is not affected materially by the transmitting antenna. This is particularly convenient if the receiving and transmitting sta-

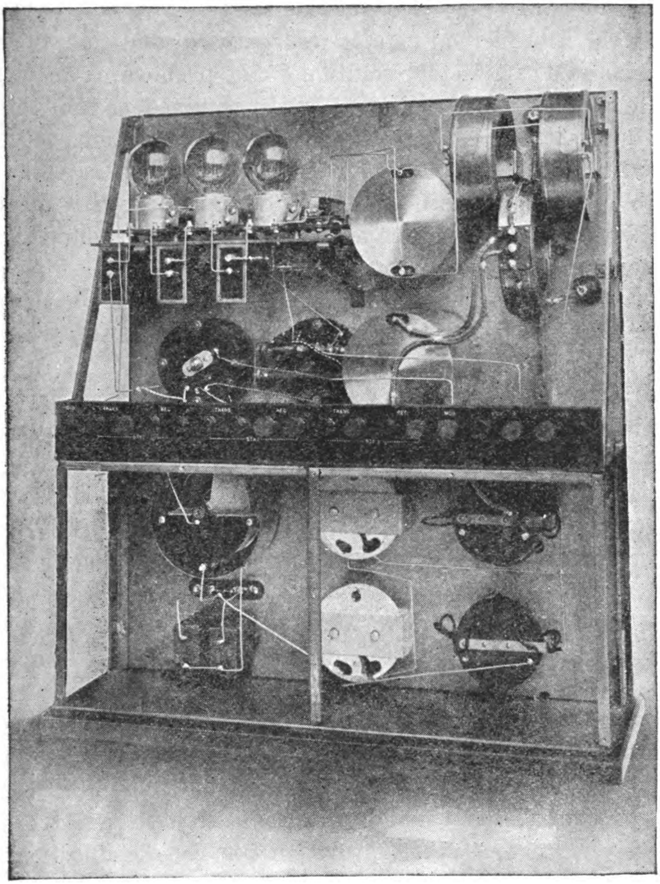


Fig. 27. The receiver is mounted above, and the dummy antenna below. This unit is also completely shielded.

tions can be separated by a distance of a few miles, the speaker being located at one or the other station or at some intermediate point and being connected to the two stations by means of wire connections. Another method would be to use a single antenna for transmitting and receiving in which some balancing scheme reduces the amount of transmitted power which enters the receiving circuits. In places of restricted space, such as sea-going vessels, it is apparent that the first method cannot well be used, and that the second method offers a satisfactory solution of the problem, if a sufficiently accurate balancing of the circuits can be obtained, so that the transmitter does not affect the receiver to any great extent even though both circuits are associated with one and the same antenna.

The Western Electric Company in co-operation with the United States Navy used the first method some years ago in connection with radio communication between Washington and battleships at sea. More recently it has built sets for the Navy based on the second method. Fig. 25 shows a photograph of such a set, which consists of two units, A and B.

The Unit A, to the left, comprises the oscillation generator with its modulator circuit and as such is the transmitting set. Fig. 26 shows the interior of this unit looked at from the rear. It will be noted that there are two vacuum tubes, one of which acts as an oscillator, and the other as a modulator tube. The Unit B, to the right, comprises an artificial antenna and the receiving circuit, and the interior of this unit, also looked at from the rear, is shown in Fig. 3. In this unit three vacuum tubes are shown, one acting as a detector and the others as amplifiers of the detected signal. In setting up the station it is only necessary to connect a terminal from the Unit A to a terminal on the Unit B; to connect the antenna to a second terminal on the Unit B, and to make two ground connections, one from the Unit A and one from the Unit B. In addition, of course, the usual connections of batteries, transmitter and receiver must be made, provision for these connections being shown in Figs. 2 and 27. This particular set is arranged to communicate with any one of three stations.

A simplified circuit diagram of the transmitter unit is shown in Fig. 28. A variety of oscillator circuits may be used, one which is particularly useful and which is shown here, is the Colpitts oscillator. This circuit includes a tuned circuit having two capacities in series, the one capacity consisting of a condenser of suitable dimensions and the other capacity being that of the radiating antenna. One terminal of the filament is connected to a point between these two capacities. The plate and grid are connected respectively to points on the inductance. Power is supplied to the plate cir-

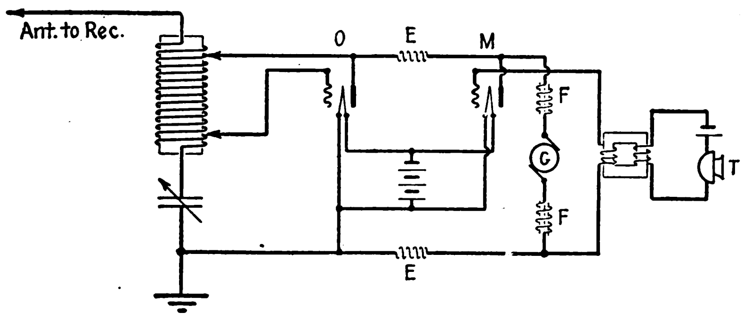


Fig. 28. A simplified diagram of the transmitting unit.

cuit by the generator G. Such a circuit will oscillate at a frequency determined by the capacity and inductance of the tuned circuit. These oscillations are modulated by the Heising method, which is shown in the diagram as consisting of a vacuum tube connected in parallel to the oscillator tube. Suitable choke coils E and F are connected to this circuit as shown. The impedance offered by the modulator tube M is determined by the potential of its grid, which in turn is controlled by the speech wave set up by the microphone transmitter T. The modulator tube therefore acts as a variable shunt to the oscillator and thus controls the amplitude of the oscillations to be radiated. As shown in the circuit one terminal of the inductance goes to a binding post indicated in Fig. 28 as "Ant. to Rec." and upon connection with the corresponding terminal on

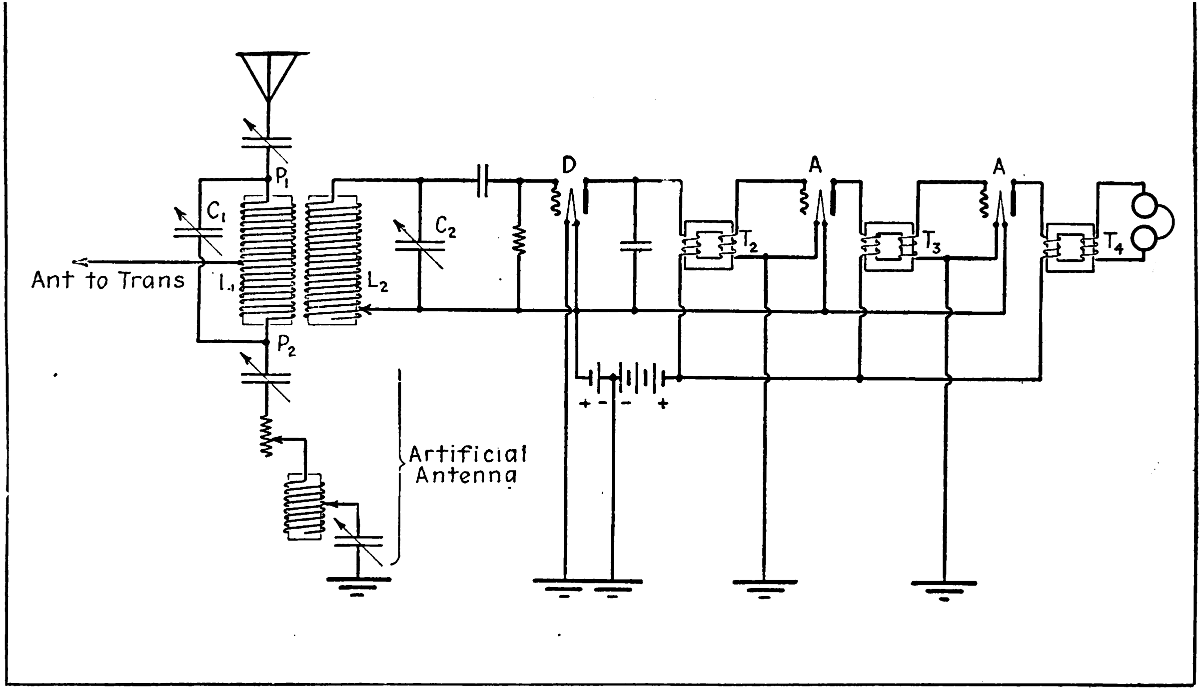


Fig. 29. The receiver circuit and dummy antenna.

the Unit B becomes connected to the radiating and the artificial antenna.

A simplified circuit diagram of the receiver unit B is shown in Fig. 29. In this circuit the coil L_1 and condenser C_1 constitute a tuned circuit which, by means of the condenser C_1 can be tuned to the signaling frequency. Associated inductively with the inductance coil L_1 is a second tuned circuit L_2C_2 which is connected directly to the input circuit of a vacuum tube D acting as a detector. The detected current is then impressed through the transformer T_2 on the input of a vacuum tube A acting as an amplifier, and the output of this amplifier tube is then impressed, by means of a transformer T_3, on the input circuit of a second amplifier tube in the output of which is a transformer T_4, the secondary of which contains the telephone receivers. The amount of amplification obtained can be adjusted by means of the variable resistance in the output circuit of the detector tube. It will be noted that one terminal of the filaments of the tubes are all connected to ground and the other terminals are connected to the positive pole of the filament battery, the negative pole of which is grounded. The filaments are thus supplied with heating current in parallel. The battery B is used for the plate circuits of the three tubes in parallel. From the mid point of the inductance L_1 is a lead going to the binding post marked in Fig. 25, as "Ant. to Trans." and is used for connecting the Unit A with the Unit B.

In view of the balanced arrangement oscillations coming from the Unit A to the mid point of the inductance L_1 divide equally half of the energy going to the antenna and the other half to the artificial antenna. This leaves the points P_1 and P_2 always at equal potentials as far as any disturbances arising in the Unit A are concerned and they therefore produce no effect upon the receiver circuit. Oscillations received upon the antenna, however, are not so balanced and therefore will produce an effect in the telephone receivers.

The essential point of this circuit arrangement is the presence of the artificial antenna, which is naturally made to stimulate the actual antenna as closely as possible, both in oscillation and damping characteristics. Obviously the greatest difficulty in a circuit of this type is in the balancing of the two circuits so that P_1 and P_2 will actually be equal potential points. In the designing of such balanced circuits the Western Electric Company has probably had more experience than anyone else because of the extensive use of such balanced circuits in ordinary telephone practice. In this circuit, however, the requirements are much more severe than in ordinary telephone circuits because of the high ratio between the transmitted and the received power.

In a later modification the set is divided into three units, A, B and C, the Unit A being the same as before, the Unit B including the receiving circuit and the inductance L and condenser C_1, and the Unit C including the artificial antenna alone. This arrangement has certain advantages in flexibility. In particular it permits the artificial antenna Unit C to be placed in a more or less inaccessible and useless space, a matter of importance in airplane work.

CHAPTER II

DESIGN FEATURES OF THE S. C. R. 112

It is unfortunate that, with the end of the past emergency, the intensive development of radio equipment for the Army and Navy practically ceased. So many things which promised great successes never had the chance to prove themselves.

This is particularly true of the S. C. R. 112 set, which was to have been built in great quantities for communication between battalion and regiment posts of command or, in special cases, between battalions and companies. Operating on the ground or in dugouts, the range of this set is over four miles, using a loop of 3 turns, 1 meter square. The weight of this set, a matter of very great importance, is only 28 pounds.

Electrical details will not be discussed in this chapter other than to say that the transmitter is of the buzzer type with an input of 60 to 85 watts at 10 volts, while the receiver is of the audion type, employing a condenser in shunt with the inductance of the loop for tuning. Adjustments are provided for transmitting wavelengths of 110, 123, and 140 meters.

Hidden away in the specifications for this set are the statements: "The box shall be capable of being dropped, with the instruments assembled within, five times the distance of 30 ins. on the earth without damage. It shall be sufficiently waterproof to operate when set upon the ground in a driving rain."

It took some time for the Signal Corps and the manufacturers to realize that apparatus, in the field was subjected to such use. Possibly the thoughts of the beautiful skies and the smooth roads of France were too firmly implanted in the minds of the designers.

The influence of European methods can be seen in the canvas-covered carrying case a practical solution for waterproofness which, although it is not as handsome as bakelite or finished wood, gives a rugged appearance. This canvas covering also protects the wooden

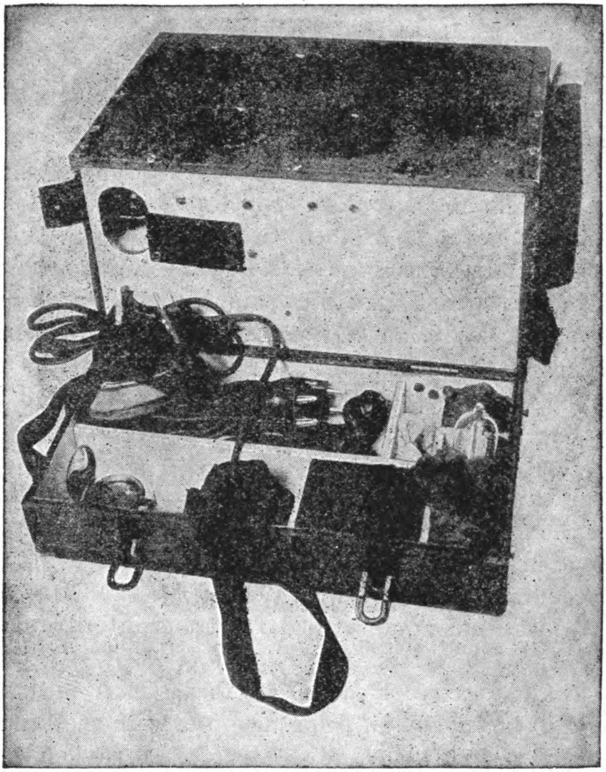


Fig. 30. The top section turned back to show the spare part box.

case from mechanical injury. Canvas flaps are also provided to guard the controls.

Figs. 31 and 32 show the flush construction of the switch handles and telegraph key. Instead of outstanding knobs to be knocked off and to strike against the legs of the man carrying the set, straight handles, easy to grip, turn in recesses. The top of the handle, flush

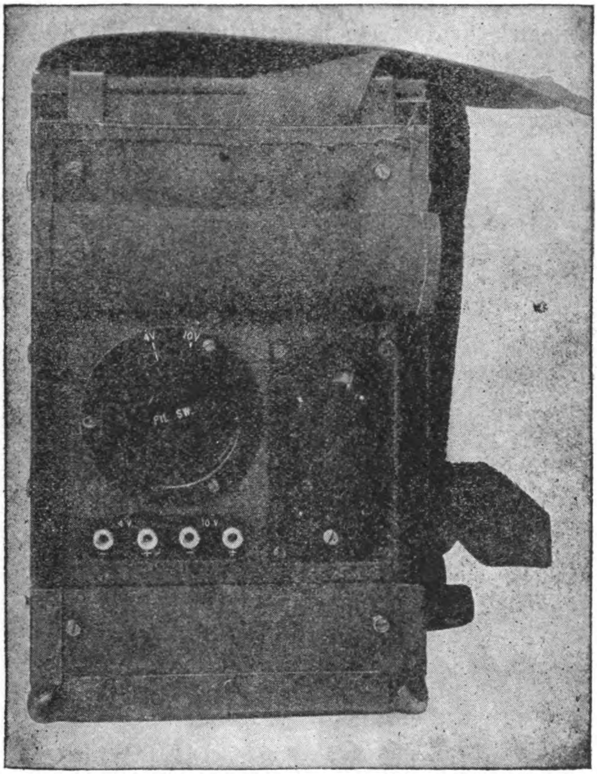


Fig. 31. Illustrating the key, in closed position, and the filament switch.

with the side of the case, is marked with a line to read against the scale.

Indications for transmitting are filled with red pigment and for receiving, with white.

The spare parts are fitted in a section below the part of the case which carries the radio instruments. Thus, while no appreciable weight or size is added to the set, the disadvantage of a separate spare part box is overcome.

A very human consideration is introduced in the design of the filament switch, shown in Fig. 31, just beside the folding key lever.

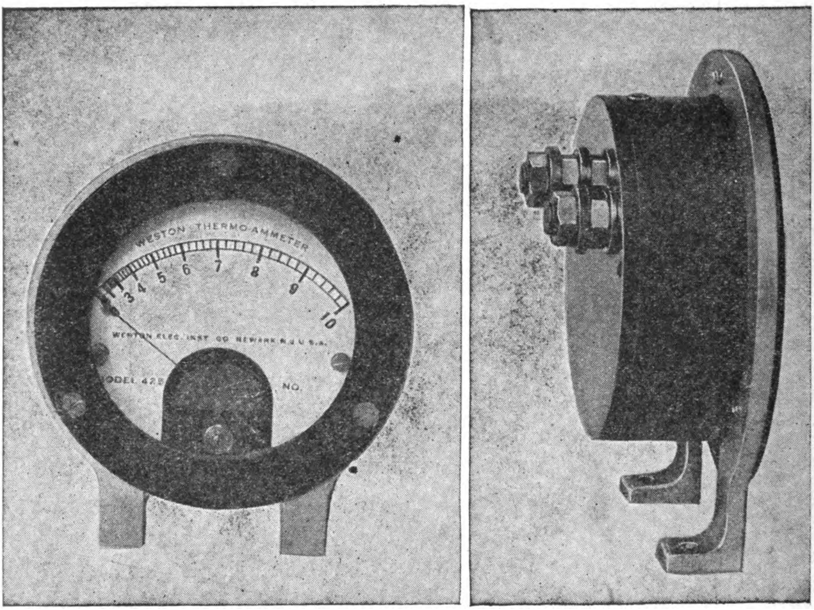


Fig. 32. Details of the thermo ammeter mounting.

The switch mechanism is mounted on an asbestos panel, while the front plate is of aluminum. Between the asbestos sheet and the front plate are two Ward-Leonard resistances.

At the 4-volt position of the switch, the smaller resistance of 1.15 ohms is cut in, or at the 10-volt position, the 6.2 ohm resistance permitting the use of a 4- or 10-volt battery on the filament of the audion. The heat from these resistances is radiated by the aluminum front plate, giving the operator a chance to warm his fingers when the weather is cold. The flap at the end of the case can be let down to enhance this effect. Very little heat is conducted into the set because of the asbestos plate at the rear of the resistances.

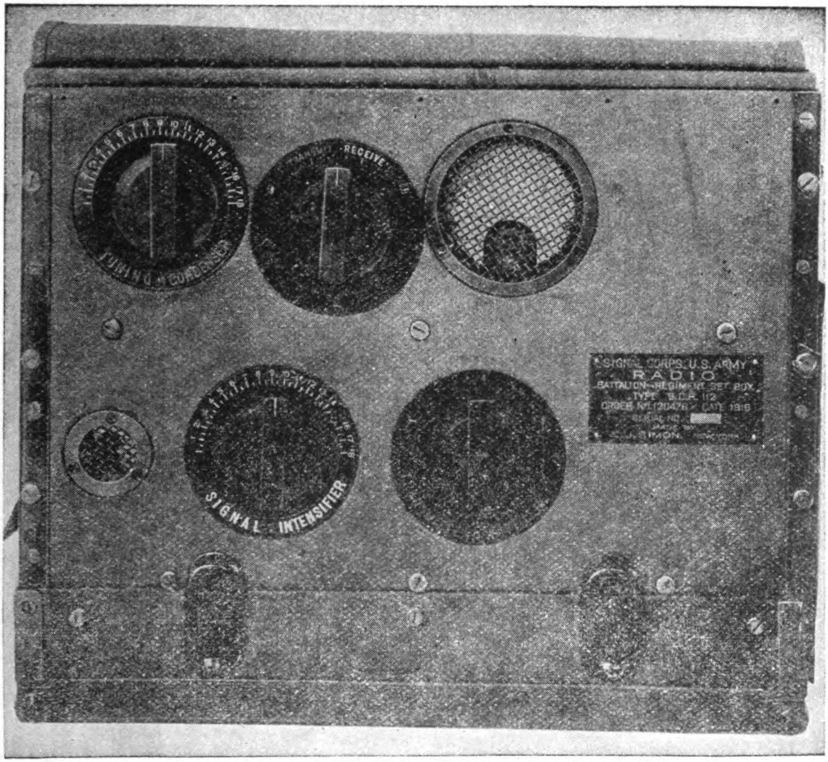


Fig. 33. Front of the case, showing the controls and location of the spare part box.

The telegraph key is unusual in that the lever folds up flush with the case when not in use. Inside is the breaking mechanism and a small resistance, shunted across the key to prevent sparking and also to keep the buzzer interrupter in vibration between the dots and dashes. This idea might be applied to spark coils as well.

Attention is also called to the protection provided for the ammeter and audion observation opening. To prevent the admission of dust, glass windows are provided behind the heavy wire mesh: Fig. 30 shows the opening through which the audion is removed.

Fig. 32 illustrates the method employed for mounting the Weston thermo ammeter. As it is not practical to use the ordinary flush mounting, a yoke was made to fit around the case, fastened to the flange by machine screws.

In this way the flush mounting effect was secured without actually putting the ammeter on the front panel.

CHAPTER III

HIGH EFFICIENCY 1 K. W. TRANSMITTER

The greatest successes are not always found in unusual things, but more often in usual things done unusually well. This is true of the standard Navy design transmitter described in this chapter, for its surprising efficiency is not due to any radical features as much as to the fact that each individual part, and the relations of these parts to the whole, have been worked out with extraordinary care, both as to electrical and mechanical design.

This transmitter, Figs. 34, 35 and 36, is of the quenched gap type, operating on 500 cycles. It is intended for ship or shore work, though it has been used chiefly by the United States Navy where space allowed a generator mounting separate from the radio panel. Although various wavelengths can be obtained by an adjustment of the controls, wavelengths of 300, 378, 476, 600, 756 and 952 meters, standard Navy wavelengths, are used ordinarily with antenna capacities from 0.0007 to 0.0012 mfd. These wavelengths are given instantly by moving the wave change switch to any one of the desired positions.

The motor-generator Fig. 38 is supplied with 120 volts D. C. giving 1.7 horsepower at 2,000 revolutions per minute. At this speed, the inductor type alternator generates 10 amperes at 125 volts, under full load, which, with a power factor of 80%, is 1 kilowatt. Controls for the motor and generator are mounted on the lower part of the panel.

A new type of quenched gap mounting is used, quite different in appearance from the more common designs. The rack and gaps will be seen in the front view. Above is the wave change switch and coupling adjustment at the right. At the top are the volt- and am-

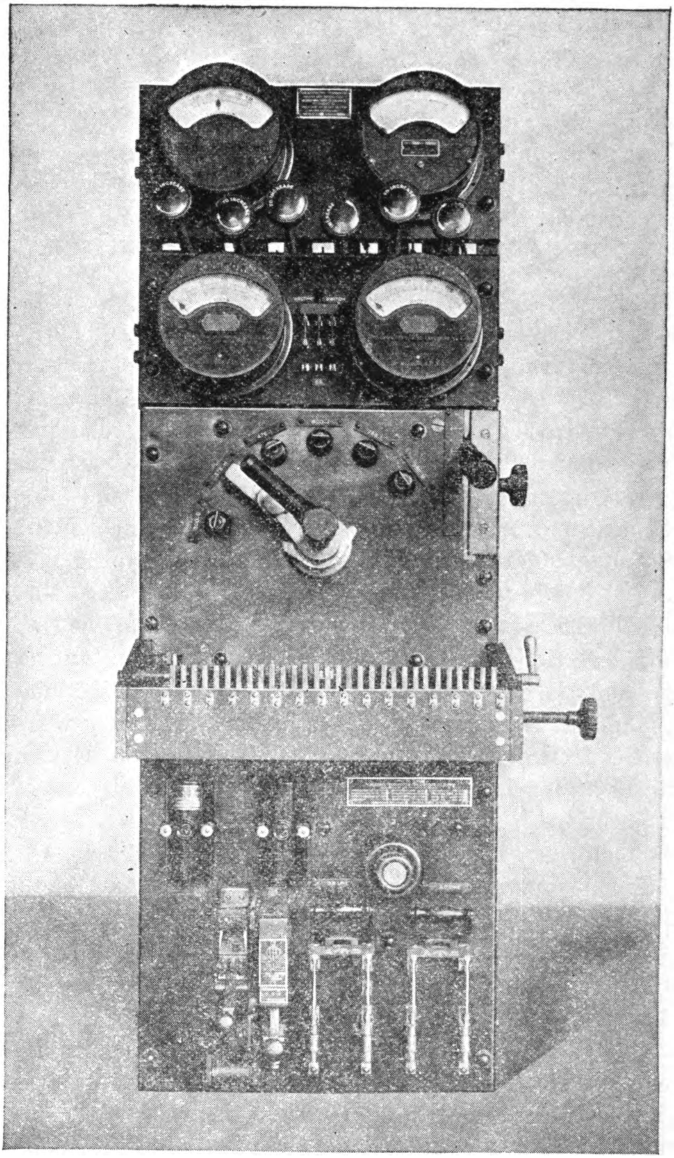


Fig. 34. A creditable example of American radio engineering is this 500-cycle transmitter.

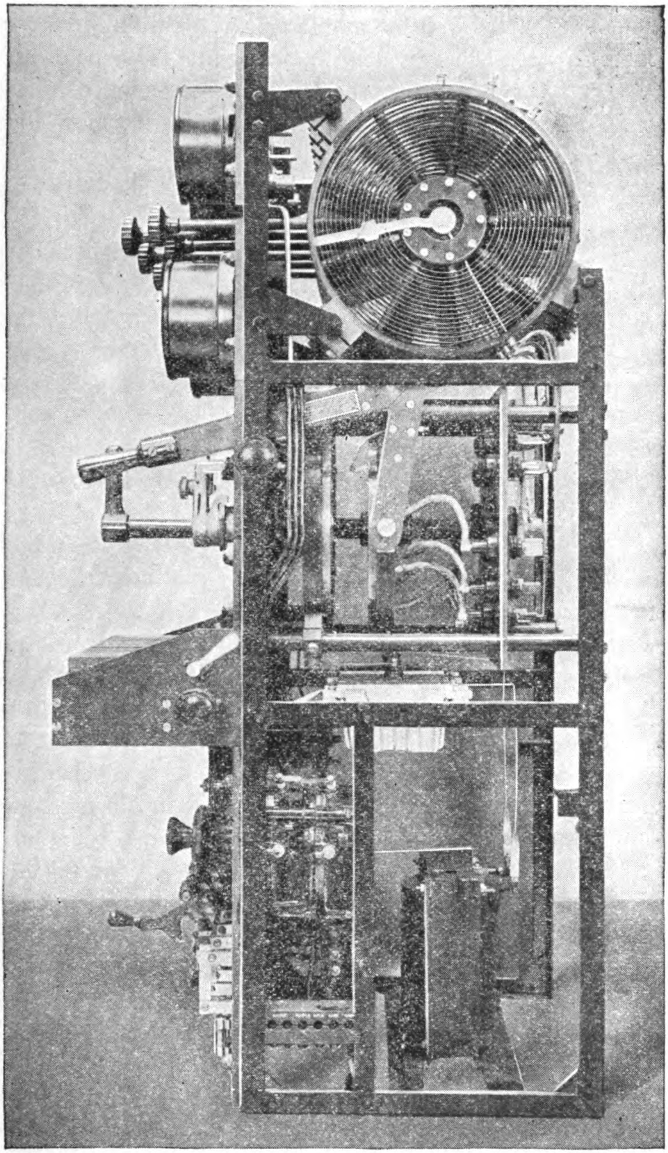


Fig. 35. A creditable example of American radio engineering is this 500-cycle transmitter.

meters, wattmeter, and radiation ammeter. Control handles, for the close adjustment of each wavelength, protrude from between the meters. Behind the panel are the transformer, mica condensers, primary and secondary coils of the oscillation transformer, and the antenna loading coils.

A simplified circuit, Fig. 37, is given here which shows the use of the various parts of this set. Three telegraph keys are provided for breaking the A. C. current. One is a hand key, another is a relay key, and a third a telegraph key operating the relay on 120 volts D. C. Included in the power circuit is the primary of the transformer and a 2-step impedance for cutting down the power. As will be explained later, the impedance switch and spark gap selector are operated simultaneously.

The secondary of the transformer is wound with a ratio of 38 to 1 to the primary turns. In the rear view a three-ball protective spark gap is shown, with two sides connected to the winding, and the center to the ground. Heavy copper strips lead to two Dubilier mica condensers, and on to the spark gap and oscillation transformer.

The quenched spark gap units are made up of two silver surfaces set in brass discs. Mounted on each disc is a copper frame giving it the box-like appearance shown in the photographs. So great is the heat-radiating surface that no air blast is needed for cooling. Two brass discs are clamped together by an insulated screw at the center, so that an airtight sparking chamber is formed. A complete unit is shown in the illustration of the spare parts, lying on the front of the left-hand chest. A fixture and wrench for taking the gaps apart or putting them together can be seen at the right of the separate unit.

Clips are provided in the spark gap rack to make connections with the units as they are pressed down in place, or to short circuit the space when the gaps are removed. At the left of the rack are two handles which control the number of gaps in use. The one with the crank carries three contacts to give the main adjustment; the one with the knob has six contacts for fine adjustments. Connec-

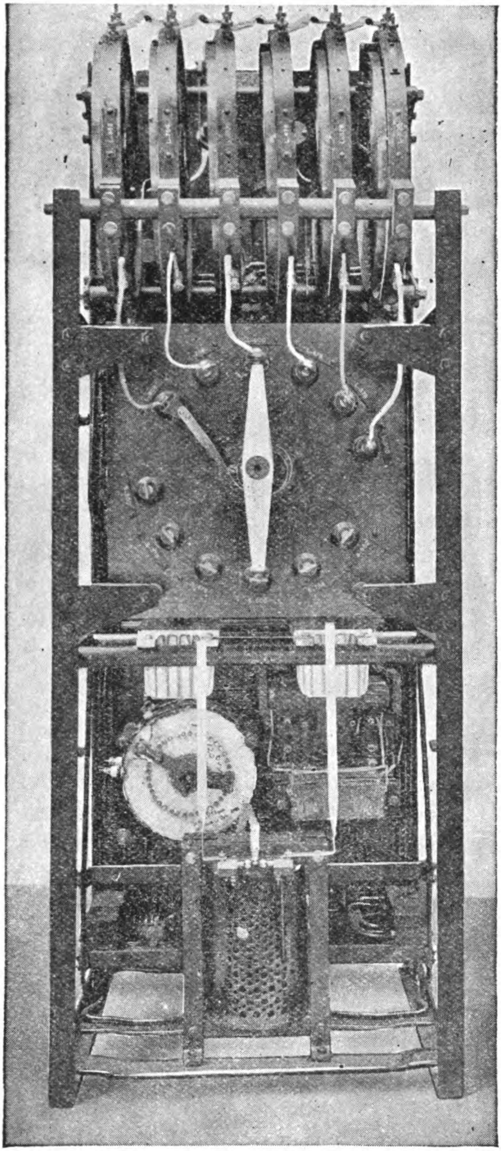


Fig. 36. The rear view illustrates the loading coils and wave changer shown in the simplified circuit diagram. All unused inductances are short circuited to prevent the absorption of energy.

tions can be traced from the first gap at the left to the three-contact shaft, across to the six-contact shaft, and out at the right-hand gap. A crank, fitted to the main adjustment shaft, just inside the rack at the left, moves the primary impedance switch. Thus, as the power is cut down by reducing the number of gaps, the correct impedance is simultaneously inserted in the generator-transformer circuit.

Contacts to vary the inductance of the primary of the oscillation transformer are set into the main panel. The pancake coil can be seen in the side view, close behind the panel. Taps on this coil are taken off by flexible leads and adjustable clips.

The antenna circuit is made up of a radiation meter, loading coils, and coupling coil. When the wavelength switch is rotated, it varies the inductance of the coupling coil and loading coils, as well as of the oscillating circuit. The coupling coil or secondary of the oscillation transformer can be moved back and forth by means of the handle at the left of the panel. A scale is provided to show the separation between primary and secondary in inches. The wiring diagram shows the use of the switches on the shaft of the wave-changer.

Each loading coil has an individual adjustment, accomplished by the rotation of one of the handles, through a bevelled gear and contact sliding on an arm secured to the gear. With this arrangement the antenna circuit can be tuned to each wave, according to the position of the wave-change switch at the front of the set. By tracing the connection from the center of the secondary switch, it will be found that the unused portions of the loading inductances are short circuited.

In the illustration of the spare parts, the antenna switch and lighting switch are shown. The antenna switch is so arranged that, in the down position of the arm, the antenna side of the receiving set is connected to the ground, the transmitter is connected to the antenna by means of the bridge at the top of the insulating post, and the A. C. generator circuit is closed by the contacts on the base.

The lightning switch is designed to be mounted overhead, so that,

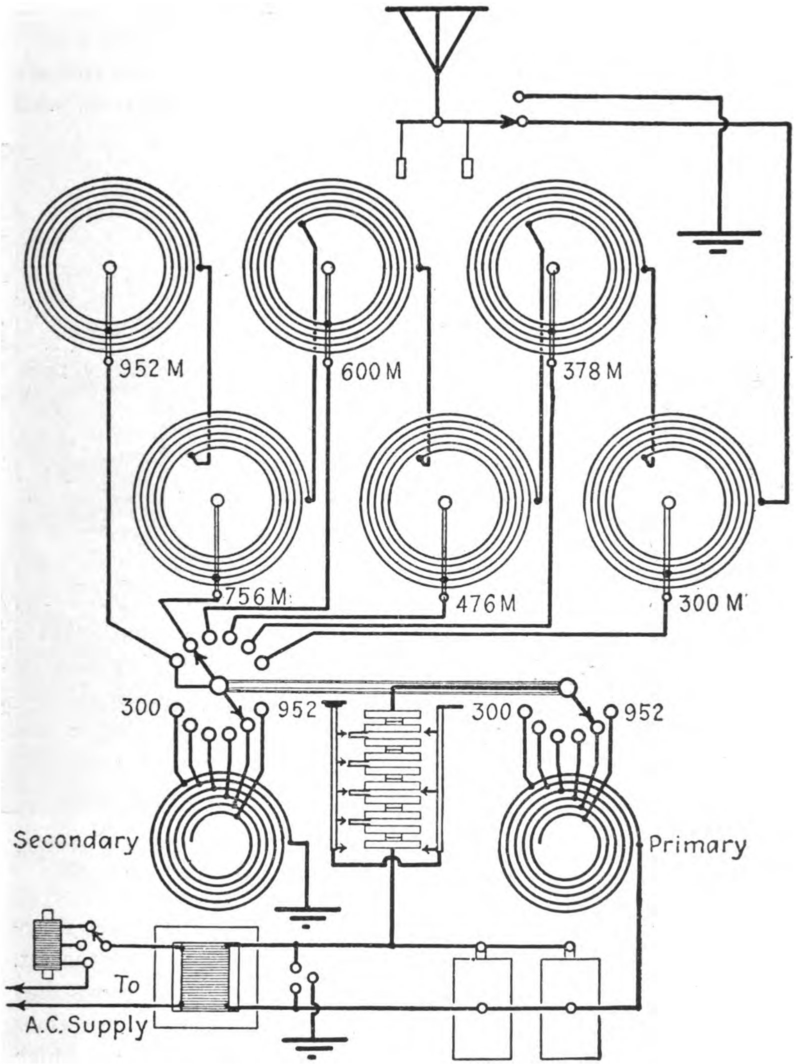


Fig. 37. Simplified circuit diagram.

by pulling the handles, the antenna can be grounded or connected to the radio apparatus.

One of the features which contributes to the efficiency of this set is the absence of metal in the fields of the tuning inductances. All

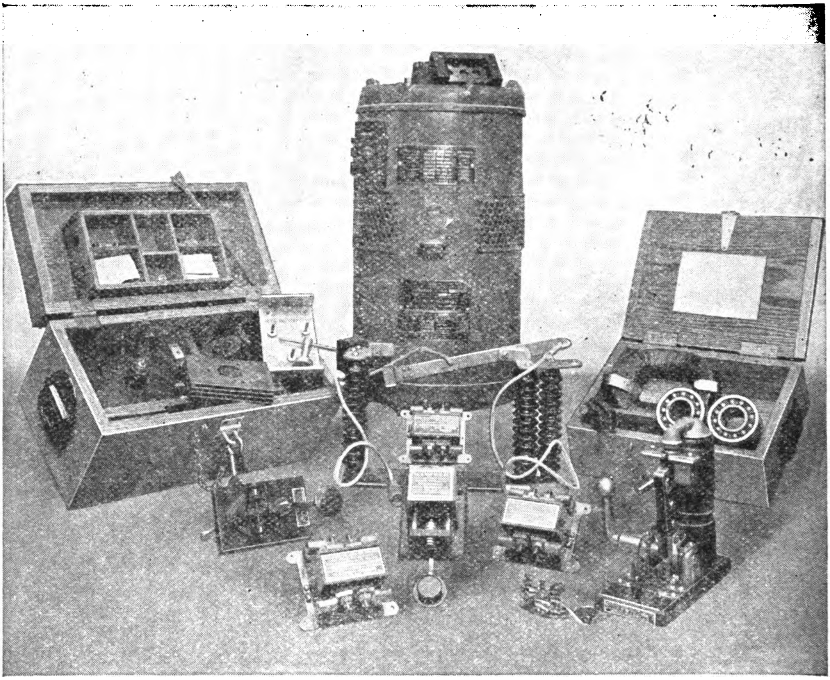


Fig. 38. Spare parts supplied with the transmitter. The lighting switch, operated by pendant handles, is designed to be fastened overhead.

the mounting rods and supports, even to the clamping screws, are of bakelite. Heavy bakelite insulation is used throughout the set. The two factors just mentioned increase the efficiency because they decrease the eddy current and leakage losses. Short connections are made possible by the compact arrangement, yet losses which sometimes occur when instruments are crowded have been carefully guarded against. Large conductors of strip or tubing join the various parts of the high frequency circuits. All power wiring is made by lead-sheathed wire, with the sheathing grounded. Moreover, the electrical design of the generator and oscillating circuits have been worked out to operate at resonance, giving the greatest possible efficiency.

On an antenna of 8 ohms, the radiation is 8 amperes or over. Since the output in watts is

$$W = I^2 R$$

where W = power in watts,
I = current in amperes,
and R = radiation resistance in ohms,
under these conditions:

$$W = 8^2 \times 8,$$
$$W = 64 \times 8,$$

or watts in antenna = 512.

If the generator is putting out 1,000 watts, the per cent efficiency will be:

$$\% \text{ Efficiency} = \frac{\text{W output}}{\text{W input}} \times 100$$

Then, for this set,

$$\% \text{ Efficiency} = \frac{512}{1{,}000} \times 100$$

or 51.2%

At the shorter wavelengths, the efficiency is higher, reaching, under good conditions, as much as 60%. The reason for the decrease in efficiency at long wavelengths is due to the additional losses introduced by the much larger amount of loading inductance necessary to tune small antennas to the lower frequencies.

CHAPTER IV

RADIO EQUIPMENT FOR SMALL BOATS

There are in general, two classes of men who own motor boats and small yachts—one class has the conviction that nothing should be installed unless its is absolutely essential; the other class is comprised of men who want everything which adds to convenience or safety. Both classes are beginning to look with favor on radio.

Although wireless equipment, even on a boat which makes trips of considerable length, may not come under the heading of necessities, it certainly belongs among the devices of safety and comfort. The reason that radio is used on so few boats and yachts is probably because of the technical understanding which appears, to the uninformed, to be required for the operation of a transmitter and receiver.

The technical part should not trouble any man who has enough of an electrical and mechanical sense to master the circuits and appliances of boat engines. As for the telegraph code, the pleasure and interest in operating a radio set is a sufficient incentive for learning quickly the use of the dots and dashes.

Of course, no one can form an accurate opinion regarding the utility of a radio installation on his particular craft until he knows something about the apparatus and its use.

The boat owner whose son has a radio station at home can, by means of the wireless, keep in touch with affairs which require his attention but not his presence. Messages can be sent through commercial and government stations which are dotted along the coast. These are augmented by the great number of experimental stations where the owners are always glad to receive and relay messages without charge. There are so many radio installations now that a

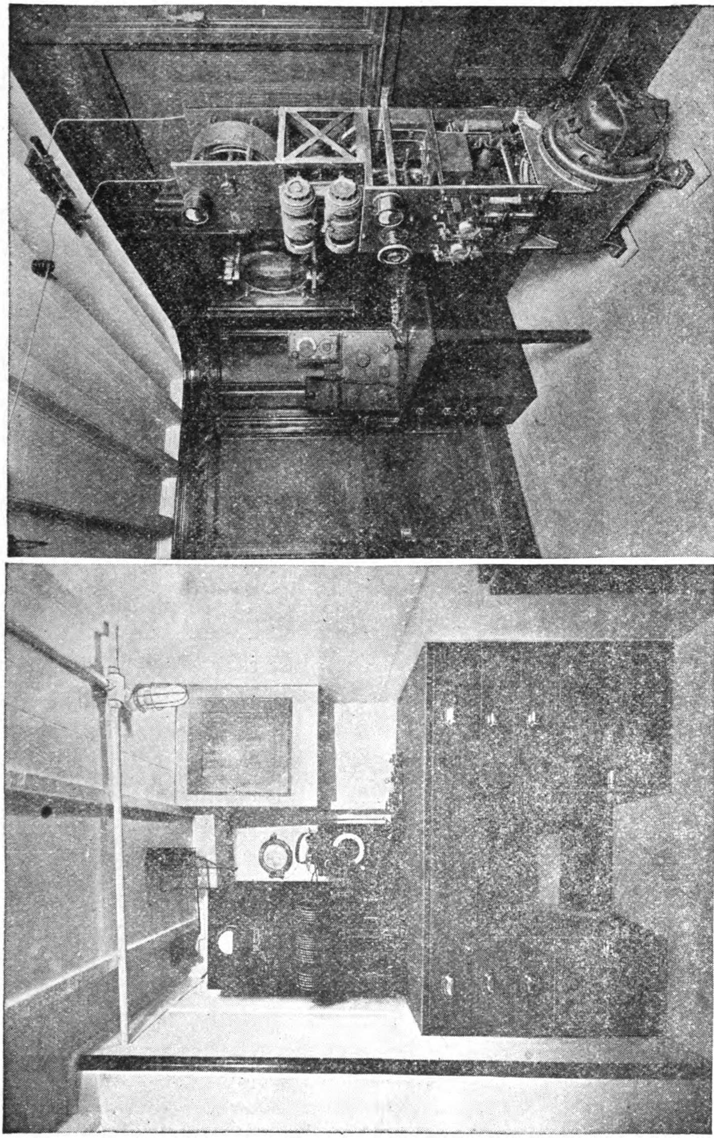


Fig. 39. Two Cutting and Washington installations for small boats. The set at the left operates on ½ k.w., and that at the right, 2 k.w. This type of equipment, because of its simplicity, is well adapted for use by inexperienced operators.

boat within transmitting range of land can almost invariably reach one station or another.

Of still greater and more general application is the use of radio as a safety device. The statements regarding communication with the land stations show the ease with which a boat in distress can obtain assistance. International radio regulations require ship and commercial land stations to maintain a receiving watch on 600 meters. The 200-meter experimental wavelength is near enough to 600 meters that private stations are generally in tune for the calling wave.

Another feature, comparatively new, is the direction finding stations which are located at certain lighthouses, and others, operated by the Navy, at the harbors. Near any of these points it is only necessary for a vessel to request a bearing report, and, by triangulation between two or more compass stations, the ship is located and informed of its position. If a direction finder is installed on the boat, the operator can obtain his own bearings on any land station.

Several types of transmitting and receiving sets are shown in the illustrations which accompany this chapter. These are typical examples, though there are many variations in design, size and power.

Fig. 39 shows two installations of Cutting and Washington equipment, the one at the left on a Russian submarine chaser, and at the right on the Noma, a more spacious craft.

The sub chaser set is made up of the transmitting panel, at the left, and the receiver, at the right. On the table are the detector and telegraph key, and overhead, a lightning switch. Power for the transmitter is supplied by a motor generator, not in view.

A set of this type is suitable for 45 to 50 ft. boats or larger craft. The motor-generator, operating on 110 volts d. c., draws 1,500 watts from the line, and delivers somewhat more than 500 watts, 500 cycles alternating current, to the transmitter. When no generating system has been installed already, a small engine, coupled directly to an a. c. generator, can be furnished.

The transmitting range of the Cutting and Washington ½ k. w.

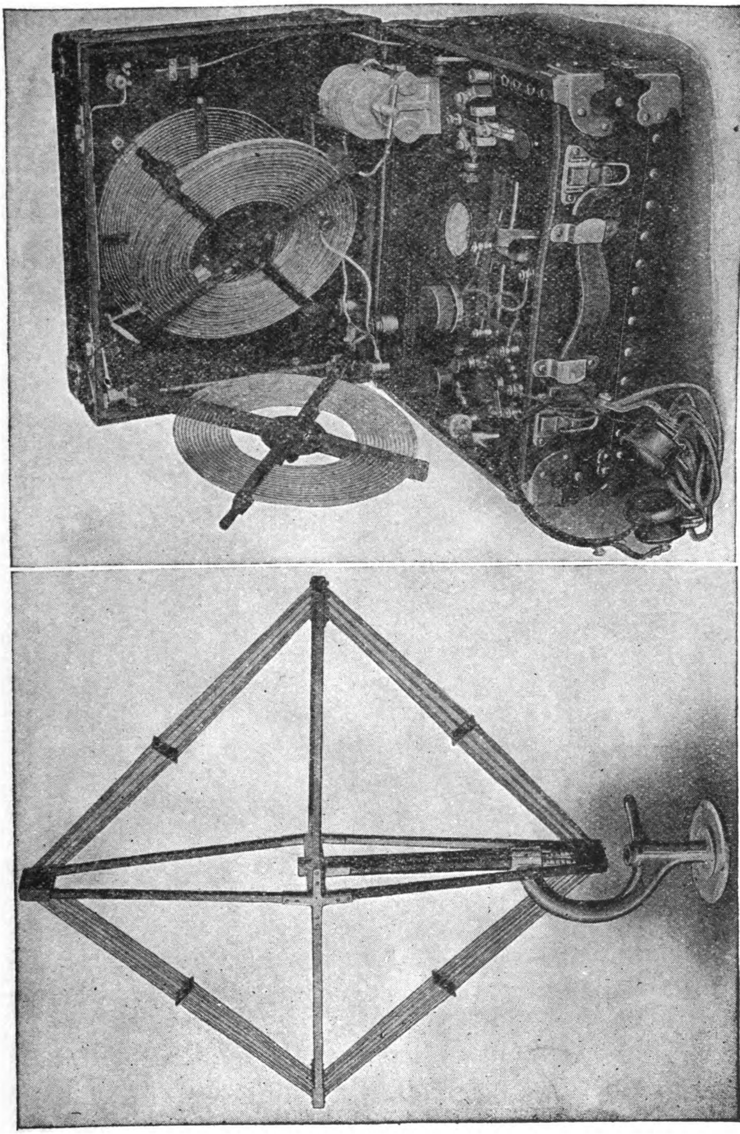


Fig. 40. At the left, a radio pelorus or direction finding loop. Right, a portable 250-watt transmitter and receiver for motor boats and yachts.

set, when used with the necessarily small antenna of a 50 ft. craft, is normally between 75 and 100 miles, although much greater distances can be covered when a very sensitive receiving set is

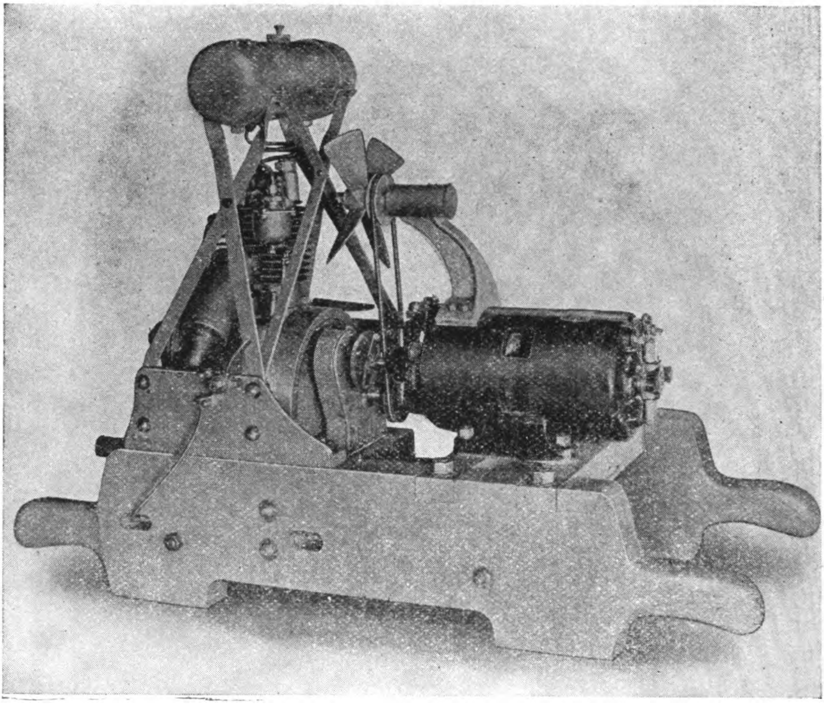


Fig. 41. The Wireless Specialty generator unit can be used on boats not equipped to furnish current for a radio transmitter.

employed at the land station. On larger yachts, where higher and longer antennas can be put up, the transmitting range is considerably increased.

There are several advantages in this type of set. No transformer is employed to step up the voltage. Consequently, there is no danger of injury from high potentials. The usual open spark gap

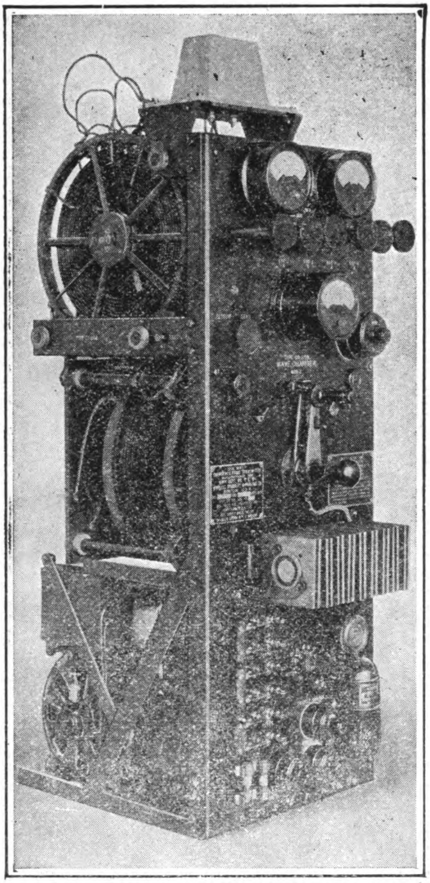


Fig. 42. A 200-watt set, operating on storage batteries or ship's mains, from the Wireless Specialty Company.

is not used, but instead, a closed type which is practically silent in operation.

For longer distance communication, the 2 k. w. equipment, at the right of Fig. 39, is designed. With it a more complete receiver is

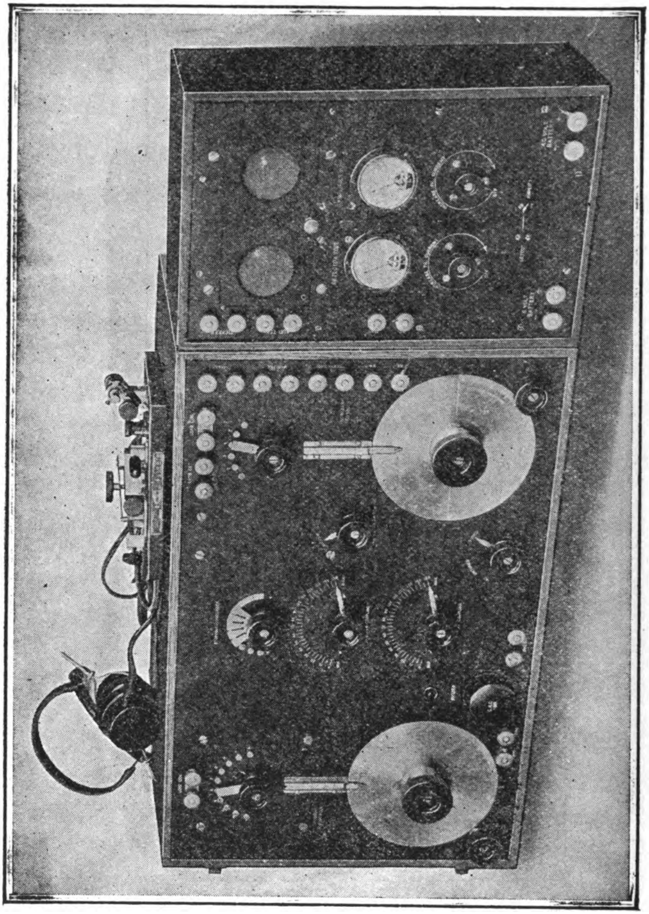


Fig. 43. A receiver of great selectivity and sensitivity, suitable for ship work.

furnished, capable of operation over a wide range of wavelengths. Communication over several hundred miles can be carried on with a suitably equipped land station.

Fig. 43, at the right, illustrates a 250- watt portable transmitter and receiver, built by the Wireless Specialty Apparatus Company. The overall dimensions of the case, when closed, are 17½ by 15 by

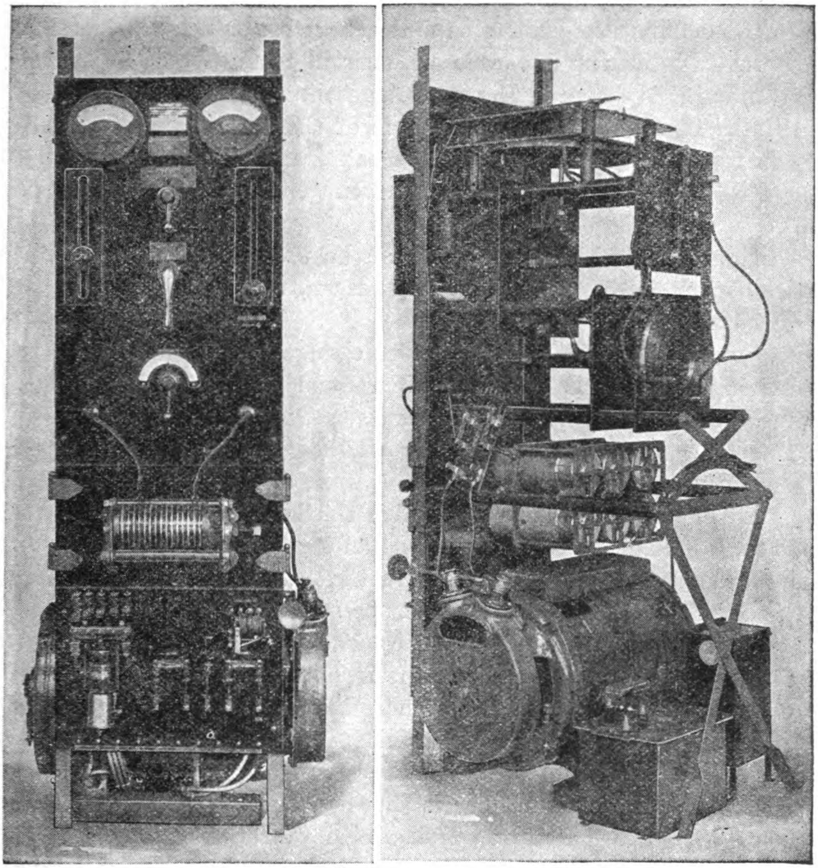


Fig. 44. Larger boats can accommodate 2-k.w. installation such as this Radio Corporation equipment.

10 in., with a weight of 55 lbs., making it an excellent outfit for small boats. All the necessary apparatus, with the exception of the generator, are mounted in the case. The U. S. Navy has used many of these sets for landing parties, where communication back to the ship was necessary.

Power can be supplied from a motor generator, a belted generator, a combination gas engine and generator, or a hand-operated generator, delivering 500-cycle a.c. current to the set. The engine driven outfit is shown in Fig. 41. A gasoline engine unit, complete in itself, is provided. The engine is of the single cylinder, four-cycle type, mounted on a portable oak frame. This unit weighs 130 lbs., while the portable hand-driven generator weighs only 77 lbs.

An antenna of the usual type can be used on shipboard, or a portable, umbrella type if, for any reason, the apparatus is to be carried ashore.

No switch is needed on the set to change from transmitting to receiving as there is an automatic control on the telegraph key. When the key is up, in the normal position, the receiving set is connected. Pressing the key to send, changes the circuit to the transmitter.

Another type of transmitter which can be used for small craft, although it is designed primarily as an auxiliary for large sets, is shown in Fig. 42. The input of this set is only 200 watts, permitting it to be run from the ship's current or storage batteries if desired.

The dimensions over all are 44 by 19 by 15 in., and the weight 210 lbs. All the controls are at the front of the panel, so that the set can be installed in a corner or other convenient place where it will occupy a minimum of useful space.

In Fig. 43, a Wireless Specialty receiving set, equipped with an audion and one-step amplifier is shown. This receiver represents the most advanced design. The efficiency of the tuning circuits and the advantage gained by the vacuum tubes, make possible the reception of signals over very great distances, depending, of course, upon the power of the transmitter and the size of the receiving antenna.

On the top of the case are the telephones and a crystal detector for emergency use. Wavelengths from 150 to 6,800 meters can be received with this set.

Only slight modifications are required to make the set just described suitable for loop reception, or radio compass work. For this purpose, a loop antenna or radio pelorus, Fig. 40, is employed. A small compass is secured to the axis of the loop, near the handle.

To determine the direction from which signals are being sent, the pelorus is rotated until the signals are of maximum intensity. Then the compass indicates the direction of their origin. Such an equipment is of great advantage, particularly on larger yachts which must be piloted with great care in fogs. Some ships have gone for days without making any other observations than those obtained by the radio pelorus. Again, this apparatus makes it possible to enter a harbor when, otherwise, it would be necessary to stand outside until the fog lifted.

A 2-k.w. transmitter, manufactured by the Radio Corporation of America, is illustrated in Fig. 44. This is a commercial type set, transmitting at 500 cycles with a quench spark gap or synchronous rotary spark gap. The former is mounted at the front on the small center panel. The rotary gap is carried on the shaft of the motor generator. Insulated terminals and the phase adjusting handle can be seen in the side view.

Any one of three wavelengths, 300, 450 or 600 meters, can be selected by the handle at the front of the upper panel. A set of this sort is generally used on such boats as can accommodate an operator, or where one of the crew is capable of handling the radio apparatus.

CHAPTER V

ENGLISH RADIO EQUIPMENT

American opinions of English radio equipment vary between the conviction that they are far behind the times to beliefs that they are considerably in the lead. Mr. Philip R. Coursey of London has been kind enough to furnish these photographs, circuits, and data on some of the apparatus built by Marconi's Wireless Telegraph Company, Ltd. This chapter, and others to follow, will show the American experimenters and engineers just what is going on across the ocean.

The ½ and 1½ k. w. tube transmitters have been selected, as there is now such interest in this type of equipment. These sets ar shown in Figs. 45 and 46, with diagram of connections for the ½ k. w. set in Fig. 47.

The first striking feature of construction is the cabinet style of mounting. When the set is not in use, the operating table is turned up, completely enclosing the apparatus. A door is also provided to cover the vacuum tube section, to keep the brilliant light from the eyes of the operator.

It will be seen that the ½ k. w. set has three panels, one at the left carrying the transmitter controls and antenna current meter, the center panel for the tubes, and the right hand panel for the receiving set and six-step amplifier.

Upon going over the circuit in Fig. 47, it will be found that there are points of similarity as well as difference between this set and the conventional types employed by American manufacturers. Starting at the input side, the potential on which the set operates is 85 volts at 150 cycles. The primaries and secondaries of the filament lighting transformers, 13 and 12, and 26 and 25 are designed to step down the 85 volts to 10 volts. The practice of operating filaments on a. c. is not new.

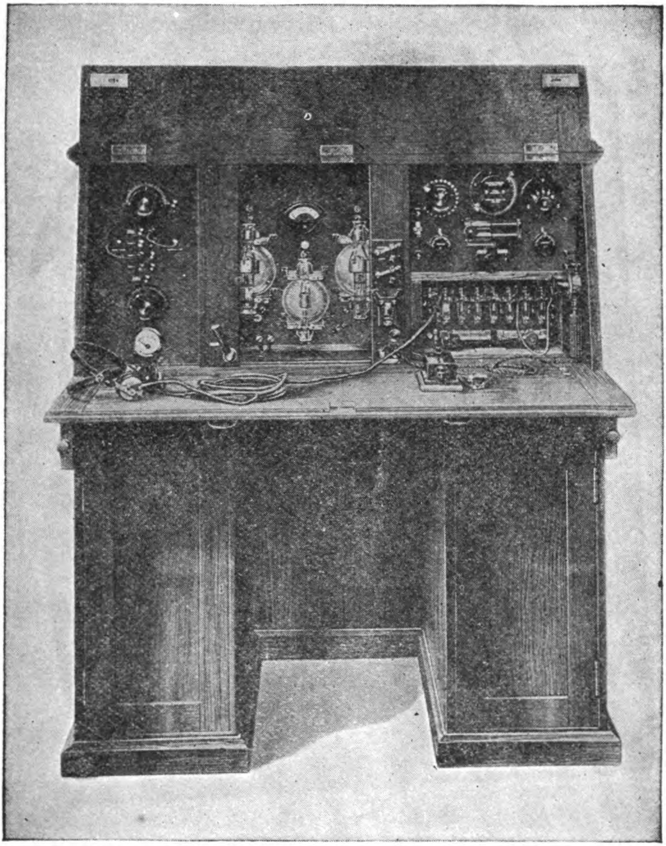


Fig. 45. The ½ k.w. installation looks quite different from the American sets.

Through transformer 28, 27, 500 volts are applied to the plates of the oscillating tube, 8, and the modulating tube, 11. In this circuit a single rectifier, 24, is placed. Because of the high frequency, 150 cycles, of the supply current, it is only necessary to use one rectifier. Condensers 21 and 23, of 0.25 to 0.5 mfd., shunt

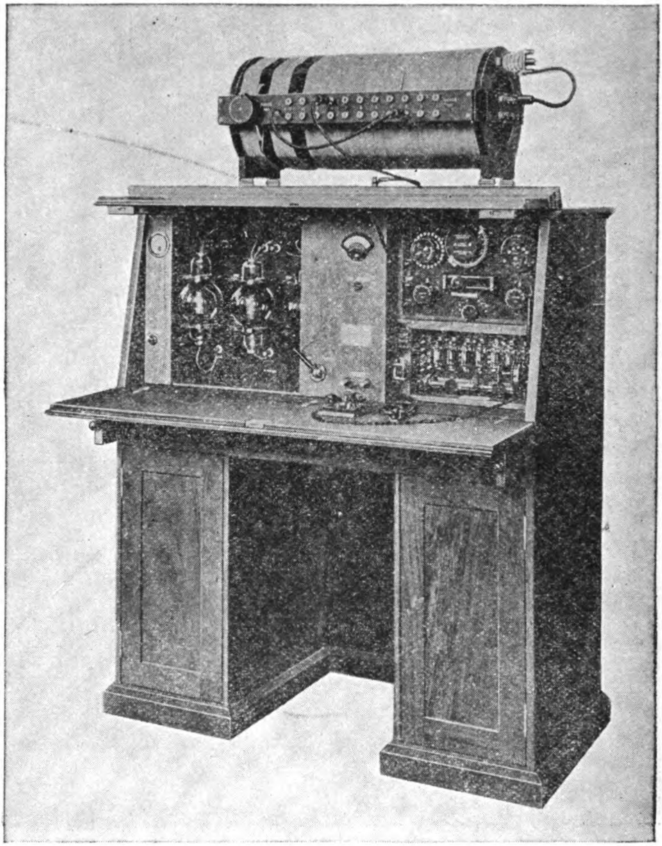


Fig. 46. A 1½ k.w. set which can be depended upon to cover 500 nautical miles.

out any alternating current component, and the modulation choke coil, of 1.5 henries, also smooths out the intermittent rectified current.

The modulation tube, 11, connected in the usual manner, can be controlled by a telephone transmitter, 16, or, for modulated telegraph sending, a buzzer, 17, according to the position of switch, 18. A key, 19, is used with the buzzer. When, however, the set is operating on undamped wave telegraphy, the sending is done by key 20, which, during telephone of buzzer modulation, is kept closed.

A plate current ammeter, indicating the current through the oscillator tube, 8, is connected between the plates. The air-core high frequency choke coil, 9, prevents the high frequency current in the oscillating circuit from backing up into supply circuit.

Distinctly different from American practice are the antenna and oscillation circuits. The lack of variable condensers is particularly noticeable. Direct coupling to the antenna is obtained by the switch from the plate lead, in which condenser, 7, of about 0.01 mfd., is connected. This prevents the short circuiting of the direct current to the ground, but passes the high frequency current. Coupling to the grid is obtained by coil 3 in the grid circuit. The condenser 6 and the resistance 5 constitute a leak circuit. A plug switch gives a rough adjustment of the antenna wavelength, and a variometer, 1, a fine control.

In the ground circuit, a few turns of wire, 4, are coupled to a coil which is in series with the radiation ammeter.

The tuning adjustments can be seen in Fig. 45, on the left hand panel. At the top is the antenna variometer, with the two plugs, for the antenna and plate connections, and 9 jacks, while below are the grill coil and radiation meter. On the center panel, the transmitting tubes are mounted at the outside, with the rectifier at the center, and, above, the plate current meter. Changes from buzzer to telephone modulation are effected by the upper two-pole switch, just at the right of the tube panel.

Two keys are furnished for the telegraph sending. The larger is for undamped wave work, while the smaller operates the modulation buzzer. When the change-over switch, mounted at the left of the center panel, is put on receive, the transmitting instruments are disconnected from the supply line, but a considerable charge

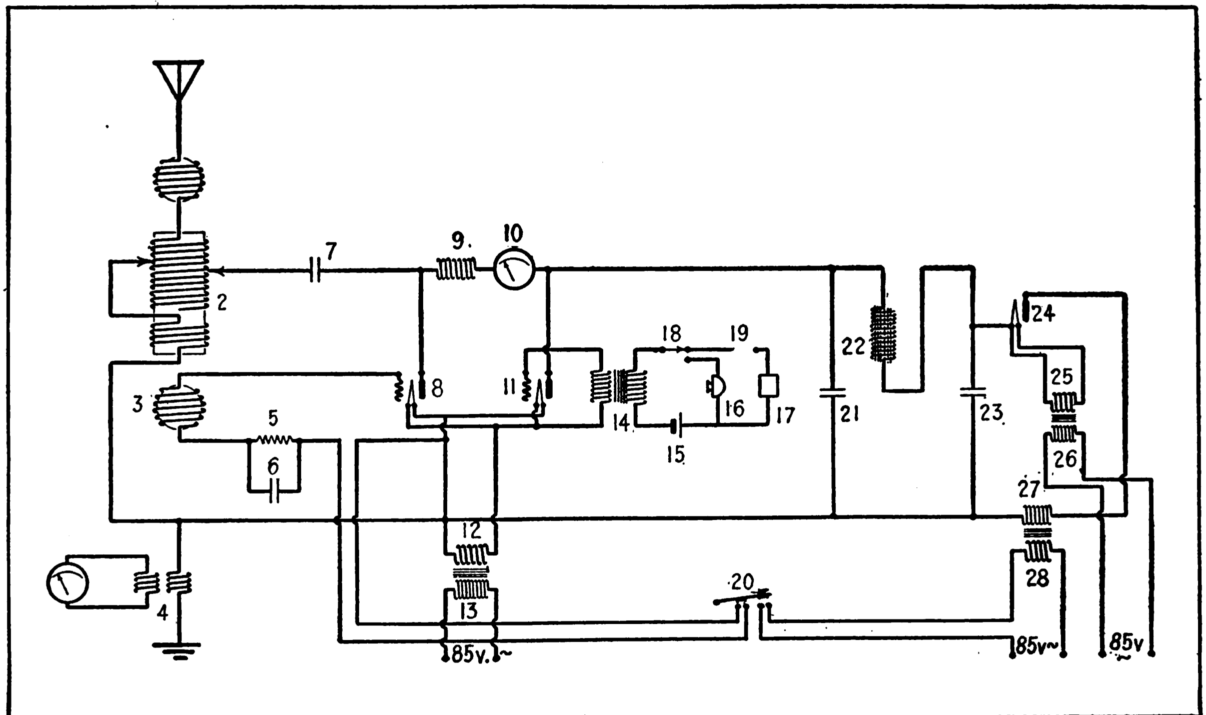


Fig. 47. Complete diagram of the ½ k. w. tube transmitter. This varies from the circuit of the 1½ k. w. set only in small details.

is retained in the smoothing out condensers. Therefore, an insulated discharge button is provided, between the center and right hand panels, to short circuit the condensers. This does away with the possibility of being shocked if any of the live parts are touched just after transmitting.

The transmitting range, on 1,000 to 2,000 meters, is conservatively estimated by the manufacturers as 100, 130, and 300 nautical miles for telephone, buzzer, and undamped wave sending, when an antenna 220 ft. long by 100 ft, high, having a natural period of at least 360 meters, is employed.

Essentially, the 1.5 k. w. set is similar to the 0.5 k. w. type just described. As shown in Fig. 46, the inductance is outside the cabinet. No antenna variometer is used, but rough and fine taps, one at the end, and the other at the front. The plate coupling plug is also inserted at these taps. The grid coupling coil is at the left hand end.

An interesting refinement is the modulation transformer. The primary coil has a center tap which acts as a common return for the transmitter, connected at one end, and the buzzer, with the key in series, at the other end of the primary winding. A battery is inserted in the common return. Therefore no switch is needed to change from telephone to buzzer modulation.

This set, operating at 1,200 to 3,000 meters on an antenna having a natural period of about 400 meters, is rated at 250, 350, and 500 nautical miles for telephone, buzzer modulated, and undamped wave transmitting respectively.

PART III

AIRPLANE RADIO EQUIPMENT

CHAPTER I

AIRPLANE RADIO AND FLIGHT CONDITIONS

Since cause must precede effect, let us consider first the purposes for which radio equipment is used in present day commercial flying. And here the distinction must be drawn between pleasant weather flights and the every day, every week schedule which must be maintained if airplane transportation is to be commercially successful.

The United States airplane mail can be taken as a practical example, for it not only operated on a 365 days in the year schedule, but from an experimental venture it has developed into an enterprise financially sound.

Few people outside of the pilots on the mail planes realize the distinction between ordinary flying, even as it was carried on in war times, and the transportation service. One can almost say that, in the latter case, "No flights to-day," is an order unknown. At the same time all possible precautions must be taken to safeguard the lives of the men in the machines and their cargoes. For this the radio operator and the wireless equipment is given almost entire responsibility when emergencies arise.

Let us take an airplane mail run in a Martin bombing type machine as an example of the use of radio in aerial transportation.

Before taking off the pilot is informed of weather conditions ahead with as much accuracy as can be obtained from the reports. However, these conditions change greatly over a period of several hours. As soon as the machine approaches the first land stations, the operator calls the station at one side of the course and then at the other, asking for information on weather conditions. Fortunately 90 per cent. of the storms are local. Therefore, if there is a storm or high winds on one side, the pilot deviates from his course in the direction of the fair weather.

Again, fogs or storms may be encountered suddenly. Then, by the radio compass, bearings can be taken on a ground station, and time saved which would be lost by straying from the course. If the machine is forced to land, either because of the storm or a breakdown, a land station is immediately notified of the fact, and the news relayed to the destination where another machine, operating on the next leg of the journey, would otherwise wait to no purpose. In the case of the mails, if a plane is forced to land the letters are forwarded by train.

Occasionally it happens that there is a storm at the hangars. The pilot is warned by radio and lands at the first convenient location, where he waits until the storm is over. Then proceeds to his destination and lands in safety.

These are the principal purposes for which radio is used. Now let us consider under what conditions the equipment must operate and the new developments needed.

At all times there is vibration. Designers, in the past, apparently have not considered that on the machine itself lock-nuts, pins, wrappings, soldered joints and many special devices are used to prevent the loosening of the various parts. Certainly if they had they would not have made instruments which in use almost fell apart. Moreover, the severe jolts sometimes experienced are sufficient to tear the parts from their supports. Therefore, while weight is an important factor, airplane radio equipment must be "built like a battleship."

Shock absorbers on the tube sockets do not prevent the transmission of vibration through the air to the glass parts. The tubes must be completely protected, possibly by surrounding them with a box formed of felt.

Interference from wind and engine noises has not been entirely overcome by the padded helmets, although those developed by the Western Electric Company have been found very satisfactory. An interesting comment may be made here regarding the all-metal planes. On these the noise is so slight that a conversation can be carried on inside the machine, a distinct advantage for the radio operator.

Another essential feature is that like the battleship, radio equipment must be water-tight. How many radio men know that, when flying through a storm, there may be several inches of water in the machine? And this at a time when communication is most needed.

Rain storms have a still more serious effect upon the transmitter. In the mail service the ½ k. w. International radio transmitters are now used. This, however, is far from being the ideal set. First off, the generator propeller breaks frequently and is invariably destroyed by the rain. This is a strong argument for a generator driven from one of the engines.

Also the rain drives in around the joints in the cover. The driving force of the rain is so great as to make the hand or face bleed when exposed. Worst of all, the insulation of the antenna breaks down to a point where it is dangerous to operate the set and doubtful if it would transmit if it were operated. At the same time this is the best equipment now available for airplanes.

Transmitting antennas require further development before they will meet emergency conditions. As it has not been found practical to erect the antenna on the plane itself, the trailing wire is still employed.

When a ship passes through an air pocket it frequently drops and rises so suddenly in the heavy air on the far side that the weight, and sometimes the entire antenna, is snapped off. This not only makes trouble in the plane but on the ground as well. Farmers have complained that bombs have been dropped on their homes.

Still greater is the danger when a machine comes down through a fog and the pilot discovers that he is headed for a house or building. During this hedge-hopping the trailing weight strikes objects on the ground and breaks away.

Another disadvantage is the changing characteristics of the antenna due to changes in its position in relation to the machine.

The résumé of conditions under which radio apparatus on transportation planes must operate shows that before it can be termed at all perfect the following developments must be made:

For receiving apparatus—

1. Receiving sets must be of greater mechanical strength.
2. They must be moisture-proof.
3. Noises due to mechanical vibration in the tubes must be eliminated.
4. The controls must be simplified.

For transmitting apparatus—

1. The wind-driven generator must be replaced by a more dependable source of power.
2. Insulation must be waterproof.
3. A substitute for the trailing wire with weight must be used.

Several special conditions and requirements have not been discussed, particularly those applying to single-seater machines. However, the small planes are being rapidly replaced by those of the Martin bomber type, for the future of aerial transportation lies in the large ships. If the developments outlined are carried to successful conclusions, flying will be much safer.

CHAPTER II

200-WATT AIRPLANE RADIO TRANSMITTER

Of the large number of radio equipments built for the Government, by numerous contractors, only a small part were actually used in war activities. The International Radio Telegraph Company's set illustrated here is one, however, which performed no small service for the Army and Navy, because of its actual effectiveness and dependability, and because the particular design lent itself so readily to the limitations of airplane work. Over two thousand of these transmitters were in use before the armistice was signed.

Fig. 48 shows the components of the set and the arrangement of the wiring. The equipment consists of a generator and casing, 6.25 ins. in diameter by 23 ins. long over all, which holds the transformer, condenser, inductance, and synchronous spark gap, two flame-proof telegraph keys with indicating winker lights, a battery and switch for the initial excitation of the generator, and an adjustment box containing a tuning inductance and hot-wire ammeter. An antenna reel, holding 250 feet of special antenna wire made up of six cables, each of seven No. 30 silicon-bronze wires, twisted together is also furnished.

The generator is usually mounted on the lower side of the upper wing. Three leads for the control of the power circuit are brought out to the cockpit of the machine, another for the ground connection to the bracing wires, and a fifth, an antenna lead, runs through an electrose insulator to the variometer box. From this box a wire goes to the brass core of the antenna insulator. In this way, a connection is established with the bare antenna wire as it is let out from the reel.

The winker lights, shunted across the sending keys, burn constantly while the machine is in the air if the field switch is closed, and show whether the generator is functioning properly. When either key is operated, however, the lights blink indicating that

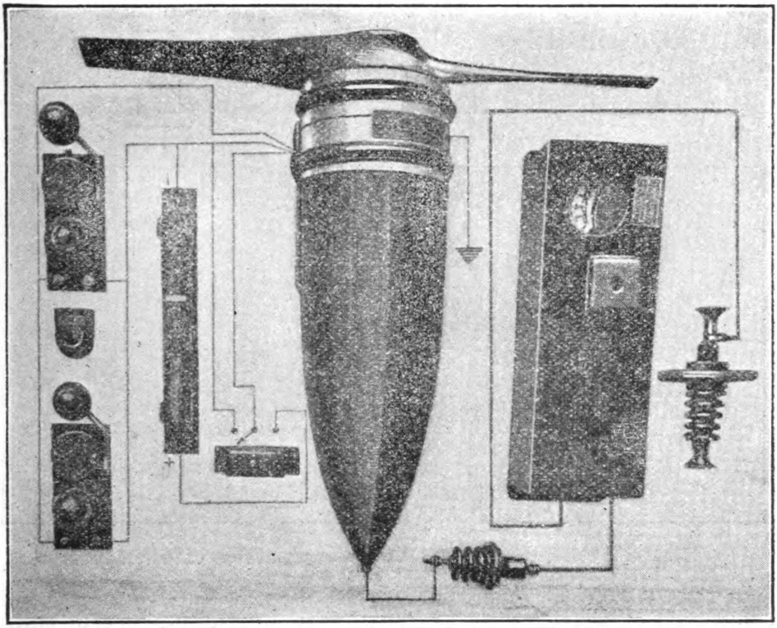


Fig. 48. The complete 200-watt airplane radio transmitting installation, used by the Army and Navy, and similar to those on the Trans-atlantic seaplanes.

either the observer or pilot is sending. This is necessary because the two men are in separate compartments.

When the generators are first installed, some difficulty may be encountered in making them build up to full voltage. Consequently, a small "priming" battery is provided. In the BAT position of the switch the battery is in series with the generator field; as soon as the lights glow the switch is put at ON, cutting out the battery and closing the field circuit. When the set has been in operation a short time this auxiliary is no longer required.

The primary oscillating circuit is made up of a condenser, shunted across the secondary of the transformer, and a rotary synchronous spark gap, in series with the transmitting inductance, around the condenser. One lead from the spark gap goes to the switch-end of the coil; the fixed end is grounded. Another switch is connected to the antenna. Thus the antenna circuit to ground includes a

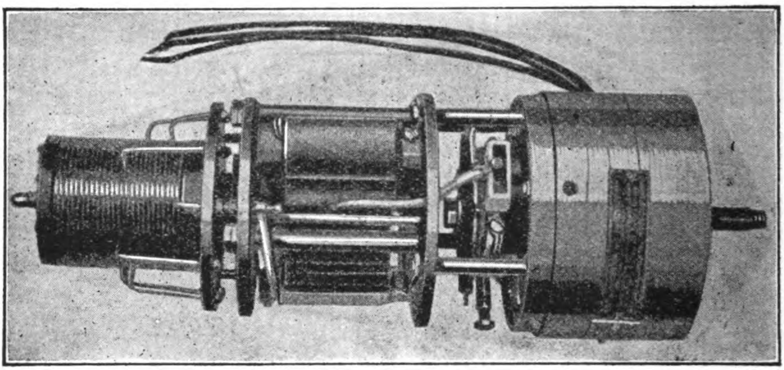


Fig. 49. The transmitter with the streamlined case removed.

small part of the inductance. This is not for the purpose of tuning the antenna circuit, but to vary the coupling to the oscillating circuit to give the desired output.

Fig. 49 shows the generator with the stream-line casing removed. The generator, at the propeller end, is run by the pressure of the wind against the 24-in. variable speed propeller at 5,000 r.p.m., developing 200 watts at 127 volts, 1,000 cycles.

The spark gap, illustrated in detail in Fig. 52 is operated from the generator shaft. Five different rotors are supplied, having 6, 8, 12, 17 and 24 teeth to give different notes. One adjustable electrode is mounted on a frame at the right of the rotor, Fig. 49. The frame fits around a disc, so that it can be rotated to adjust the time of the cycle at which the spark occurs. A special handle is provided so that the adjustment can be made while the gap is running. It can be seen in Fig. 52 extending toward the left. The thumb nut is on a shaft carrying a pin which moves in a slot. In this way the thumb nut can be pulled out, away from the rotor, and adjusted as the conditions require. The sparking electrode is

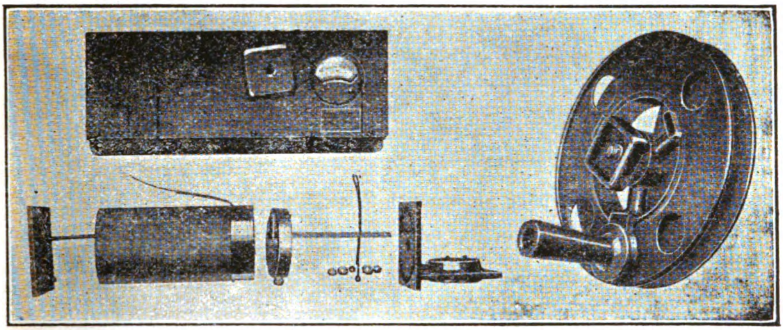


Fig. 50. The radiating circuit is adjusted to resonance with the calibrated oscillating circuit by means of a variometer.

Fig. 51. Atenna reel.

held in a bakelite plate in such a way that the length of the gap can be varied.

Figs. 49 and 52 show the transformer, an unusually small type because it is used on 1,000 cycle current. Directly below the transformer, Fig. 49, is a Dubilier mica condenser of 0.004 mfd.

The construction of the helix is quite interesting. The winding is on a cast bakelite form, arranged to rotate on a shaft fixed to the plate at the left of the transformer and condenser. Taps to vary the inductance in the oscillating circuit are brought to points at the base of the cylinder. The faces of the switch points are convex, so that the hollow contact springs over the switch buttons. To vary the inductance, the coil is simply rotated to the point corresponding to the required wavelength.

Fig. 52 illustrates the coupling switch at the other end of the tube. These taps are taken off near the grounded end, so that a few turns of the coil will be included in the antenna circuit. By adjusting this coupling, the radiation can be controlled. This was

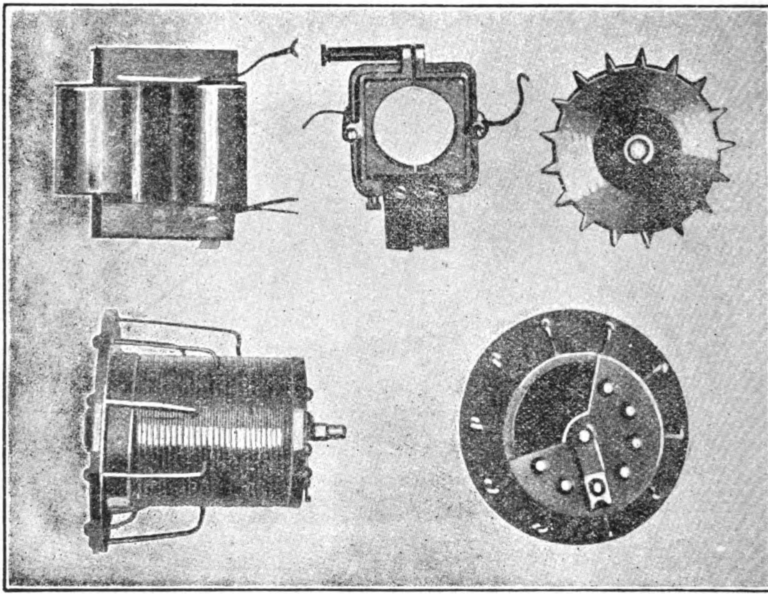


Fig. 52. Detailed views of the transformer, spark gap, and the transmitting inductance.

found to be the most satisfactory way to cut down the power when only short distance transmission was required.

An inductance, mounted within reach of the operator, is used to adjust the wavelength of the antenna circuit. The oscillating circuit is calibrated for various wavelengths, so that it can be set before flight. When the machine is in the air, and the antenna let out, the operator adjusts the antenna inductance for maximum radiation, at which point the radiating circuit must be in approximate resonance with the oscillating circuit.

An illustration of the complete variometer and the parts is given in Fig. 50. The winding is on a slotted tube. This gives a means of contact with the rolling wheel which moves inside the coil. A

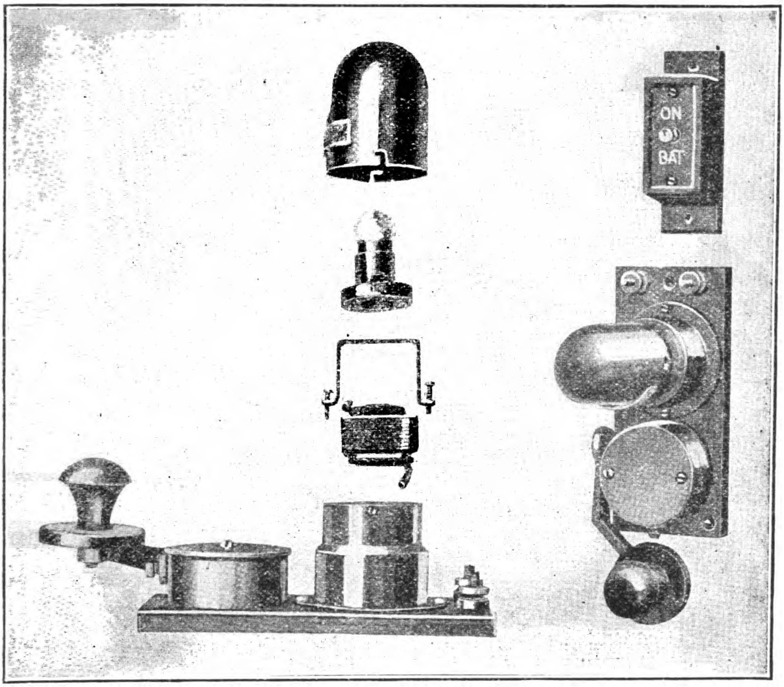


Fig. 53. The flame-proof key and the winker light and transformer mounting.

gear on the handle engages with a rack secured to the slider, so that it can be moved in and out.

Antenna reels caused much trouble from breaking down electrically and mechanically. It is interesting to know that the International Radio reel, Fig. 51, was the only one finally accepted by the Government. This reel holds 400 feet of wire, though only 250 feet are used for communication. In case the wire breaks, more can be let out, or the reduction of the wavelength compensated by additional inductance in the variometer.

Fig. 53 illustrates the flame-proof key and a special arrangement for the pilot light. It will be seen that the key knob is unusually large, designed rather for pounding, since the heavy gloves worn in the air make it impossible to operate the key in the usual manner.

On all sets supplied to the Navy a small step-down transformer was used to supply current to the 6-volt lights, as these stood up better under vibration and shock than higher voltage lights. The transformer is fitted into the socket with the lamp base above, Fig. 53.

The range of this set is from 100 to 150 miles dependable communication, though, by means of the antenna coupling switch, it can be reduced to 15 miles. At full power, 2.25 amperes are put into the antenna of 10 ohms, giving 50 watts radiation.

Apparatus of this type, with higher power, was used on the transatlantic Navy seaplanes.

On the first flight across, a world's record of 1200 miles was officially established. Unofficially, the set transmitted 2200 miles. A simpler receiver, with no amplifier, was used to copy the signals. As far as it is known, this is the lightest weight set for its power and range.

CHAPTER III

RADIO TELEPHONE APPARATUS FOR AIRPLANE COMMUNICATION

A certain amount of very general description has been given of the Western Electric apparatus used during the War for communication between airplanes and the earth. It is not the object of this chapter to expand upon the uses and advantages of such equipment, but to give some definite information regarding the instruments and their operation. Fig. 54 shows the ground equipment used to talk with airplanes by radio telephone.

It consists of a set box containing the apparatus to generate radio frequency oscillations and modulate them at speech frequencies for transmitting, and the detector and amplifier by means of which the words of the aviator in his machine are made audible on the ground. There is also a storage battery to operate the motor-generator set on the power panel, from which current is supplied to the transmitting and receiving set, and a telephone, a transmitter, and a push button to change the connections to transmit or receive.

A rear view of the set box panel is given in Fig. 55 and a diagram of the transmitter connections in Fig. 56. Only the unnecessary details of the circuit have been omitted.

The transmitting set can be divided into two parts, the oscillator, or power circuit, and the modulator circuit, by which the vibrations of the voice are impressed upon the radio frequency current radiated from the antenna.

To make the operation more clearly understood, consider Fig. 57, in which the circuit 1, 2, 3 is oscillating at its natural period. A high frequency alternator of the same frequency, coupled at 2, 4, supplies additional power as it is dissipated in the condensers and

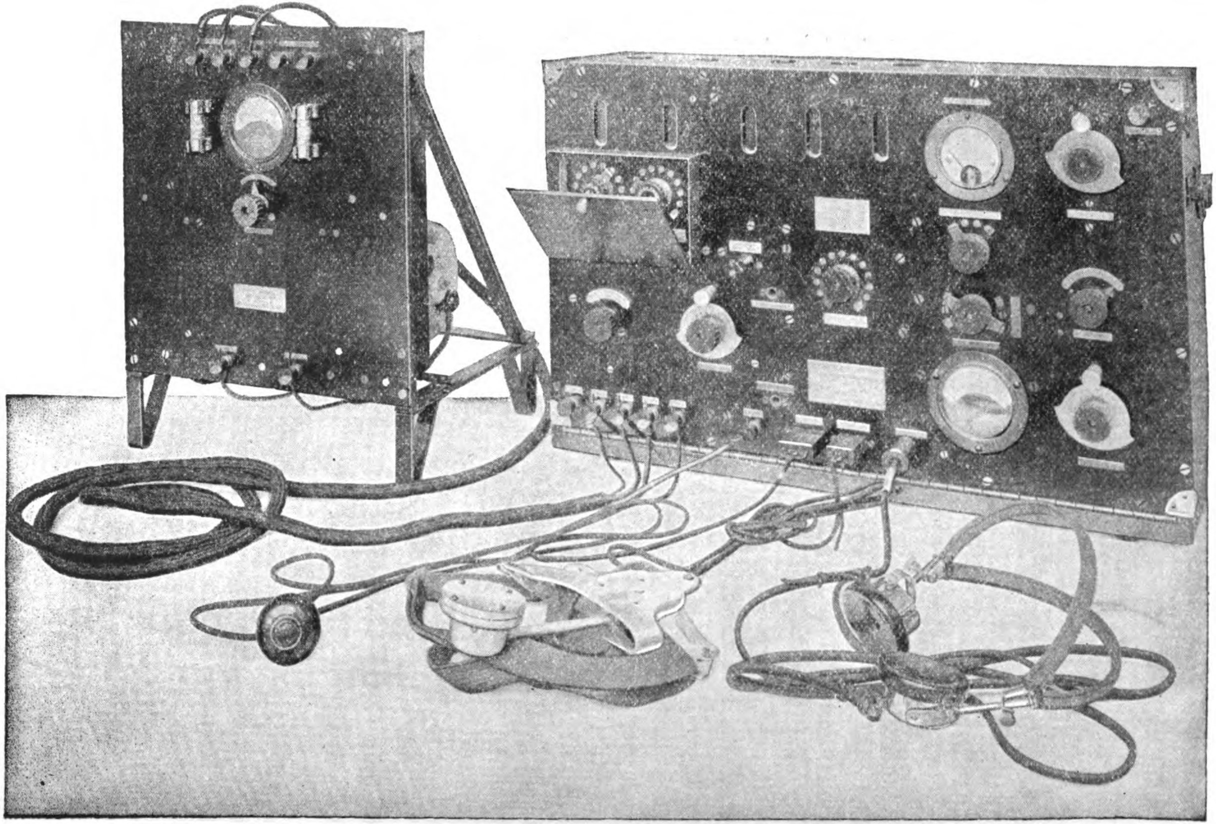


Fig. 54. A complete equipment for communicating from the ground with airplanes. This is one of the standard sets used by the Signal Corps.

inductance. Then, comparing Fig. 57 with Fig. 58, a simple vacuum tube oscillator, it will be seen that the plate-filament circuit performs the function of the alternator in supplying more power as fast as it is radiated from the antenna. The grid varies the plate-filament current in time with the oscillations in 1, 2, 3, so that the 2, 4, 5 circuit applies its periodic driving force at the moment

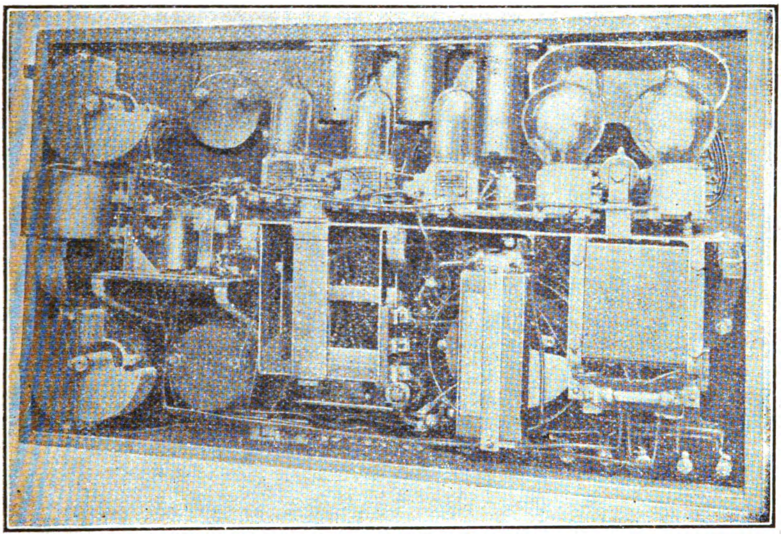


Fig. 55. The interior of the set, showing the various instruments in their places.

needed for maintaining the oscillations. The whole system is analogous to a clock pendulum in which the plate circuit power supply takes the place of the clock spring and the grid of the vacuum tube acts as the escapement releasing the energy at the requisite moment to keep the pendulum swinging.

An examination of Fig. 58 shows its similarity to Fig. 56. The antenna switch, S, controls the wavelength, and S_1 the coupling of the power to the oscillating circuit. Condenser C, of about 1,500 mmfds., keeps the high voltage direct current from going into the

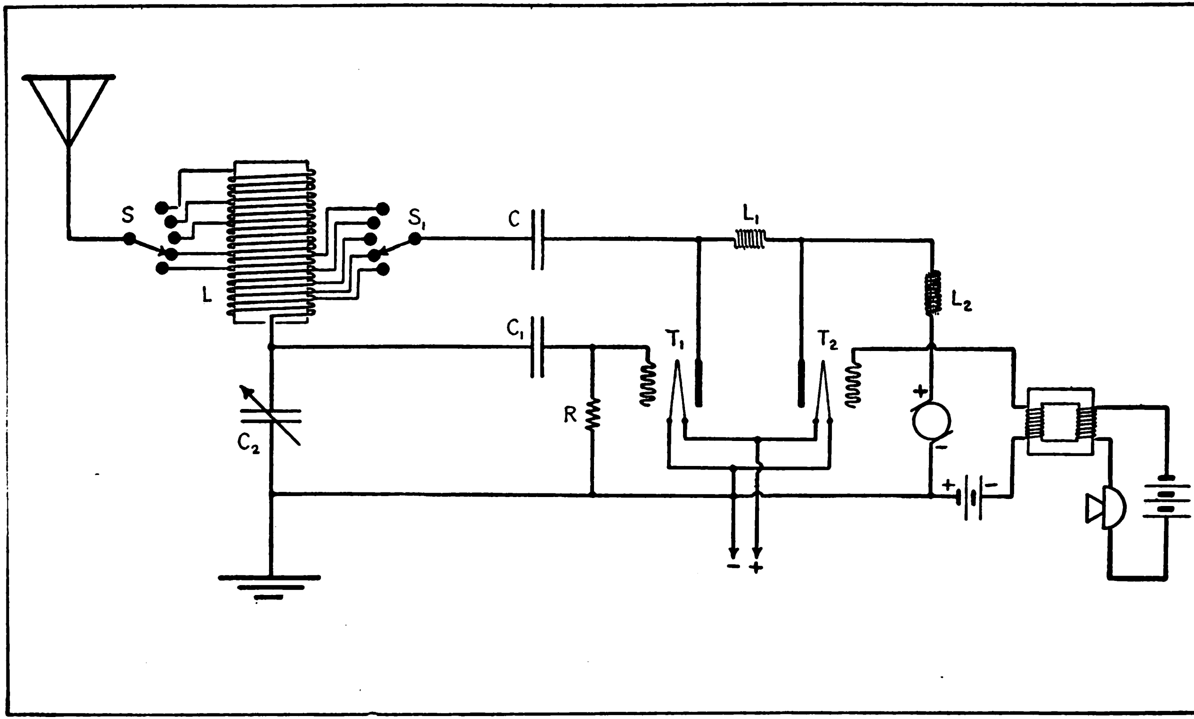


Fig. 56. A circuit diagram of the Western Electric radio telephone transmitter.

antenna; C_1, of about the same capacity, and the resistance, R, about 20,000 ohms, correspond to the stopping condenser and leak used with detector tube; C_2 controls the amplitude of the grid voltage.

In tuning the set, S, S_1 and C_2 are varied for maximum power at the wavelength required.

The plate of T_1 is connected to the plate of T_2 with a high impedance, low resistance choke coil between them, to keep the high

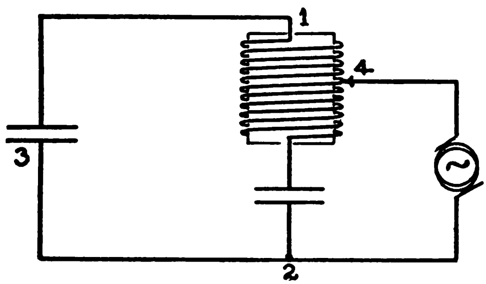


Fig. 57. An oscillating circuit supplied from a high frequency alternator.

frequency current from backing into the generator. Between T_2 and the generator is a high impedance choke, L_2, on which the operation of the modulator depends, as will be explained.

A carbon transmitter, taking in actual practice its current from the drop across the receiving tube filaments, is joined to one side of a speech transformer, the other side goes to the grid of the transmitter tube T_2 and the ground. A battery is shown here, to give a negative grid potential, though actually the supply is taken from the drop across a resistance in the negative side of the supply generator.

When the current is varied by speaking into the transmitter an alternating current is set up in the grid side of the speech transformer, varying the charge on the grid of T_2. This, in turn, changes the plate-filament current in T_2. Now because of the high impedance of L_2, almost infinite to alternating current of voice frequency, the amount of current through L_2 will not vary with variations in the plate-filament current of T_2—instead, more or less current will flow in T_1.

Therefore, an increase in T_2 causes a decrease in T_1, or if the current in T_2 is decreased, the current T_1 will increase. In this way the power of the oscillations in the radiating circuit is modulated according to the vibrations of the voice, so that audio fre-

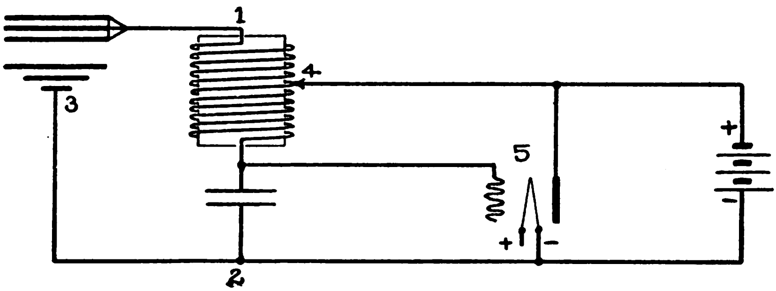


Fig. 58. Showing the similarity of an oscillating audion circuit to the one in Fig. 57.

quency oscillations, made up of radio frequency oscillations, are radiated from the antenna.

A diagram of the receiver is given in Fig. 61. It will be seen that the tuning circuit is arranged so that the detector can be connected directly to the antenna. The switch which makes this connection also gives two variations of secondary inductance.

The detector and amplifier circuit is very simple, because there are no filament rheostats or plate potentiometers, and only two sources of current supply, one for the filament and one for the plate. This is accomplished by using high vacuum tubes with their filaments adjusted to the temperature saturation point of the tube. Thus slight variations in the plate voltage do not affect the signals, as the tubes are at a non-critical adjustment.

Impedance coupling is used between the tubes. These impedances are made up of a core about 2 in. long and ½ in. in diameter, wound with No. 38 enameled wire to a diameter of 1 in. The coil is enclosed in a soft iron case. Fixed condensers of approximately 15,000 mfds. are connected in the amplifier circuit.

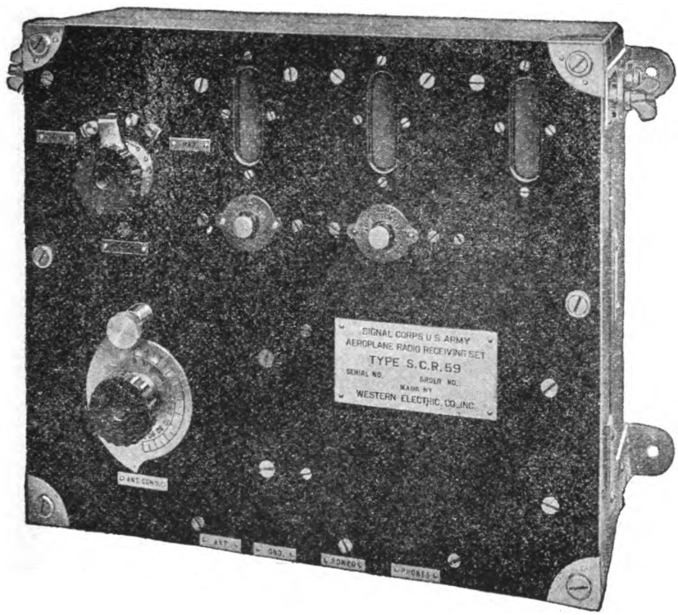


Fig. 59. This Western Electric audion receiver and two-step amplifier was used extensively for airplane reception, both in action abroad, and in training pilots here in the United States.

The front view of the set box, Fig. 54, shows the arrangement of the controls. At the left is a box enclosing the wavelength and coupling control switches and below the power switch and imput condenser. On this end there is also a switch to control the amplification of the receiver and plugs for meters to measure the plate-filament and grid current of the transmitter. A filament current rheostat is located at the center of the panel. Five celluloid windows permit the operator to observe the brilliancy of the vacuum tube filament. On the right are mounted the antenna ammeter, primary receiving condenser, primary inductance switch, second-

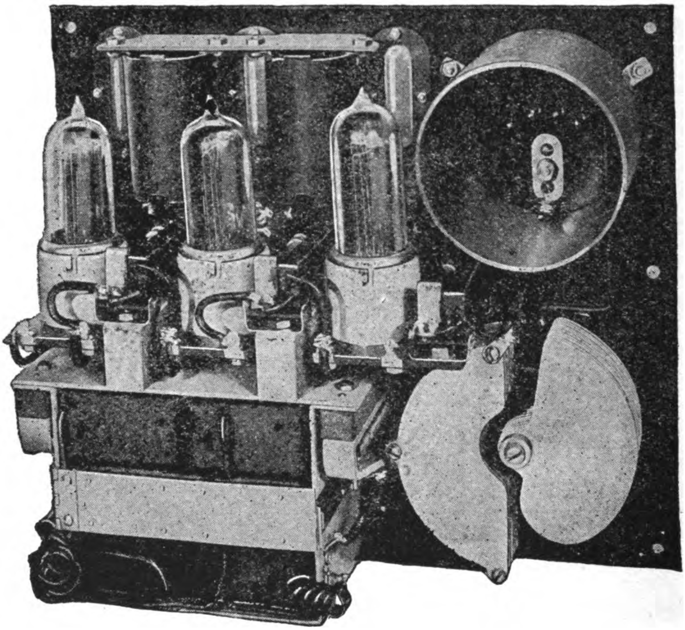


Fig. 60. This Western Electric audion receiver and two step amplifier was used extensively for airplane reception, both in action abroad, and in training pilots here in the United States.

ary switch, coupling handle, filament ammeter and secondary condenser.

The rear view, Fig. 55, illustrates the instruments themselves. On the left are the variable condenser, primary inductance, and rotating secondary coil of the receiver. The relay, operated by a hand push button, changes the connections to sending or receiving.

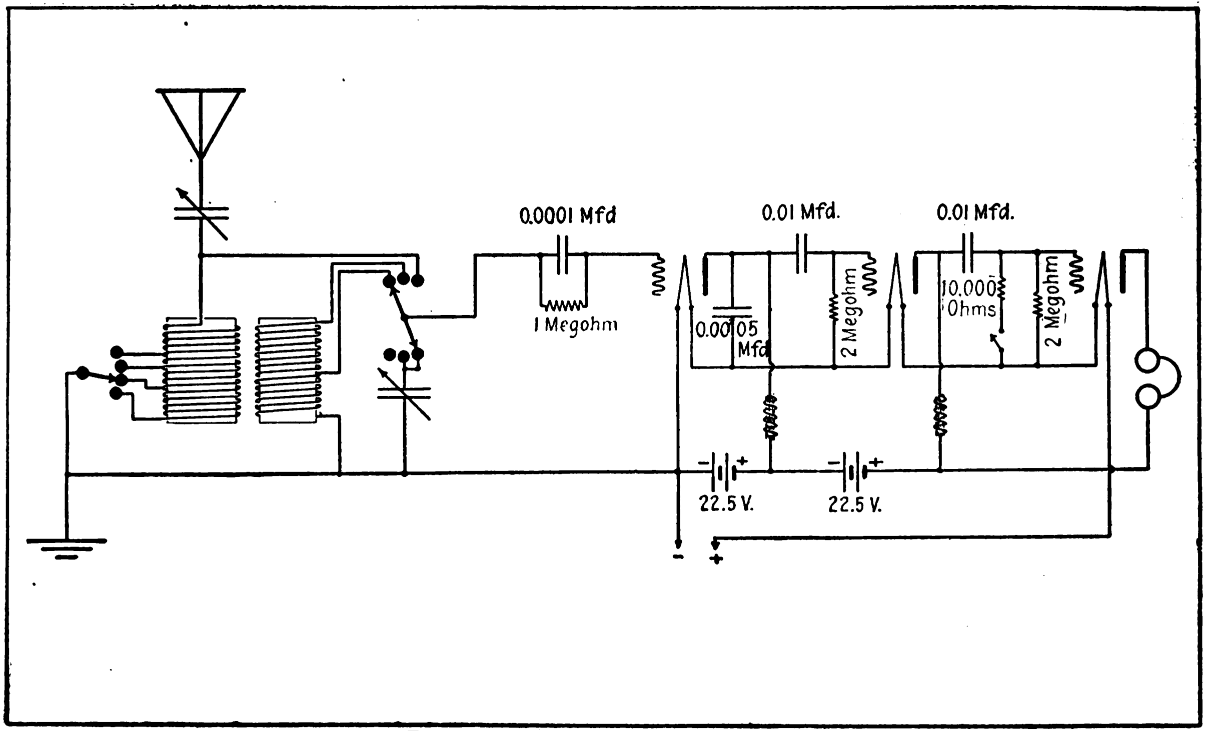


Fig. 61. Connections of the airplane receiving set. It will be seen that one set of batteries is used for the filaments and one for the plate.

At the upper part of the illustration, the tube mounting plate can be seen. The three tubular bulbs, type VT1, are for receiving, and the round bulbs, VT2, for transmitting. In front of the receiving tubes are small series resistances which give the grids a slight negative charge, and between the tubes the paper condensers and grid leaks.

These leaks are made up of a short piece of paper dipped in carbon ink and carefully sealed in a glass tube with metal electrodes at the end. By putting on or taking off ink, the resistance can be varied.

At the right of the third receiving tube is a 10,000 ohm resistance shunted across the last tube, when desired, to cut down the amplification. Above are the two amplifier impedances and the transmitter plate impedance.

Behind the round bulbs is the transmitting inductance on an oval form, shaped in this way to economize on space. The tube mounting plate and plate battery box are mounted on sponge rubber to absorb vibrations and shocks. Two 22½ volt batteries are held in the box by means of the clamp.

The speech transformer and input condenser are mounted below the transmitting tubes. It will be seen that a grounded brass shield surrounds the condenser to prevent electrostatic interference.

Apparatus used in the airplanes for both transmitting and receiving is similar to the set shown in Fig. 54, with the substitution of a wind-driven generator to supply the power. In some cases, where it is only necessary to receive, the set shown in Fig. 59 is employed.

Here tight coupling, or a single-tuned circuit, is used with a detector and two-stage amplifier. The connections are the same as that in Fig. 6 except for the primary coil.

These sets and others won great credit for the Western Electric Company as the most successful radio telephone apparatus developed in any country during the War.

CHAPTER IV

AIRCRAFT RADIO APPARATUS FOR SEAPLANES AND DIRIGIBLES

A number of unique features have been incorporated in the Simon receiver for airplanes. The front of the panel and the instuments mounted behind it are shown in the accompanying illustrations, Figs. 65, 66 and 67. The set is intended for operation on an antenna of 0.00029 to 0.00035 mfd. on wavelengths of 275 to 2,500 meters. The circuit is single tuned with a regenerative method of coupling. Tuning is accomplished by means of a five-point commutator switch. This changes the connections of the inductance coil as well as of the condenser. The first three adjustments have the condenser in series with the inductance, while on the fourth and fifth points the condenser is shunted around the inductance for long wavelengths. The inductance is in two sections on a bakelite core. The smaller section has two banks, the larger six, wound with three cables of 16 groups of No. 38 wire.

The listening-in switch marked oscillator, detector, on the case is of the cam type constructed for low capacity. When pressed to the right it opens the circuit leading to the plate through the plate condenser and stops the oscillations. At the left it closes the condenser and oscillations start.

The plate voltage and filament current controls are different from those of other makes of apparatus. It will be seen that these controls are in the form of bakelite gears, the teeth of which protrude through the front panel. Voltages and currents corresponding to the positions of these gears are marked in the depressions between the teeth. The filament rheostat is the usual toroidal coil resistance wire, such as is used on porcelain base rheostats.

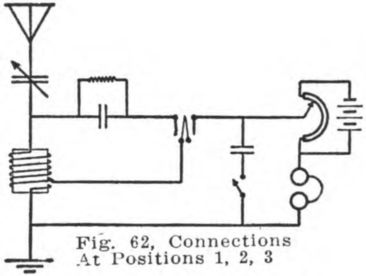


Fig. 62, Connections At Positions 1, 2, 3

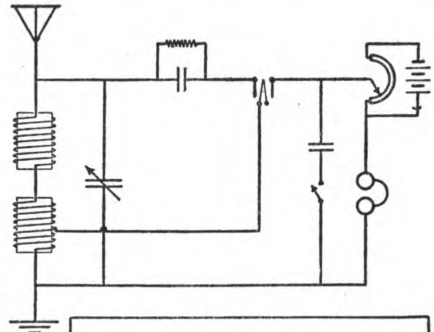


Fig. 63, Connections At Positions 4, 5

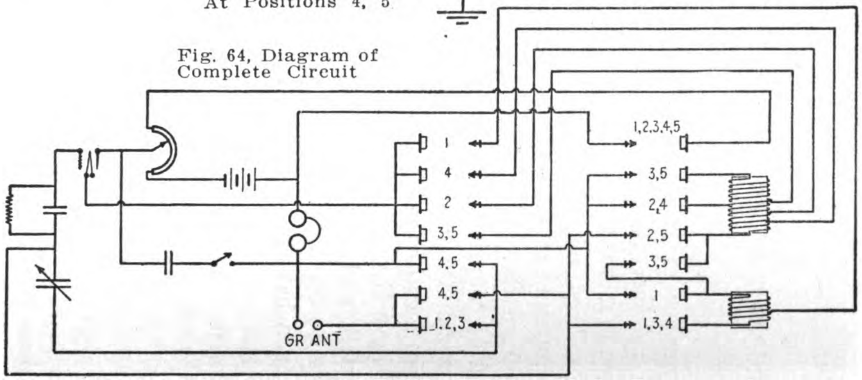


Fig. 64, Diagram of Complete Circuit

A spark and arc receiver using a commutator switch to change the inductance and the connections of the tuning condenser.

The plate potentiometer is a graphite segment with a resistance of approximately 17,000 ohms.

Rough variations in wavelength are obtained by means of a five-point switch on the panel. The shaft carries a bakelite drum. Spring contacts on a bakelite frame are operated by buttons on

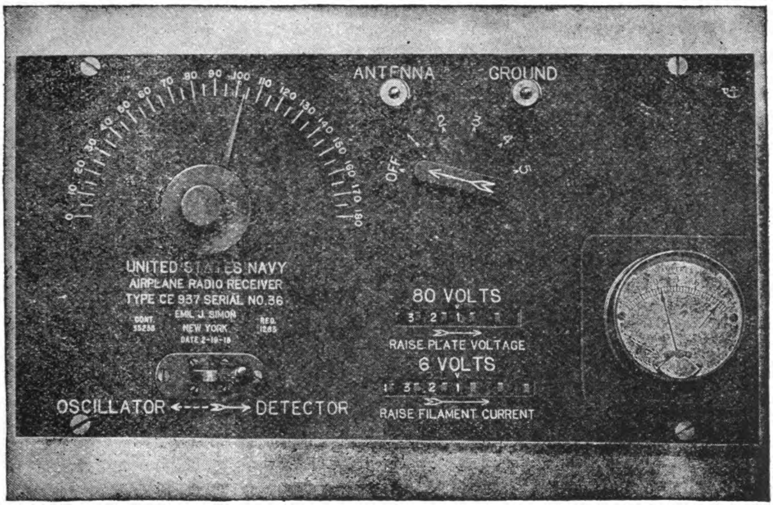


Fig. 65. The panel of the Simon aircraft receiver, carrying the tuning condenser, inductance switch, filament current ammeter, plate and filament controls, and listening-in switch. The panel measures 11½ in. by 5¾ in. This offers new ideas to the experimenters for the design of their own apparatus.

the drum to vary the connections as shown in the diagram. Final adjustments are made with the condenser. An interesting feature of this condenser is the fact that the plates are in a slightly spiralled position. This is to give a larger angular movement for the capacity variations at the end of the range.

An auxiliary adjustment, known as the oscillation control resistance is furnished with sets where there is no adjustment of the strength of oscillation. It is made up of No. 32 enameled Advance wire, variable over a range of 0 to 120 ohms. This resistance is inserted in the antenna lead. When arc signals are being received the resistance is cut out, but for spark signals only enough resistance is used to allow sufficient oscillation for maximum amplifi-

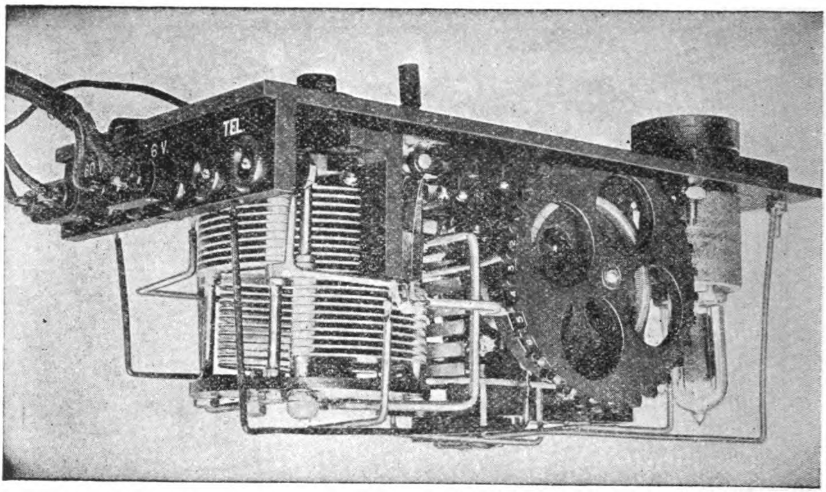


Fig. 66. The front side of the receiver, showing the battery connections, balanced condenser, audion mounted on sponge rubber, and the gear type rheostat controls.

cation. The proper adjustment of the oscillation control resistance will prevent squealing in the receivers.

The panel of this set is approximately 11½ in. long and 5¾ in. wide. The weight of the receiver without telephones or batteries is 10½ lbs. Both the high potential and storage battery are carried separately from the receiver.

High powered sets have been used to a considerable extent on dirigibles and the large seaplanes. The accompanying illustrations, Figs. 68, 69 and 70, show a ½-k.w. 500-cycle airplane transmitter built by the Emil Simon Company for the Navy. This transmitter operates on 425 to 600 meters from a fan-driven generator.

The generator is a self-excited alternator, consisting essentially of a direct current generator to supply the exciting current and an alternator which furnishes power for the transmitter. 500 watts at 500 cycles are developed when the propeller is turning 5,000

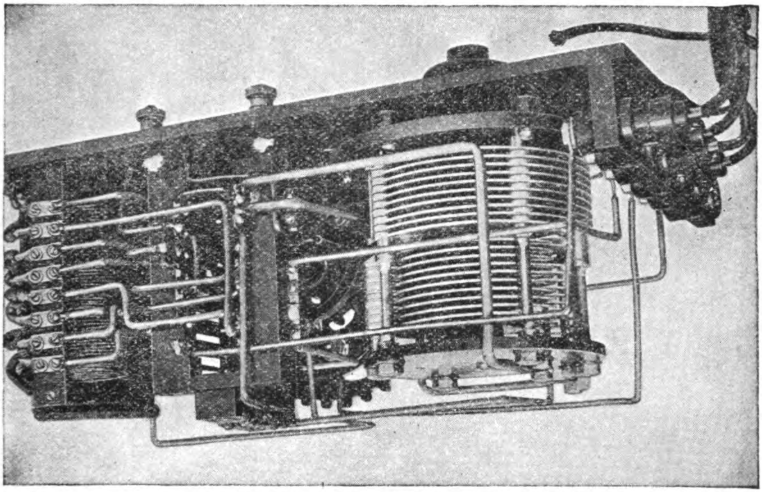


Fig. 67. The rear side of the set. The method of tapping the coil can be seen, and the frame of the commutator switch.

r.p.m. A brake is supplied to stop the generator when it is not in use.

All the instruments are mounted on the panel as shown in the photographs. At the top is the oscillation transformer and wave changer. The frames are made of bakelite wound with edgewise copper strip. The primary has 16 turns. The rear plate has a wave changer switch consisting of a rotating arm making connections on ball contacts. The secondary of 40 turns is adjusted simultaneously when the handle is moved at the front of the panel. The entire coupler can be removed from the panel.

The key is flame proof, that is, the contacts are enclosed in a flexible airtight chamber to prevent accidents from fire, particularly

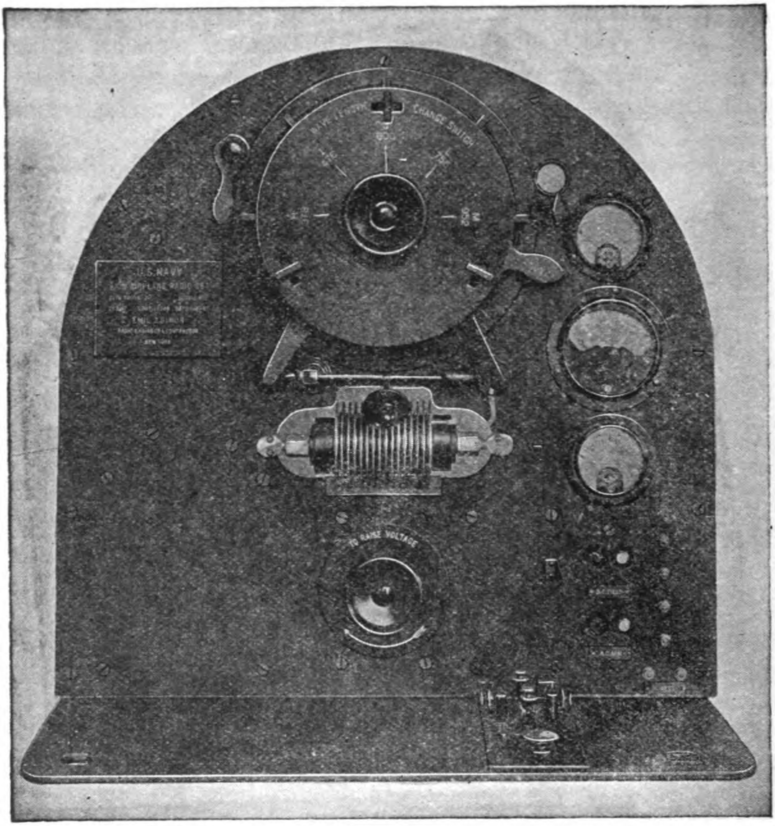


Fig. 68. Views of Simon Transmitter, front.

when the apparatus is used on dirigibles. The chamber is made of specially treated kangaroo skin. When the key is not in use it is turned upward on hinges and held by a catch.

A reactance of about 20 ohms is connected with the transformer to produce resonance. The transformer is of the closed core type mounted at the rear of the panel. It will be noted that this transformer is unusually small, owing to the fact that it is operated on a high frequency. Insulation is provided for 30,000 volts, but it is protected by a gap set at 23,000 volts. The transformation ratio is 60:1.

A quenched spark gap is mounted in an opening in the panel to allow air to circulate around the gap, as it is necessary to keep it cool. There are 16 circular plates of aluminum alloy with silver sparking surfaces. An adjustable contact is fastened upon the gap to allow various numbers of plates to be connected. A spark gap tester is furnished with the sets to short-circuit the gaps. If no sparking occurs at this operation it is evident that the gap is not functioning properly, perhaps because the surfaces are pitted or rough.

The transmitting condenser is of the Dubilier mica type having a capacity of 0.004 mfd. It is designed to withstand twice the maximum potential at which it operates. It has low dielectric resistance and hysteresis losses. The wave meter, frequency meter and field rheostat are mounted on the panel for the control of the generator.

The antenna reel is constructed entirely of bakelite. A revolution counter is provided to indicate the number of turns or feet of wire let out and with a brake to lock the drum during the flight. 600 feet of tinned copper wire are furnished with the reel, although only 300 feet are used for transmitting. The antenna weight is of stream line form weighing 1¾ lbs. All the insulators outside the machine are stream lined to reduce the air resistance.

The three wires forming the ground or counterpoise on airplanes extend between the skid fins above the top plane to the vertical stabilizer above the fuselage. The wires are connected together so they may make a triangular conducting circuit. Each forward apex of the triangle is connected to the nearest bracing wire on the machine, while the rear apex is connected to the aluminum cowl by a wire running forward inside the fuselage. On dirigibles the usual practice is to connect the stay-wires and engine for the ground.

There are considerable possibilities for explosions due to the radio apparatus. It is well known that there is a potential in the atmosphere of nearly 100 volts per meter, near the earth's surface. When the antenna wire hangs vertically downward as in stationary dirigibles, a charge as high as 10,000 volts may be collected. The

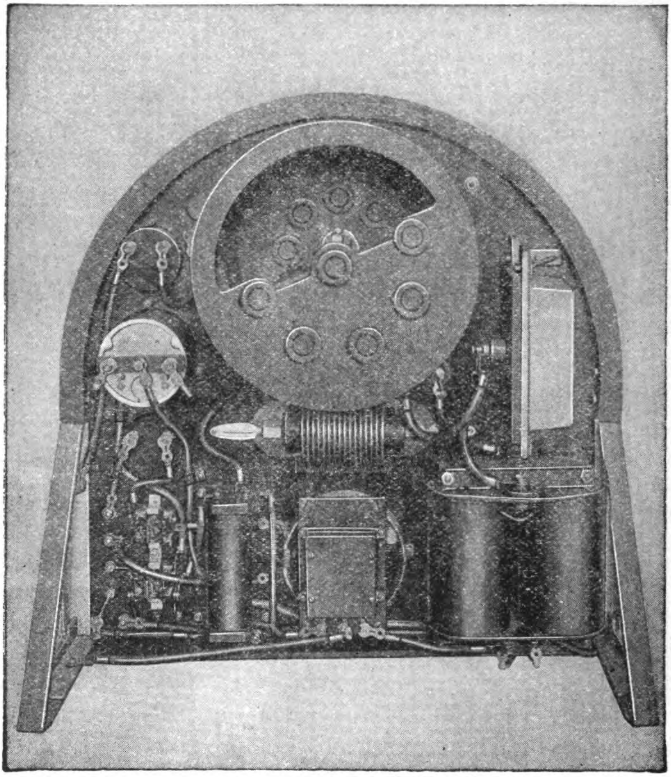


Fig. 69. Views of the Simon Transmitter. At the rear, right to left, the transformer and condenser, voltage rheostat, impedance, meters, and generator controls.

collection of electric charges occurs principally through contact with dust or moist particles in the atmosphere. Operating is much safer at higher altitudes since the potential decreases away from the surface of the earth. At 15,000 feet the potential is only 10 volts per meter. During squalls and electric storms, however, this atmospheric potential has been observed to be as high as 10,000 volts per meter.

Brush discharges sometimes occur when a dirigible ascends or

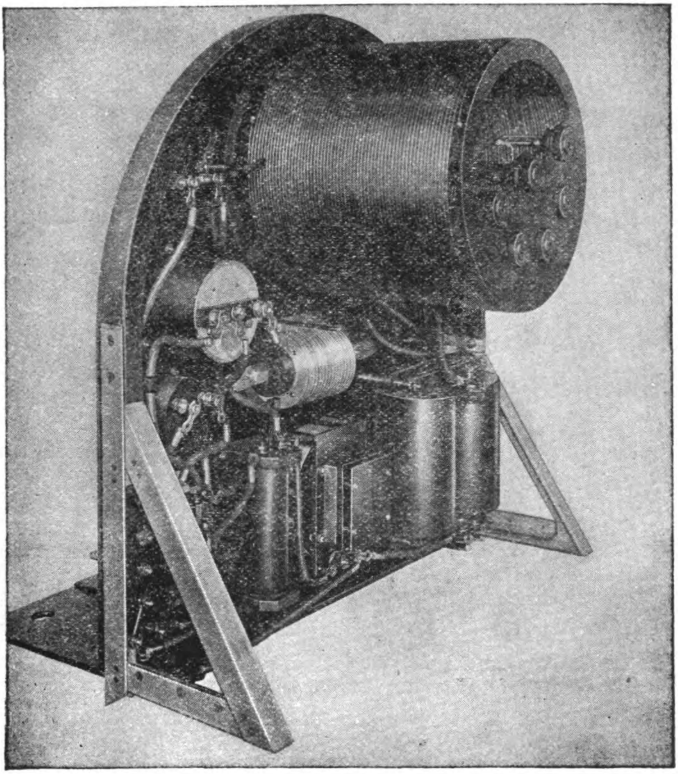


Fig. 70. Views of the Simon Transmitter, side.

descends rapidly during storms. The discharges occur most freely from metallic points facing outward. They also occur with considerable intensity from wet areas on the gas bag.

The danger on dirigibles has been reduced greatly, however, by the use of helium instead of hydrogen gas.

CHAPTER V

LIGHT WEIGHT AIRPLANE TRANSMITTER

Sturdy and simple construction should be the keynote of the new transmitters which are going into commission now that sending sets are operating once more.

The day of the wobbly oscillation transformers, the connections that fall off, and the condenser that sparks around the edges has

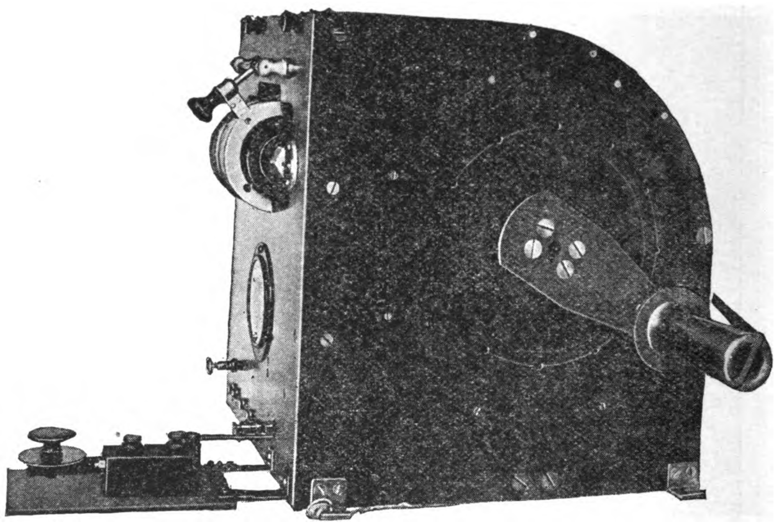


Fig. 71. Showing the spark gap mounting, key, and antenna reel handle.

passed. Of course, there will be beginners always. Experienced workers must take upon themselves the task of pointing out the proper ways and means to those who are just answering the call of experimenting.

The design of the transmitter illustrated in this chapter, Figs. 71, 72 and 73, though intended for airplane work, can be easily adapted to the requirements of an experimenter's set. At the front of the

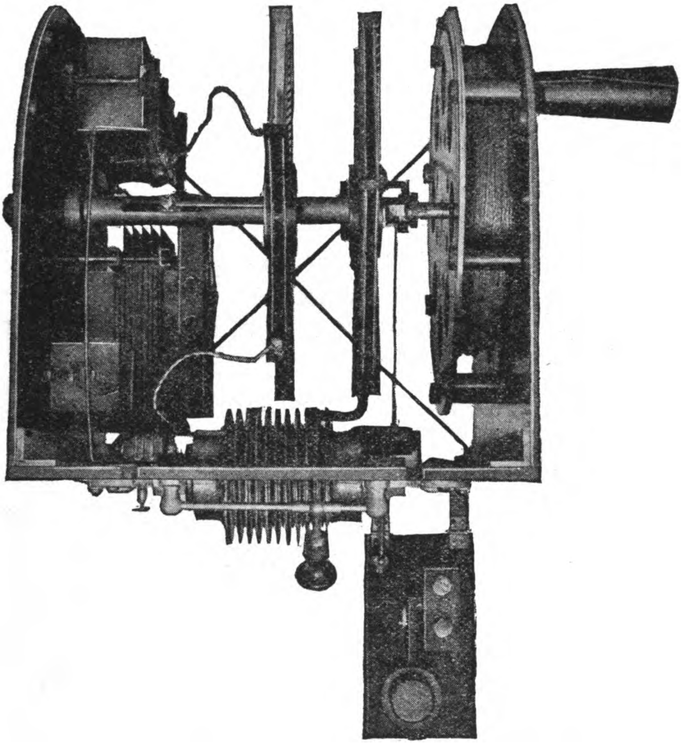


Fig. 72. An arrangement of instruments which, with the exception of the antenna reel, might be followed in making a 200-meter set.

panel, a key, radiation ammeter and quenched spark gap are mounted. Inside the case are the antenna reel, oscillation transformer, condenser and transformer. The case measures 11 in. deep, 11 in. wide and 12 in. high.

Such compactness is largely due to the fact that a 1,000-cycle generator is used to supply current to the transformer. Increasing the frequency reduces the size of the transformer and condenser

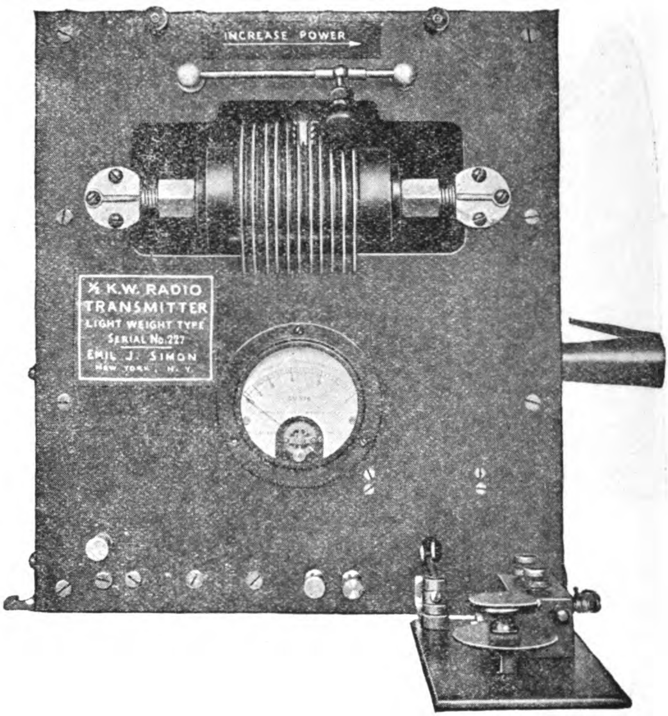


Fig. 73. An arrangement of instruments which, with the exception of the antenna reel, might be followed in making a 200-meter set.

needed. Nine hundred or 1,000-cycle machines are bound to come into extensive use among experimenters as soon as some company realizes the present unfilled demand for them.

An interesting feature of the oscillation transformer is the winding and supports. Instead of using copper ribbon, the conductor is of stranded wire, set into notches, cut at an angle, in the bakelite supporting strips. This is a simple method construction, and, as in the case of copper ribbon, the wire cannot jar loose from the slots. Coupling adjustment is obtained by moving one of the coils along the bakelite mounting rod.

It will be seen that the quenched gap is mounted in an opening in the panel. At the rear of the case, a 3-in. ventilating tube and scoop are attached so that, when the airplane is in motion, a draft is let in which blows out on the spark gap.

Although the generator produces a constant frequency of 1,000 cycles, a spark note of 1,000 or 2,000 cycles can be made by adjusting the length of the gap, or the number of sections. With a short gap spark discharges occur at every alternation of the generator, while with a long gap, a greater charge is required in the condenser with a corresponding longer time between sparks. Thus it is that a full gap gives a 1,000-cycle note, and half the gap, 2,000 cycles.

Moreover, the transformer input and the transmitting range are increased by lengthening the gap. The variation is from 250 to 500 watts input to the set.

The side view shows that the telegraph key is hinged. In the horizontal position, connections are made for sending. The rod, passing through the panel, actuates a switch, when the key is pushed up, which disconnects the antenna and generator. In this way the necessity for an antenna switch is overcome.

PART IV

SPECIAL NOTES ON MISCELLANEOUS EQUIPMENT

CHAPTER 1

MULTI-PURPOSE WAVEMETER

The Simon wavemeter illustrated in the photographs of this chapter has been used extensively by the Navy Department, Figs. 74 and 75. Although there are no unusual points of construction, it may serve experimenters as a guide in designing their own radio instruments.

The case contains a variable condenser having a maximum capacity of 0.0016 mfd., a thermo-galvanometer, crystal detector, buzzer, telephone switch with four inductance coils to give the range from 70 to 2,500 meters. A diagram of connections is given at Fig. 76. In Figs. 77, 78 and 79 elementary diagrams are shown for the circuit at different positions of the telephone switch.

In the forward position, the inductance coil, condenser and galvanometer are connected in series with the detector and telephones joined unilaterally, for the purpose of measuring the wavelengths of transmitting apparatus. The condition of resonance is indicated by the galvanometer and by the telephones as well when the detector is in adjustment.

In the center position the coil, galvanometer, inductance and condenser are in series with the posts marked B. Thus the instrument forms a dummy antenna since resistance can be introduced at B.

In the back position of the switch the coil is in series with the

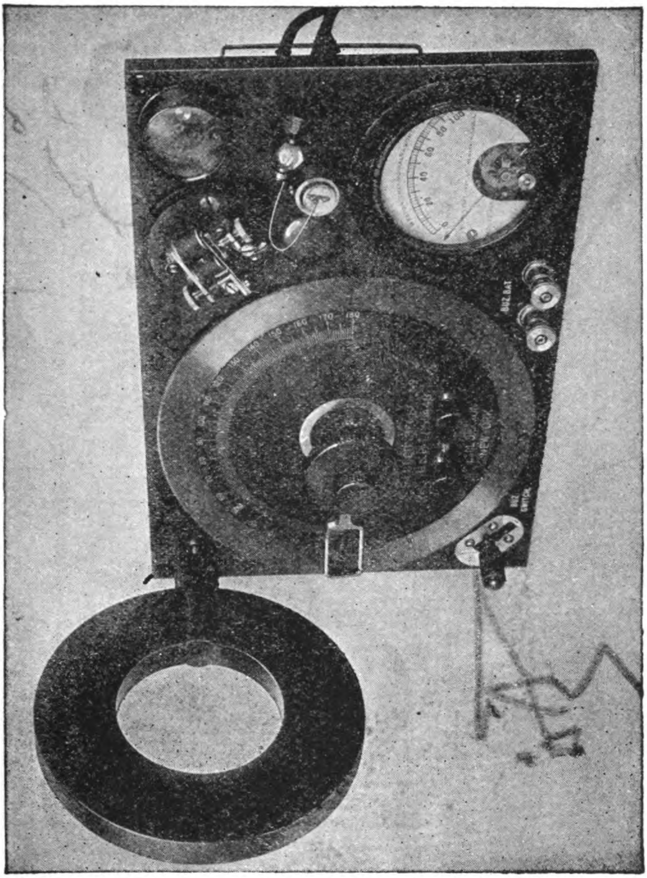


Fig. 74. The panel of the Simon wavemeter, illustrating the arrangement of the various instruments.

buzzer and battery connected at B, while the condenser and galvanometer are shunted across the inductance. Thus the wavemeter can be used for transmitting signals of various wave lengths for the purpose of calibrating receiving sets or similar apparatus.

Fig. 80 shows the position of the contacts on the telephone switch at adjustments 77, 78 and 79. The figures refer to the three circuits previously described.

The switch represented by Fig. 80 is of the usual telephone cam switch type. The two sets of movable contacts are bent in such a way that they naturally bend toward the center—that is, their natural position is as in 3. Moving the handle to either side presses one or the other set of contacts outwardly.

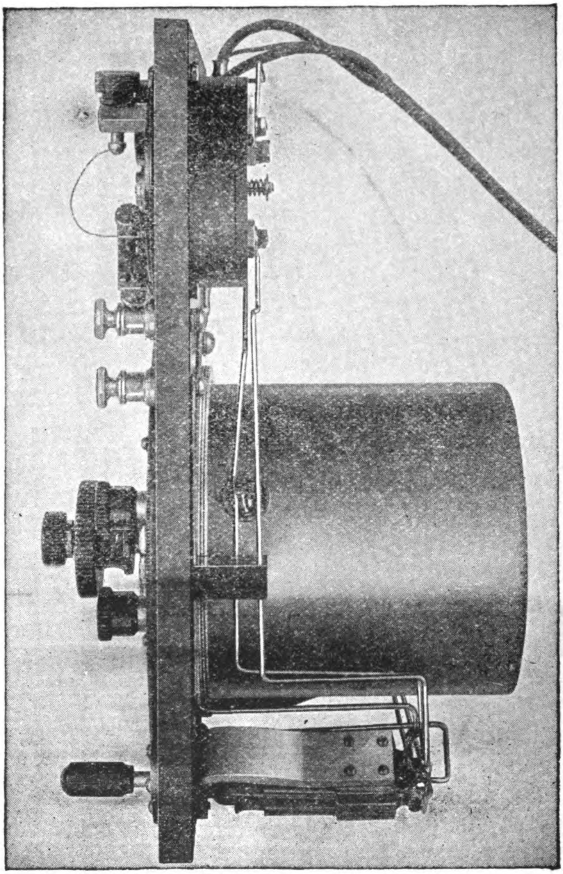


Fig. 75. A side view of the meter showing the telephone switch, condenser mounting, and the simplicity of the wiring.

In Fig. 76 the points at the centers of the groups of three correspond to the movable contacts in Fig. 80. Thus, the movement of this switch will be up and down, similar to the representation at Fig. 80.

For receiving purposes an audion can be employed in place of the detector, by connecting the grid to the condenser instead of the detector, Fig. 76. The plate, B battery and telephones should be

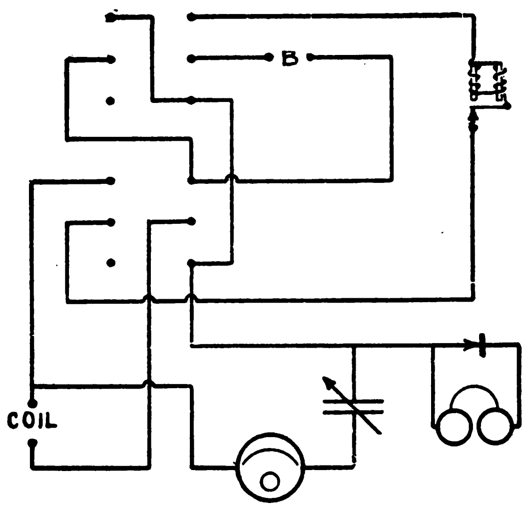
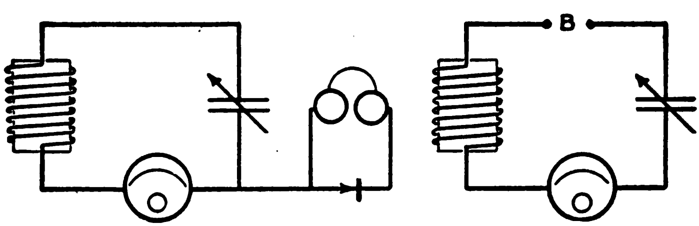


Fig. 76. Wiring diagrams of the wavemeter. By means of the switch, three circuits can be obtained for receiving or transmitting at definite wave-lengths, or for making dummy antenna measurements.



Figs. 77 and 78. Wiring diagrams for wavemeters.

joined in series to the filament, according to the usual practice, except that no connection is made from the filament to the remainder of the wavemeter circuit.

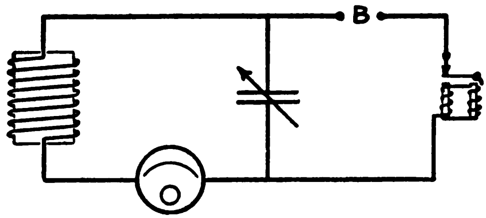


Fig. 79. Wiring diagrams for wavemeters.

Great care has been taken to keep the distributed capacity in the inductances and leads as low as possible to preserve the accuracy of the meter, for distributed capacity increases with the frequency. Trouble is particularly liable to occur in a wavemeter in tuning

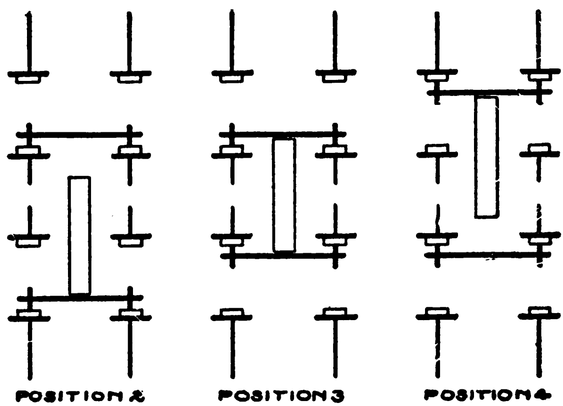


Fig. 80. Wiring Diagrams for wavemeters.

a quenched gap circuit, for the shock excitation often causes a wavemeter circuit to vibrate between the fundamental period and the first harmonic.

It should be noted that the thermo galvanometer gives readings proportional to the square of the current. A Weston meter is used in this set. Aside from the measurements taken by means of the thermo galvanometer, this instrument gives an indication of the proper amount of coupling between the wavemeter and the transmitter whose wavelength may be measured. If, as the condenser handle is rotated slowly, the pointer moves gradually up and back, as the resonance point is reached and passed, the coupling is too tight. When the coupling of the inductance coil is properly adjusted, the pointer will jump quickly at the resonance value. In making measurements, as slight an indication of the meter as possible should be used to prevent the occurrence of humps. This is an important point to remember when using any wavemeter for receiving.

The simplicity of the winding and general arrangement of the apparatus should be noted, as this is of great importance in wavemeters. The wiring is of No. 14 bare copper wire covered with Empire cloth tubing. The elimination of complicated connections obviates the difficulties of unwanted resonance points for the range of the meter.

CHAPTER II

AN INSTRUMENT FOR THE PRODUCTION OF UNDAMPED WAVES

Among other apparatus constituting a new line of experimental equipment brought out by the Wireless Specialty Apparatus Company are the Eaton Oscillator and Eaton Circuit Driver.

These names may be misleading at first thought, but the description which follows will make clear the use of the instruments.

Oscillating circuits, either for the reception of undamped waves or for laboratory experimenting, generally contain tickler coils and condensers which must be adjusted for different wavelengths or

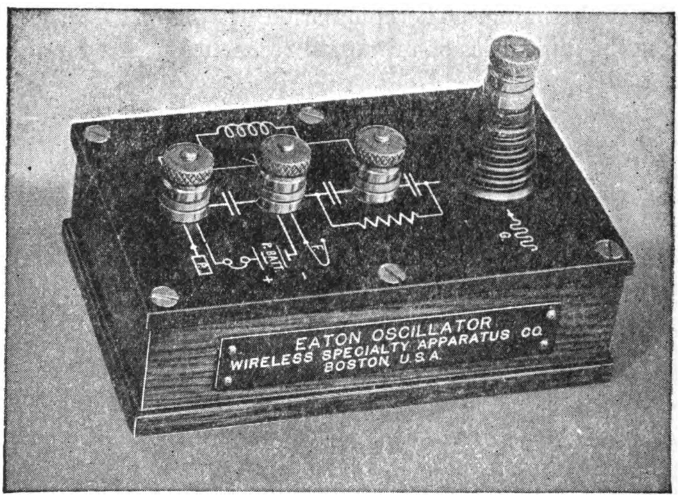


Fig. 81. A new instrument for undamped wave reception or generating oscillation.

conditions. The Eaton Oscillator does away with all the extra apparatus which must otherwise be added to an audion detector circuit to make it oscillate. In other words, a loose coupler, tuning condenser, and the audion with the necessary batteries are the only instruments used with the Eaton Oscillator.

Those who have used the usual oscillating circuits for reception over a range of 200 to 25,000 meters will appreciate what it means

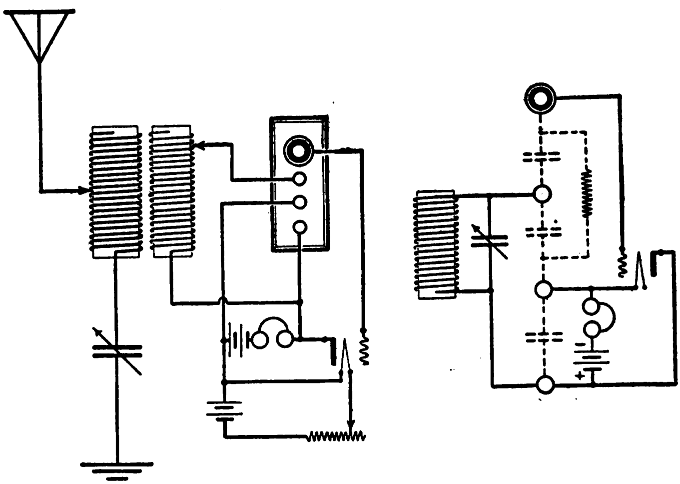


Fig. 82. Circuits for the non-adjustment oscillating set for 150 to 25,000 meters.

to do away with all the auxiliary instruments generally required to keep the circuit oscillating. It is a great advantage in tuning undamped wave stations to do all the tuning with the loose coupler and secondary condensers only. An antenna tuning condenser may be used also, of course.

Fig. 81 shows the Eaton Oscillator, and Fig. 82 a complete receiving circuit. The large circles indicate the oscillator binding posts, and the dotted lines, the connections within the instrument. The secondary circuit is also engraved on the top of the panel. The condensers and resistance are sealed in a low dielectric loss compound as a protection against the absorption of moisture.

When the audion is to be used as an oscillion for the generation of undamped waves, a coil and capacity, corresponding to the

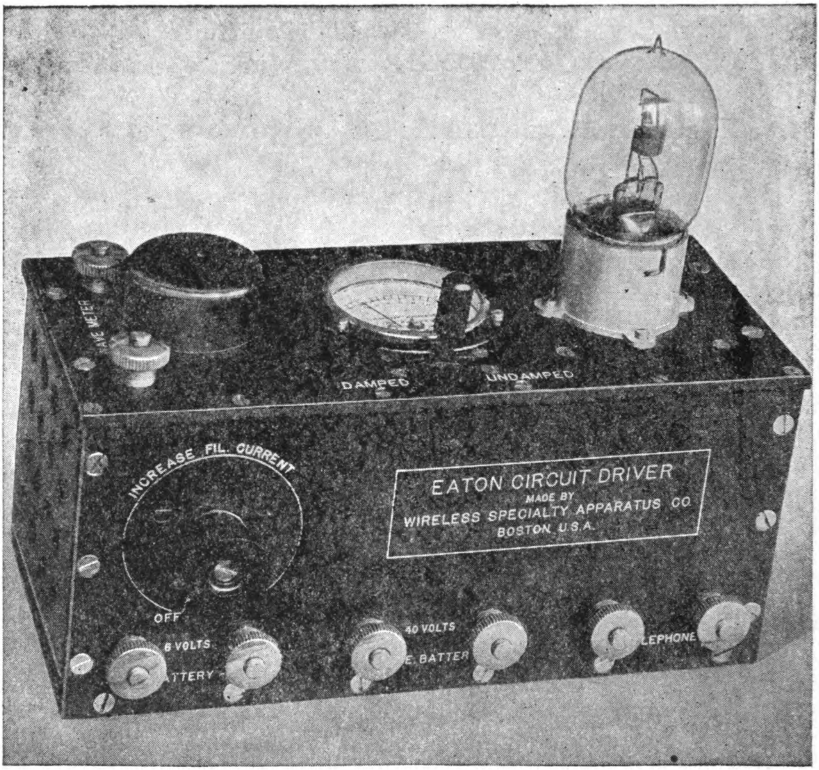


Fig. 83. A more complete set for undamped wave work.

secondary and secondary condenser, can be connected to the oscillator, or a wavemeter can be used in the same way without an appreciable change in the calibration.

The United States Navy has standardized on this type of circuit for undamped wave reception.

Fig. 83 illustrates the Eaton Circuit Driver. This instrument is made up of an Eaton Oscillator with the addition of a tube socket, filament rheostat and ammeter, a buzzer and a telephone switch. This switch starts or stops the buzzer. In the UNDAMPED position, the instrument is connected for the reception or generation of undamped waves. At DAMPED, the buzzer is set in operation to modulate the radio frequency waves so that it will transmit audible signals, as for a wavemeter used in calibrating a receiving set.

CHAPTER III

BUREAU OF STANDARDS LONG-WAVE WAVEMETER

There are many radio men who can design instruments, and quite a number are unusually capable, but the best of us can learn a number of things from the photographs and description given here of the long-wave wavemeter, designed by the Bureau of Standards and sold by John Firth & Company. Much of the credit for the mechanical design is due to A. E. Cardwell, under whose direction this instrument is made. This is one of the finest examples of the coordination of electrical and mechanical skill among all measuring devices.

Essentially the wavemeter is made up of a variable condenser, four inductances, an inductance switch, and Weston thermogalvanometer. The range of the meter is controllable in three steps:

1,500 to 5,500 meters,
3,000 to 11,000 meters,
and 6,000 to 22,000 meters

On the top of the panel there is a condenser dial, half of which is divided into 180 degrees, and the other half bearing three direct-reading semi-circles for the three ranges. So accurately is this meter made that the wavelength values are engraved directly on the scale. A knob to operate the inductance control switch and another to rotate the variable condenser are provided.

All the parts are mounted on the panel but, contrary to the usual practice, the panel is not supported by screws into the top of the case but from the bottom. In Fig. 84 the two rods from the panel and three legs on the lower condenser plate can be seen. By these means the instrument is secured with machine screws to the bottom of the case. Thus changes due to warping of the box are eliminated. Felt packing under the panel at the top of the case allows a slight

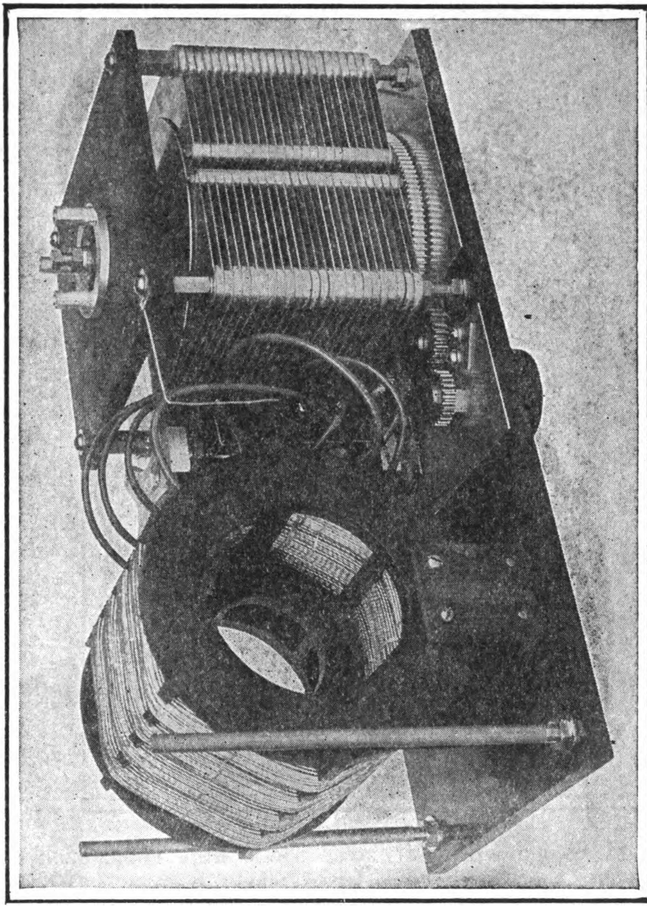


Fig. 84. A wavemeter circuit can hardly be reduced to essentials more than this one.

freedom to take up the effects of warping. The overall dimensions are 18½ by 8½ by 10½ inches.

The condenser is a marvel of electrical and mechanical skill.

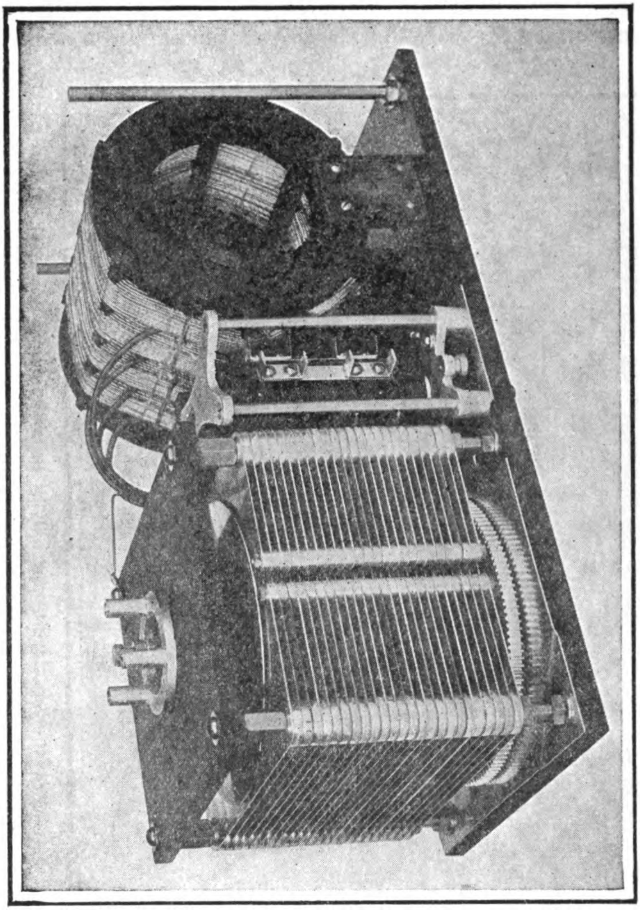


Fig. 85. Only an examination of the instrument itself discloses the skill of the designer and builder.

Figs. 84 and 85 show that it is of the double type, such as is described in the next chapter.

Every possible means is employed to keep down surface leakage, dielectric losses, and to localize the capacity in the condenser itself. For example, the three-legged support on the end plate, Fig. 85, is relieved so that the ring touches the bakelite only under the legs.

The shield beneath the panel is bent up to keep it away from the panel save at the outer corners. A very difficult construction is used to support the moving plates so that they are insulated almost entirely by air from the main shaft, except at the top and bottom. Where, ordinarily, moving plates are kept in place by keys in the holes, these plates are recessed to take a key on the supporting rod, and the plates are forced into position.

The reducing gear to the adjusting knob can be seen in Fig. 84. So perfect are these gears, and so accurately located, that there is no perceivable play through the train.

Beside the condenser, Fig. 85, is the inductance control. Here again the path through insulating material is cleverly made very small. The contacts are mounted on strips which are, in turn, held to bakelite rings. The purpose of all these painstaking methods is to make the damping of the circuit negligible and, consequently, to procure an extremely sharp resonance curve. The switch blades are made with large contact surfaces, and the stationary leaves are mounted non-rigidly so as to take position freely on both sides of the blades.

When the switch handle is rotated, one of three numbers, 1, 2, or 3, appear in a hole in the panel, showing the position of the switch. At the same time, a pointer on the calibrated half of the condenser scale moves to the proper semi-circle. Everyone is familiar with this pointer arrangement, as it is used on so many of the Navy receivers. On those sets, however, the switch handle can be turned between limits only, while on this wavemeter the handle can be rotated continuously. Instead of relying on a spring return for the pointer, a cam is used by means of which the pointer is moved in or out, according to the position of the switch. Therefore the possibility that the switch would turn and the pointer remain stationary is eliminated.

The four inductances are wound on a skeleton framework in order to keep down the dielectric in the field of coils. Six slotted strips are fitted into the supporting rings, with a third ring inside at the center for extra strength. At each side of the slots in which the wire is wound are semi-circular recesses into which strips of insulating material are set to act as separators between the layers of the coil. This produces an air spacing between the layers.

On the low wavelength range, all four coils are in parallel, on the intermediate range, they are in series-parallel, and on the long range, in series. This does away with absorption from unused turns and gives an overlap of wavelengths great enough that the calibration of points at one position of the switch can be checked against those on the succeeding position.

Another feature of this instrument is the galvanometer switch. Normally it is short circuited and a resistance inserted equal to that of the galvanometer. When the condenser-adjusting knob is depressed, however, the resistance is cut out and the galvanometer put in the circuit.

It is hoped that this description will give the readers an insight into the methods employed by designers and manufacturers of the finest types of equipment.

CHAPTER IV

CONSTRUCTIONAL DETAILS OF THE DOUBLE CONDENSER

Although the peculiar constructional problems of the double condenser has prevented its wide use, for apparatus where expense is not a primary consideration it has the advantage of giving double the capacity of the usual type of condensers without an increase in the overall dimensions.

Fig. 86 illustrates the principle of the instrument. There are two sets of semi-circular fixed plates and two sets of semi-circular rotating plates. The sets of rotating plates are insulated from each other, but by the use of commutators and brushes, one movable set is connected to one fixed set, and the other movable set to the other fixed set.

When the rotating plates are in the position shown at Fig. 86, they are inside their corresponding fixed plates. Consequently, the only capacity in the condenser is from the edge effect across the straight parts of the semi-circular plates. It should be kept in mind that sets No. 1 and 1 are the same as a group of plates on an ordinary condenser and No. 2 and 2 act as the other group.

Then, when the movable plates are rotated, variable plates No. 1 go inside fixed plates No. 2, and variable plates No. 2 go inside fixed plates No. 1. The result is the same as that obtained with the single variable condenser. At maximum capacity, opposite plates are intermeshed.

Fig. 87 shows the separate parts of the double condenser, with the assembled instrument in Fig. 88. This particular type was used for a large number of wavemeters built for the U. S. Signal Corps. The use for this purpose called for extraordinary stability and permanence. Because the wavemeters were used for portable work in the field, it was necessary to make the condensers so sturdy that rough handling would not change the calibration.

The plates are of thick brass, set in milled brass posts and soldered in the slots. Brass posts which hold the movable plates are supported on bakelite washers, to which the shafts are clamped. Accuracy was carried to an extreme by using jigs and fixtures in drilling and machining the parts. Details of the rotating plates and commutators are shown in Fig. 87.

The idea of soldering plates to the uprights is not new, though it is not done for experimenters' equipment. However, standard

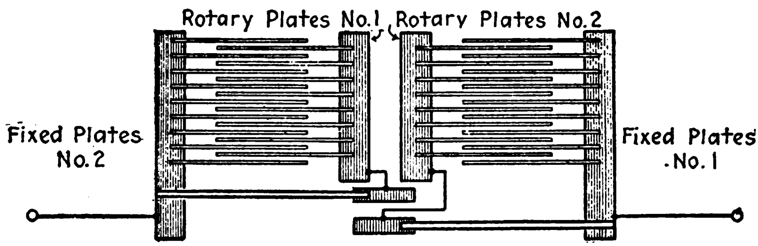


Fig. 86. In this position the capacity is minimum, for each rotary set is within its own fixed set.

condensers, such as those made by the Leeds-Northrup Company, are made in this way. It is not practical, with aluminum plates, to use solder, but brass plates can be secured in that way. Aside from the added rigidity, there is an advantage over the washer separated plates in that the latter are liable to offer considerable resistance due to poor contacts between the plates.

Stopping pins on the under side of the panel intercept short arms projecting from a brass piece on the upper part of the movable plate assembly. Thus, the plates are prevented from turning more than 180°.

Bearings for the upper part of the steel shaft are provided by a brass bushing set in the hard rubber panel. The use of a drilling jig made possible the accurate location of the bushing hole through the panel. There is a shoulder on the shaft which bears against a heavy phosphor bronze spring washer.

At the lower end, a thick bakelite panel is screwed to the brass plate supports and carries, at its center, an adjustable bearing of

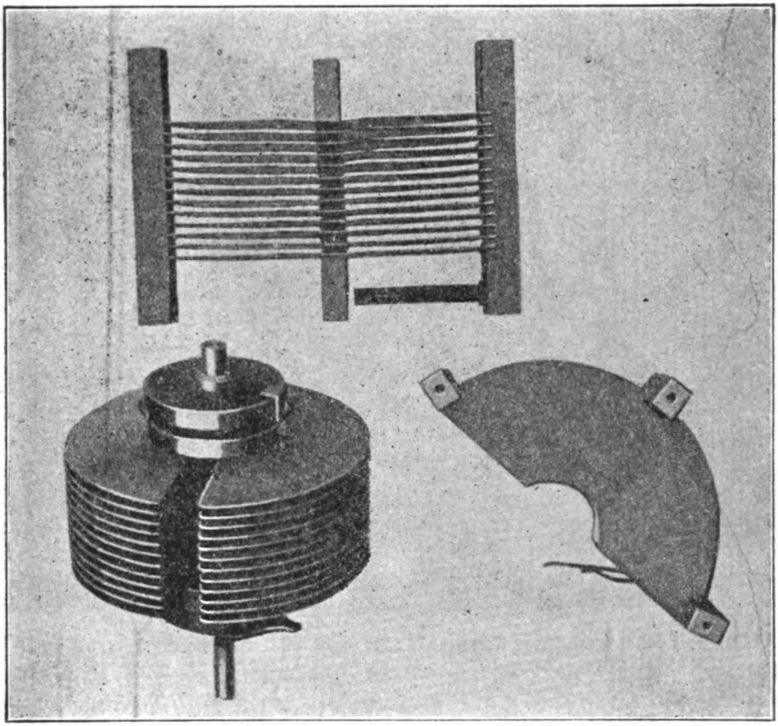


Fig. 87. Views of the fixed plates and the rotating plates, bottom up, illustrating the commutator.

conical shape. The conical shoulder on the lower shaft centers itself in the bushing. This bushing is threaded and fitted with a lock nut. In adjusting the position of the movable plates, the lower bearing is screwed up, pushing the shoulder on the upper shaft against the spring washer. When the rotating plates are accurately centered between the fixed ones, the lock nut is tightened and the plates are maintained securely in position.

A conical bearing for the lower end is more satisfactory than a pointed screw adjustment, because the former has a large bearing

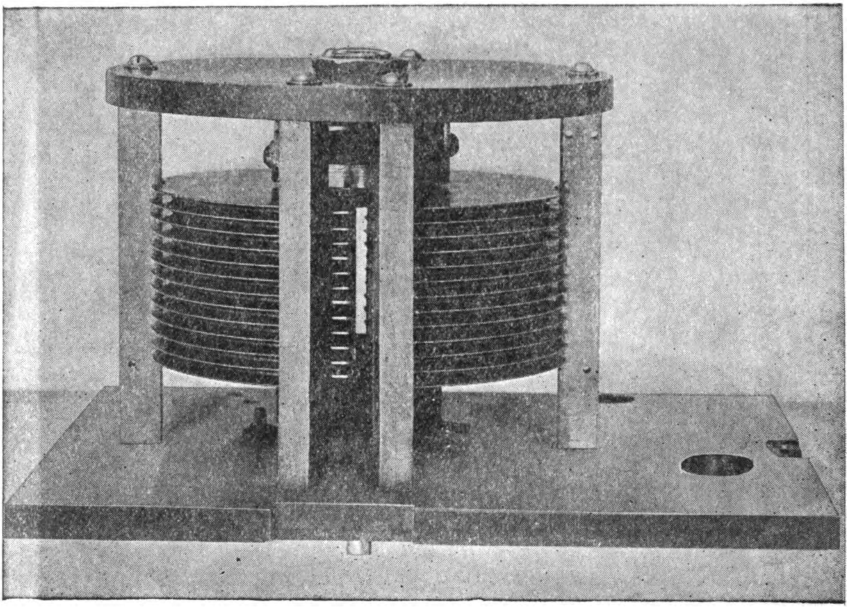


Fig. 88. The condenser inverted, showing the assembled instrument.

surface, while the latter operates entirely against the point of the screw. On heavy condensers of this type, such a point would wear away quickly, and wearing, permit the plates to drop. This would change the capacity of the condenser and the wavelength calibration of the meter.

CHAPTER V

PRECISION RADIO MEASURING INSTRUMENTS

The General Radio Company, specializing on laboratory equipment of high precision, has recently brought out three instruments of special interest to experimenters. From the photographs and description a number of excellent ideas can be obtained also for the construction in the experimenter's shop of equipment for his own work.

In Fig. 89 is shown the standard inductance made with values of 0.05, 0.20, 1.0, and 5.0 mhs.

The design of this standard by means of which extreme accuracy is obtained is quite interesting. Those who have attempted to build cylindrical coils of exact values appreciate the difficulties attaining to construction of standards of that type. Moveover such coils have large outside magnetic fields, a factor which introduces considerable errors into measurements.

Both of these difficulties have been overcome in the General Radio inductance standards. As can be seen from Fig. 87, two D-shaped coils are used one of which is mounted below the main supporting plate and the other on a circular bakelite plate. High frequency cable is of course employed to give a low-frequency resistance. The shape of these coils produces a very small external field. The form of winding is referred to as astatic.

Practically no metal is in the field of the coils with the exception of the necessary non-magnetic screws and nuts. The formwound coils are bound with tape to prevent any change in their shape and are firmly secured to the bakelite plates.

When the instrument is assembled a final adjustment of the inductance is necessary to give the accuracy which is not obtainable by ordinary manufacturing methods. This is obtained by varying the mutual inductance between the coils. For this purpose the four screws which hold the upper-round bakelite plate are loosened and the plate rotated until an exact value is obtained. The accuracy of this adjustment gives a value of inductance having less than one tenth of 1% error.

The continuous capacity of the two small sizes is 2.5 amps., the 1.0 mh. coil, 2 amps., and 5.0 mhs. coils, 1 amp.

For laboratory measurements the ordinary condensers show losses and variations in adjustment which are not in evidence

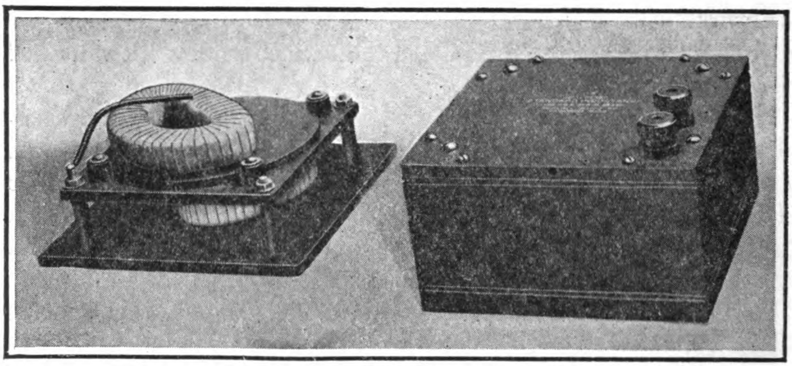


Fig. 89. An exact value of inductance is obtained by adjusting the mutual inductance between the upper and lower coils.

when the condenser is used for ordinary receiving work. Not only must the bearings be absolutely accurate to insure an unchangeable calibration but a vernier adjustment is necessary, and losses through insulation between the fixed and movable plates must be negligible to give the lowest possible phase difference.

The General Radio condenser is constructed to attain the ultimate in these respects. Heavy aluminum plates widely spaced are the first steps toward permanence of adjustment. The supporting pillars as shown in Fig. 90 give a strength to assure the calibration against variation from jars and hard use. Aluminum end plates are provided but the insulation between them and the rotating plates is not located at the bearings according to usual practice, but at points in a weak dielectric field. As little insulating material as

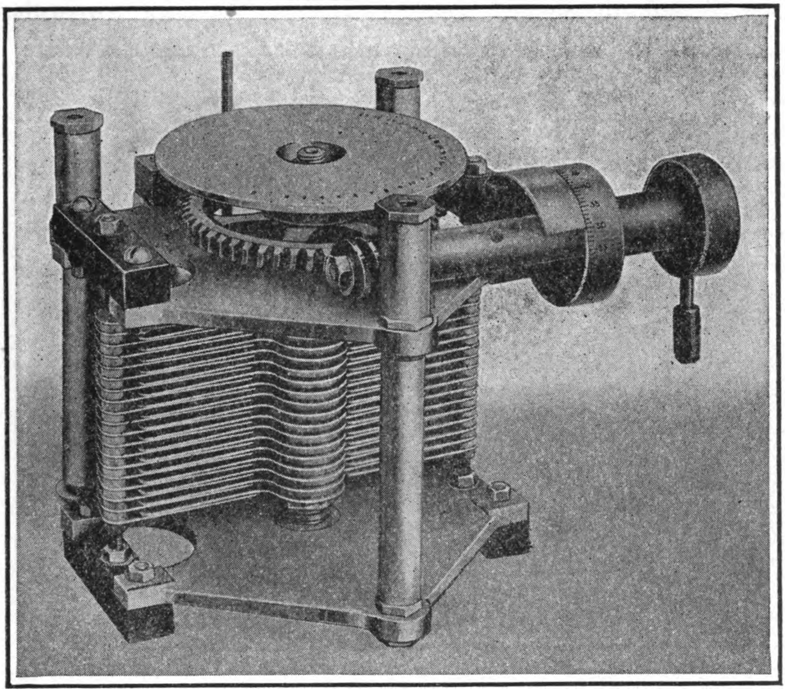


Fig. 90. The design of this condenser, giving great strength and low losses, is quite unusual.

possible is used to keep down losses from this source. Conical brass bearings with a steel shaft tend to reduce wearing.

An interesting feature is the worm adjustment of the rotating plates. At first thought it might appear that considerable play would be present between the worm and gear, either from inaccuracies of manufacture or wear under use. Such an occurrence is guarded against by using a spring tension to hold the worm against the gear. This method is similar to that employed in the precision dividing engines.

The scale on the main shaft covers 180° but it is divided into twenty-five equal parts. On the worm shaft is a second scale of one hundred equal divisions. Since a rotation of the worm moves the

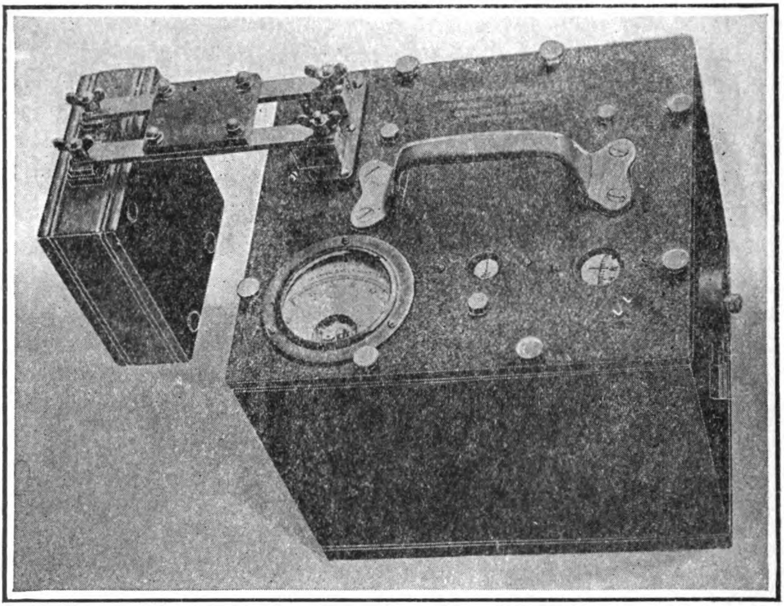


Fig. 91. The simplest circuit, with the fewest instruments, is employed for this wavemeter.

variable plates one division on the large scale, the setting of the condenser can be read to one part in twenty-five hundredths of a semicircle.

The copper lined mahogany case in which the condenser is mounted provides perfect shielding. This case fits into a strong carrying box furnished with a handle and lock.

As a result of the care employed in the design and construction of the precision condenser it can be seen for purposes of measurement that the condenser is equivalent to two parallel condensers, one fixed, containing all the losses and the other a perfect variable condenser. Potentials of one thousand volts can be employed without danger of a breakdown. A calibration curve made from twenty-six points readable with an accuracy of one tenth of 1% is supplied with the variable condenser.

The Precision Wavemeter, Fig. 91, to eliminate errors and variations due to elaborate circuits, contains only a condenser, of the type just described, a type 425 Weston thermogalvanometer, and the inductance coil. With five coils a range of 75 to 24,000 meters can be obtained. No exciting means is furnished, for, in accurate work, such excitation is not required. The use of a buzzer calls for a special calibration, when it is in use, and at best causes errors of too great a magnitude for such a precision instrument.

By the elimination of losses in the condenser and wiring, and by winding the inductance coils with high frequency cable in a manner to make the distributed capacity minimum, an accuracy is obtained which permits the determination of the resonance point for undamped waves to less than one-half a division on the vernier scale, which is equivalent in wavelength to 1 part in 10,000.

The wavemeter is carried in a mahogany case, fitting in a strong whitewood carrying box which also holds the coils and calibration data. Mahogany boxes, with bakelite ends, are used to mount the inductances. The general design of the instrument is intended to combine strength with accuracy of reading.

The wavelength calibration is made at 24 points for each coil, and a capacity calibration at 26 points on the condenser is also furnished.

CHAPTER VI

BALDWIN TYPE TELEPHONE RECEIVERS

During the last few years the United States and other governments have used Baldwin telephones, but it is only recently that they have been available for experimenters. While they have become familiar now, identified by the mica diaframs, their action is not apparent even to those who have looked inside. It is generally known that they are proportionately more sensitive to very weak signals than to strong ones, but an inquiry as to why they work seldom brings an intelligent answer.

It is obvious that the single magnet does not draw down the diafram in the usual way, for, as can be seen from Fig. 92, the axis of the magnet is parallel to the diafram. Moreover, the permanent magnet is of an unusual shape. It is this difference that makes the Baldwin phones interesting, and accounts for their efficiency.

Fig. 93 shows one of the phones with the cap removed, exposing the mica diafram set in a wide aluminum ring, to which the other parts are also fastened. Although the diafram is much smaller than those of steel, the mica gives a very sensitive response to vibrations imparted to it.

From Fig. 92 it can be seen that a U-shaped iron pole-piece is secured to each end of the circular permanent magnet, making one pole-piece north, and the other, south. Between the pole faces a steel armature is mounted, held at one end by a pivot set into the lower pole-piece, and at the other end by a linking wire fastened to the diafram. The armature is carefully located so that the pull from one pole of the magnet is equal to the pull from the other pole. In the same way, a nail can be set between the poles of a horse-shoe magnet so that it is attracted equally in both directions, and does not move.

Set in the opening formed by the U-shaped pole-pieces is a single solenoid magnet, just large enough inside to fit over the armature and to allow it a slight play. Actually the movement of the arma-

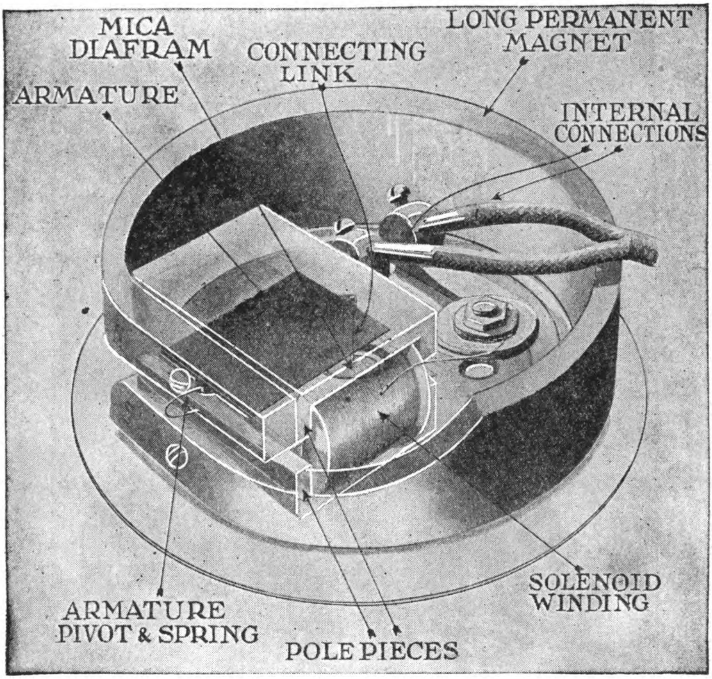


Fig. 92. A phantom picture of the receiver.

ture is imperceptible. This magnet, when a current is passed through it, becomes polarized, north at one end and south at the other.

For example, let us suppose that the upper pole-piece, Fig. 92, is north, and the lower one south. If, when a current flows through the magnet, the left hand end becomes north, the balance of the armature will be upset, the combination of two north poles being greater than one south pole. Thereupon the armature will be drawn up sharply at the left end, as a nail jumps to one or the other pole of a horse-shoe magnet. At the right hand end, however, the mag-

Fig. 93. A head set with one cap removed.

net will have a south polarity, which, with the south polarity of the lower pole-piece will draw the armature down. This movement of the armature, up at one end and down at the other, is transmitted to the diafram through the connecting link.

Thus it can be seen that the telephone does not depend entirely upon the current in the coil to operate the diafram, but utilizes it to produce the unbalancing effect, by which the permanent magnet actuates the armature.

Fig. 92 illustrates the method employed to secure the terminals of the connecting cord. The socket shell and cap is of moulded bakelite. The head band, although duplicated by other manufacturers, was originated by Mr. Baldwin, the inventor of the telephone receiver.

Three types of these phones are made, each with its particular advantage. Type C is the U. S. Navy Standard. The mica diafram is $2\frac{1}{8}$ inches in diameter, larger than the others. The complete headset weighs 18.5 ounces. Each phone is wound to a resistance of 1,000 ohms.

More sensitive is the type E, though the diafram is smaller and the resistance the same. The weight is 15.5 ounces.

Type F phones are made for extra lightness, weighing only 13 ounces. In sensitiveness they are slightly superior to the type E, and many operators find them more comfortable to wear.

Some experimenters who buy expensive phones do not treat them as the delicate instruments which they really are. Removing the cap never does the phones any good, and frequently prying fingers break the connecting wires. The diafram is bound to suffer from handling. Most important of all is to protect them from shocks. Dropping them on the floor, or even setting them down roughly on the operating table is hard on the mechanism, and causes the permanent magnets to lose their magnetism.

Telephone receivers cannot be expected to keep their sensitiveness if they are not accorded the proper treatment.

CHAPTER VII

MANUFACTURING DETAILS OF THE B BATTERY

Great reticence has been shown by battery manufacturers in giving details of the processes they use. However, the makers of the G. A. Standardized B Batteries have furnished the photographs and details which are given here.

The first step in making a battery is the mixing of the chemicals which form the coating of the positive electrode. Here lies the greatest and most important secret. The formula for this mixture is known only to the chemist who worked it out. To prevent the discovery of the formula, the weighing scales are not marked in pounds. The beam simply carries marks at which the weights are set for different chemicals. Mostly unskilled men handle the ingredients because they know nothing of what they are doing.

When the depolarizer, as this mixture is called, is ready for use, it is carried to men who mold the cartridges, shown at the left of Fig. 94. The man fits a piece of low resistance carbon rod into a tamping mold, fills the mold with depolarizer, and tamps it into a solid form.

It may be said that the depolarizer contains manganese, dioxide, a high grade natural graphite, artificial graphite—purer than the natural grade—and an electrolyte. Due to a chemical action within the cell, hydrogen is liberated which, if not counteracted, would collect around the carbon rod and insulate it. As a result, the resistance of the battery would rise so high that no current would flow.

To prevent such polarization manganese dioxide is used because it liberates oxygen which combines with the hydrogen, making water.

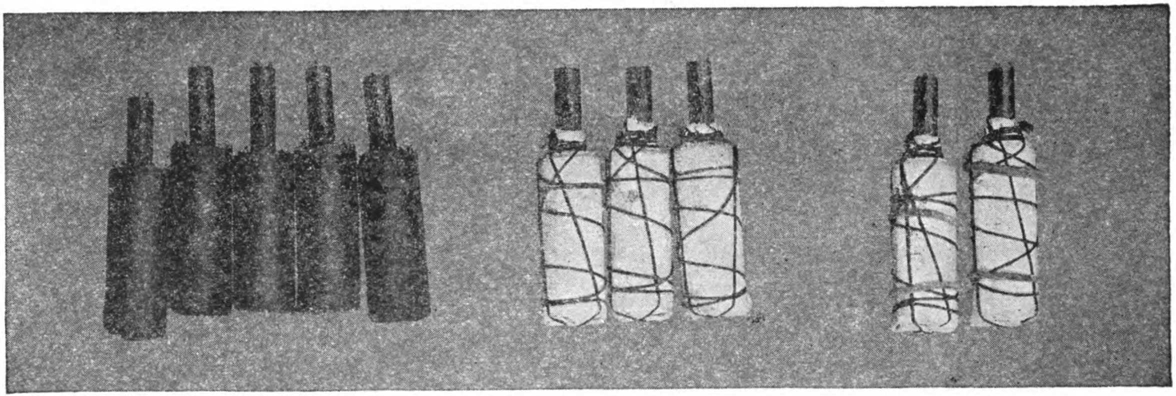


Fig. 94. First three stages of the B battery—the cartridge, bobbin, and bobbin ready for the zinc cup.

The cartridges are set in trays and put aside to dry. When ready, they are carried to another room where skilled women workers wrap each cartridge with cloths and bind them with a few turns of thread. The result is called a bobbin, Fig. 94. This wrapping keeps the cartridge intact while it is handled, and prevents it from falling apart when it is soaked in electrolyte later on. Before the bobbins leave this room two rubber bands are put around each one to keep it properly centered in the zinc cup.

Again the bobbins are arranged in trays and taken to the soaking room. A rapid and accurate method of determining the length of time the bobbins should be soaked has been developed by this company. Previously the foreman made a guess at the condition of the cartridge, and estimated the soaking thereby, a time ranging from ten minutes to twenty-four hours. The electrolyte is made up chiefly of a salammoniac and zinc chloride solution.

The mounting room next receives the batteries in process. Here the bobbins are put into zinc cups, which serve as the container for the battery as well as the negative pole. A paste to hold the moisture is poured around the bobbin and allowed to solidify.

An interesting automatic machine takes a tray of mounted bobbins and, after pouring a small amount of paraffin in the top of each cell, puts a paper washer around the carbon rod on the paraffin covering. This process prevents the sealing wax from running into the cell.

Another machine picks out the cells from the tray and sends them in a long file under a hopper containing the brass caps which top the carbon electrodes. A cap is gently pressed on each carbon. Emerging from this part of the machine, they pass to the next section, where sealing wax is poured around the cell, over the cardboard washer previously mentioned. A number of batteries are treated in this way at one time, because some little time is required to pour the wax, while the brass caps are put on at a much greater rate of speed.

Several grinding wheels are mounted at the end of the machine just described. When the cells reach the end of their journey

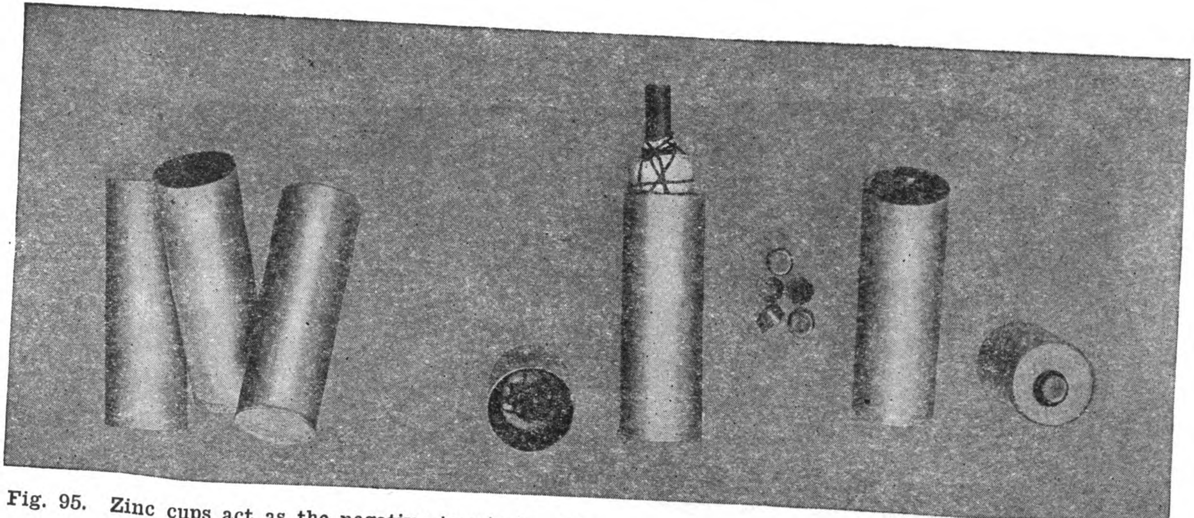


Fig. 95. Zinc cups act as the negative terminals. **Mounted bobbins and brass caps. The washer in place, ready for the paraffin.**

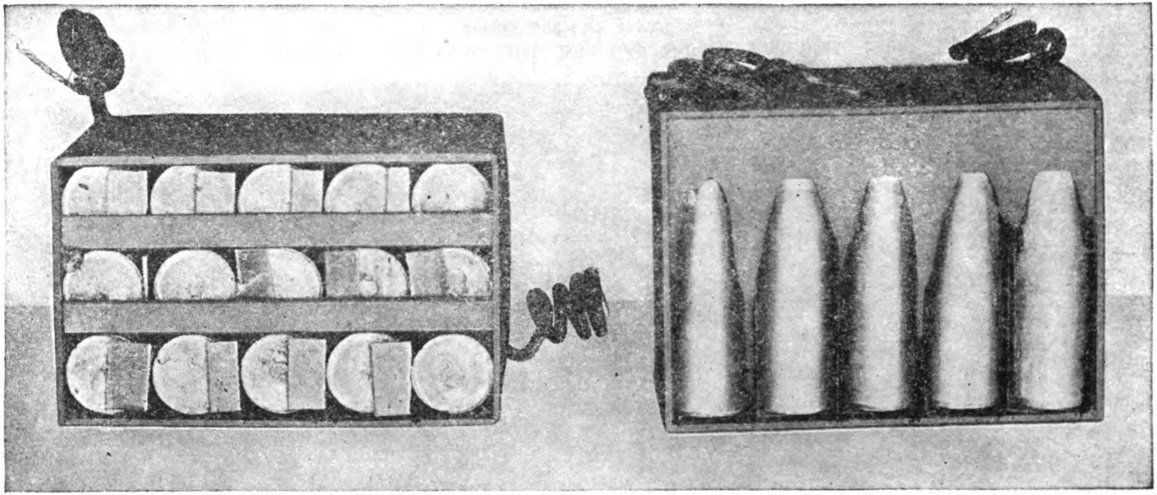


Fig. 96. The side and bottom of a completed battery were removed to show the construction.

through this device the grinding wheels touch lightly on the brass caps and the zinc containers, giving clean surfaces for soldering.

Now the cells are ready for a final testing before going into the boxes. They are passed individually through a machine which applies contacts to the carbon and zinc electrodes. If they deliver the rated current they go on to the carrying trays. If not, they drop into a hopper on the floor. This eliminates the possibility of mounting defective cells in the completed battery, where, at the last test, it would be necessary to reject the entire set.

It is necessary to solder the connections between the batteries by hand, although the speed with which the workers perform this operation is almost mechanical. Paper boxes of great strength, impregnated in paraffin to exclude moisture, are used to hold the cells. Flexible leads are put on the terminals and sealing wax poured slowly over the cells.

Fig. 96 shows the type of container used. Paraffin cardboard separators keep the cells apart. By bending over the strips at the bottom, the cells are prevented from forming short circuit in any possible way. Because the box is of waterproof construction no protection is necessary to prevent short circuiting from moisture which would otherwise collect inside the box.

The separators and the sealing wax keep the batteries perfectly rigid, so that there is no trouble from noise due to a change in resistance of the contacts under vibration. Chemical noises have been eliminated by a process which is kept secret with the manufacturers.

During the war the U. S. Government ordered so many of these batteries that they could not be made in one factory. However, the manufacturers were not willing to make public the formulas they had originated. Therefore they mixed the chemicals and sent completed compounds to the other companies.

Although it is not possible to give the experimenters sufficient data that they can make their own batteries, this description will give an idea of the way in which they are made.