RADIO OPERATING

QUESTIONS AND ANSWERS

FORMERLY PUBLISHED UNDER THE TITLE OF
RADIO QUESTIONS AND ANSWERS

BY

ARTHUR R. NILSON

Lieutenant (Technicist) (Communications) U. S. N. R.; Member Institute of Radio Engineers; Fellow Radio Club of America

AND

J. L. HORNUNG

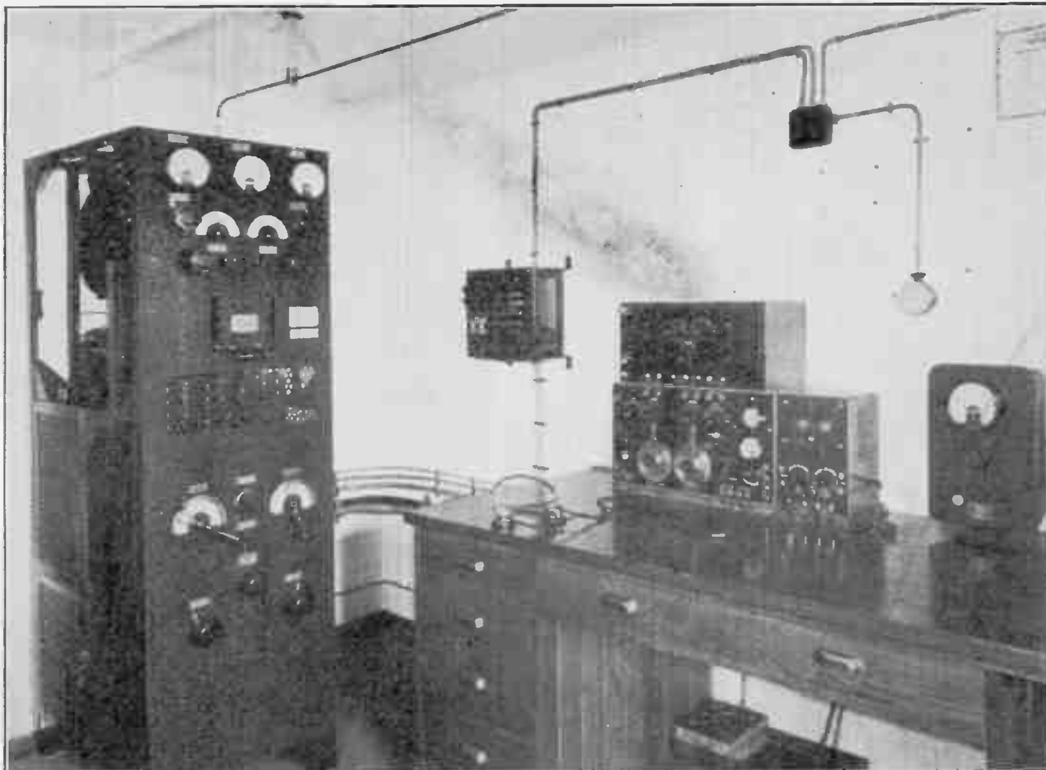
Fellow Radio Club of America; Associate Member Institute of Radio Engineers; Radio Instructor

SECOND EDITION
REVISED AND ENLARGED

McGRAW-HILL BOOK COMPANY, INC.
NEW YORK: 370 SEVENTH AVENUE
LONDON: 6 & 8 BOUVERIE ST., E. C. 4
1929

PRINTED IN THE UNITED STATES OF AMERICA

THE MAPLE PRESS COMPANY, YORK, PA.



Frontispiece.—Modern ship radio installation with vacuum tube transmitter and long wave receiver.

PREFACE TO THE SECOND EDITION

Since the first edition of this volume appeared in 1921, many advances have been made in the art of radio communication. Vacuum tube transmitters and receivers have largely replaced the spark and its contemporary, the crystal detector. The advent of broadcasting has greatly increased the interest in amateur radio operating, and there has evolved a new technic of broadcast-station operation with which many professional radio operators are concerned.

In addition, the International Radio-telegraphic Convention, which met in Washington in 1927, made new laws and regulations governing radio operators and the operation of radio stations. The United States passed the Radio Act of 1927 to replace the old Radio Act of Aug. 13, 1912.

To meet these changed legal and technical aspects of radio, this enlarged volume is offered as an aid to commercial and amateur operators about to take government and civil-service examinations.

The authors intend that this book shall be a companion volume to their text "Practical Radio Telegraphy." These volumes, taken together, contain all of the essentials needed by students preparing to become licensed amateur and commercial radio operators. It is hoped, also, that the information contained herewith will serve to guide commercial and amateur operators in the operation of their stations and in their study of radio theory and practice.

THE AUTHORS.

NEW YORK CITY,
March, 1929.

PREFACE TO THE FIRST EDITION

This book is written especially for students and operators who are about to take the government examination for a radio operator's license.

The material contained herein has been drawn from many sources, carefully chosen and compiled from the commercial radio operator's standpoint. While the reader may not be willing to accept the text as sufficient in all points, it must be remembered that there are many ways of answering questions, and as all viewpoints cannot be taken in a work of this kind, the one considered most expedient was chosen. It is assumed that the reader understands radio operating and theory completely and that this book will merely serve to bring out certain salient points as well as to show the general form of answering questions of this kind.

In conclusion, let me caution all applicants who take the radio operator's license examination to answer all questions fully, never using et cetera to explain a meaning. **Do not be brief.**

A. R. N.

New York City,
December, 1921.

CONTENTS

RADIO OPERATING
QUESTIONS AND ANSWERS

PART I

DIAGRAM AND EXPLANATION OF COMPLETE COMMERCIAL TRANSMITTER, RECEIVER, AND AUXILIARY EQUIPMENT

Ques. 1. Draw a diagram of a complete commercial transmitting and receiving equipment, including the emergency equipment, and explain the function of each part.

Ans. Figure 1 illustrates the wiring diagram of a complete commercial transmitting and receiving system. The function of the apparatus is as follows:

Emergency Equipment

Underload Circuit Breaker.—This device is a trip relay for opening the battery-charging circuit if the ship's voltage drops below the charging rate; it also serves, when the battery is fully charged, to automatically open the charging circuit. This is accomplished when the ampere-hour meter pointer touches a contact at the full-charge point which short-circuits the solenoid coil of the underload breaker and opens the charging circuit.

Ampere-hour Meter.—This meter determines the state of charge and discharge of the batteries during the charging and discharging periods. A third contact is provided which short-circuits the solenoid coil of the underload circuit breaker and opens the charging circuit when the pointer reaches its full-charge position. The pointer moves clockwise during discharge and counterclockwise during charge. A fixed, red pointer on the meter shows the discharge point of the batteries.

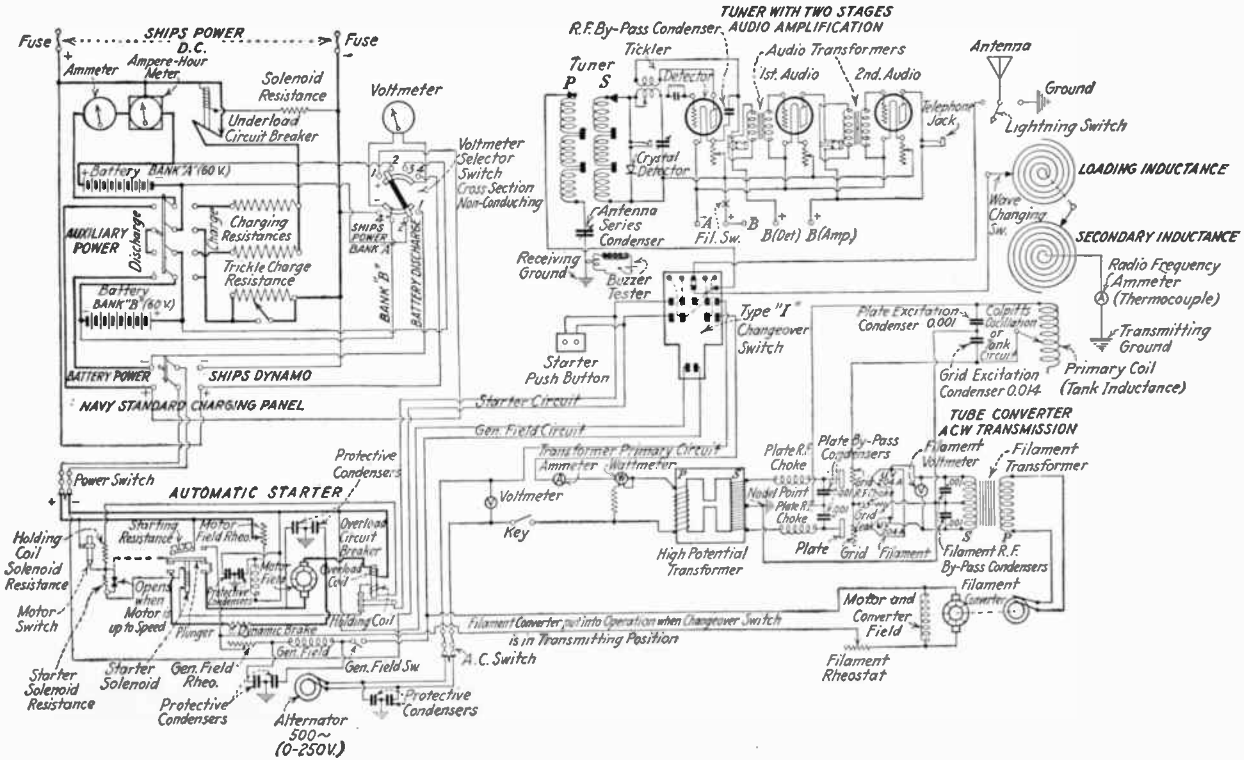


FIG. 1.—Wiring diagram of complete commercial-type transmitter and receiver.

Voltmeter.—This instrument indicates the voltage readings of:

1. Bank A and B discharging.
2. Bank A charging and discharging.
3. Bank B charging and discharging.
4. Ship's power.

Voltmeter Selector Switch.—This is used for connecting the voltmeter into the various positions indicated in 1, 2, 3, and 4.

Ammeter.—This meter shows the number of amperes flowing through the batteries on charge and discharge.

Charging Resistances.—These are heavy current-carrying resistances for controlling the number of amperes flowing through the banks of batteries during charge; each resistance passes approximately 10 amperes through each bank in the standard commercial battery installations.

Trickle-charge Resistance.—This is an additional resistance connected in series with the main charging resistance and which decreases the charging rate to approximately 3 amperes. This is provided to prevent sulphation due to internal action and any small creepage discharge along the moist tops of the batteries when they are not in use. The trickle charge, therefore, tends to keep sulphation at a minimum.

D. P. D. T. Switch.—This is used for connecting the motor generator to either the storage batteries or the ship's power.

4 P. D. T. Switch.—This is used for connecting the batteries in parallel for charging and in series for discharging.

Motor Generator and Starting System

Power Switch.—This switch connects the motor generator to the source of power.

Motor Switch.—This switch controls the power supply to the automatic starter. It is normally closed, and the motor generator operated by the starter push button, or antenna switch.

Starter Solenoid Resistance.—This resistance controls the amount of current flow through the starter solenoid; it is in the circuit only when the motor is up to full speed and is short-circuited when the motor is at rest and starting.

Dynamic Brake Resistance.—This arrangement is used to bring the motor to an abrupt stop when the starter solenoid is opened by the starting switch. This action is caused by the resistance being shunted directly across the armature when the plunger drops, resulting in a large value of current flowing momentarily through the resistance as a result of the armature temporarily becoming a direct-current generator. The magnetic field then set up by the armature produces a bucking effect upon the field poles which results in a dragging action and brings the armature to an abrupt stop. This resistance is provided to bring the motor to a quick stop when receiving weak signals; when running, the motor induction might be so loud in the headphones as to drown out the signal.

Starting Resistances.—These allow the current to flow into the armature gradually and give the counter e.m.f. a chance to build up.

Plunger Bar.—Its use is to gradually short-circuit the starting resistances. When the plunger is up to the last contact, all of the starting resistances are short-circuited and the motor is running at full speed. In addition, as soon as the plunger connects with the last contact, the generator field is excited.

Motor.—This machine is used for driving the generator armature and is usually directly coupled to it.

Motor-field Rheostat.—This is a controlling device used for controlling the speed of the motor and for varying the generator frequency (frequency control).

Generator.—This is a machine used to generate the alternating current necessary for the operation of the power transformer.

Generator-field Rheostat.—This device controls the voltage output of the generator (power control).

Overload Circuit Breaker.—This is an automatic switch, the function of which is to open the motor-armature circuit if excessive current flows through it due to the plunger of the automatic starter rising too quickly. It is a safeguard against a possible burning out of one or more of the armature coils. The circuit breaker is fitted with an overload and a holding coil. The overload coil is connected in series with the motor armature so that when an excessive current flows through this circuit the coil becomes heavily magnetized and draws up the contact bar of the circuit breaker. This action opens the plunger solenoid circuit. The holding coil which has a protective resistance in series with it will keep the armature circuit broken until the cause of the trouble has been removed.

Protective Condensers.—These are used for protecting the various circuits from possible damage due to high-frequency kick-backs. The condensers across the motor armature also tend to minimize the sparking at the commutator.

Power Circuit

Alternating-current Voltmeter.—This meter indicates the no-load and full-load voltage delivered by the generator.

Alternating-current Ammeter.—This meter indicates the number of amperes flowing through the primary circuit of the power transformer.

Wattmeter.—This meter indicates the true wattage (power) input to the transformer.

Transformer.—This is a device for stepping up the low voltages delivered by the generator (0 to 250) to high voltages necessary to the plate supply of the transmitting tubes (5,000 to 10,000 volts).

Transmitting Circuit

Filament Converter.—This is a machine for supplying the filament transformer with the proper voltage and frequency.

Filament Rheostat.—This is a device for regulating the speed of the converter and, consequently, controls the filament-current supply.

Filament Transformer.—This is a device for stepping the voltage down to the proper tube voltage.

Filament Voltmeter.—This meter indicates the filament voltage of the tubes.

Tubes.—These are power tubes used for generating high-frequency oscillations. (Type 204A-250 watts.)

Plate Radiofrequency Chokes.—These devices are used for maintaining the high-frequency oscillations through the oscillatory circuits constant by preventing the high-frequency currents from flowing through the transformer secondary.

Plate-excitation Condenser.—This condenser is used for producing the proper plate excitation by providing the proper voltage drop across the grid-excitation condenser.

Grid-excitation Condenser.—This condenser is used for properly exciting the grid for the generation of high-frequency oscillations.

Tank Circuit.—This is a load circuit, a high-frequency generating circuit for transferring the oscillations to the antenna system. The frequency of this circuit is determined by the values of capacitance and inductance of which it consists.

Tank Inductance.—This is used for varying the oscillatory frequency and to induce energy by electromagnetic induction into the antenna system through the medium of the secondary inductance.

Secondary Inductance.—This is used for transferring the oscillations generated by the tank circuit to the antenna and adjusting the coupling between the two circuits.

Loading Inductance.—This is used for varying the inductance of the open radiating circuit and thereby putting it in resonance with each change of frequency or wave length in the primary circuit.

Radiofrequency Ammeter.—This meter indicates the points of resonance for each change in wave length.

Antenna and Ground.—These together with all inductance and capacitance connected between them make up the radiating and intercepting open oscillatory circuit.

Lightning Switch.—This is used for grounding the antenna directly in case of severe lightning or electrical storms in the vicinity of the antenna.

Receiving Circuit

Tuner.—This is a device for adjusting the receiving circuit to the various wave lengths in the commercial band and to provide proper coupling between the primary and secondary circuits.

Antenna Series Condenser.—This is used for decreasing the wave length below the fundamental of the antenna and to assist in carefully resonating the primary and secondary circuits.

Vacuum-tube Detector.—This is used for rectifying the high-frequency oscillations into audible groups.

Tickler.—This is a small coil which couples the plate and grid circuits, thereby reinforcing signal variations on the detector-tube grid to increase signal strength and also to produce self-heterodyning for the "beat" reception of continuous waves.

Radiofrequency-bypass Condensers.—These are used for bypassing the high-frequency variations in the plate circuit across the high primary transformer impedance.

Audiotransformers.—These are used for stepping up the rectified signal to a higher volume.

Telephones.—These are used for converting the electrical and magnetic variations into audible sound waves.

Antenna-change-over Switch.—This is a switch for changing the antenna from the receiving to the transmitting circuit and *vice versa.*

In addition, this switch is provided with additional contacts to permit simultaneous control of various circuits. For example: When the switch is in a receiving position (up), various circuits in the transmitting system are opened as follows:

1. Transformer primary.
2. Generator field.
3. Motor starter (this circuit is usually also individually controlled by a push button).
4. When the switch is thrown into the transmitting position (down), these circuits are closed and the antenna is disconnected from the receiver.

Various other circuits may be opened or closed if desired, but the above are the most common controls provided for.

PART II

TUBE TRANSMITTERS

Ques. 2. How many amperes does the filament of a UV 204A (250-watt) tube draw? What is the source of supply? What is the proper filament voltage and current for a UV 204A ube; for a UV 211 (50-watt) tube?

Ans. The filament of a UV 204A tube draws 3.85 amperes; the UV 211 draws 3.25 amperes. The source of filament current supply is a rotary converter which feeds 80 volts into a small step-down transformer, which reduces the voltage to the proper working voltage of the tube. The proper working voltage for the UV 204A and the UV 211 is 10 volts.

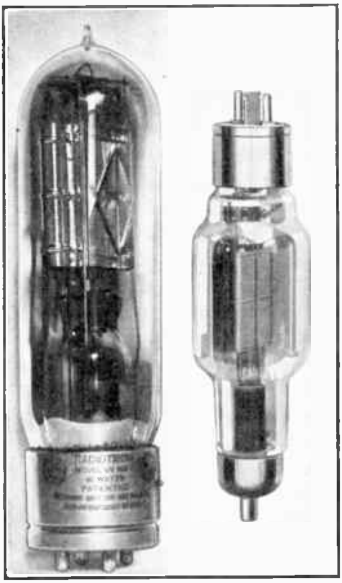


FIG. 1*a*.—Typical transmitting tubes.
Right—UV 204A. 250 watt.
Left—UV 203A or 211. 50 watt.
(*Courtesy*, Radio Corporation of America.)

Ques. 3. What causes overheating of a transmitting tube?

Ans. The plate voltage or current may be too high, or there may be a punctured plate blocking condenser, or the circuit may not be oscillating properly. An improper bias, loose or corroded connections may also cause overheating. It is possible, also, for overheating to be caused by defective tubes, and, if in an amplifier circuit, such as the master oscillator system, the plates overheat, the trouble may be due to a defective coupling transformer or an insufficient number of plate turns in use.

Ques. 4. How are continuous waves broken up into interrupted continuous waves in either an arc or a tube transmitter?

Ans. Continuous waves generated by arcs and vacuum-tube transmitters may be broken up into groups (interrupted-continuous waves, or ICW) by the use of a chopper, connected in some portion of the high-frequency circuit, as illustrated in Figs. 6 and 10, or an audiofrequency-tube oscillator coupled to a high-frequency tube oscillator.

Another form of ICW can be produced with vacuum-tube oscillators by applying an alternating potential to the plates of the tube. If one tube is used in this manner, an interrupted wave will be produced due to self-rectification. This is called a half-wave ACCW transmitter. If two tubes are used to operate on both halves of the cycle, then the waves emitted from the antenna will be termed as full-wave ACCW transmission.

Thus, by using a chopper, audio oscillator, or self-rectifying arrangement, the wave will be of a modulated character and may be received with a crystal detector or non-oscillating vacuum-tube detector.

Ques. 5. Why is it necessary to use a current-regulating device in series with a vacuum-tube filament supply?

Ans. To control the amount of electronic emission by regulating the filament voltage to the proper operating point. A filament voltage higher than that for which the tube is designed would decrease the life of the tube. This is especially true in tubes using thoriated tungsten filaments. Resistance-type current regulators are also necessary in battery installations to allow for slight battery recuperation during idle periods. The variable resistance (rheostat) should always be increased when the tubes are shut off to prevent an excessive rush of current when the tubes are again lighted.

Ques. 6. What is meant by ICW? How is it obtained?

Ans. **Interrupted continuous waves.** They are produced by means of a chopper, an audiofrequency-tube oscillator, or by using alternating current on the plate (see Ques. 4 above).

Ques. 7. What is a tank circuit? Explain fully its theoretical operation.

Ans. A tank or absorption circuit is fundamentally any form of oscillatory system in which high-frequency oscillations may be generated.

One of the most common types of tank circuits is the Colpitts split-capacity arrangement shunted by an inductance; as illustrated in Fig. 2. The theoretical operation of this circuit is as follows:

C_1 is the plate-excitation condenser.

C_2 is the grid-excitation condenser.

L is the tank inductance.

R_1 is the inherent circuit high-frequency resistance.

The wave length of this circuit when oscillating is, therefore, dependent upon the values of the oscillatory constants L, C_1, and C_2 in series, and, therefore, the entire circuit L, C_1, C_2 and the circuit resistance R_1 is called the *load* or *absorption* circuit.

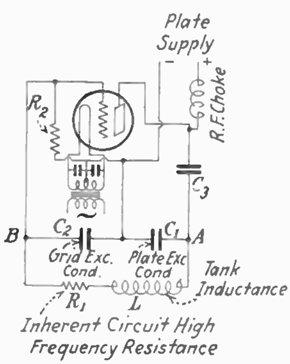


FIG. 2.—Theoretical tank circuit.

Assuming the filament to be heated and the plate potential applied, the tube will begin to oscillate.

The generation of oscillations is a result of a voltage drop across the plate-excitation condenser C_1, which incidentally creates a drop of potential across the grid-excitation condenser C_2, resulting in the excitation of the tube grid.

The application of a potential to the grid will now produce a further variation in the plate circuit again resulting in a potential difference between C_1 and C_2 which further increases the effect upon the plate circuit.

It is important to note that the blocking condenser C_3 keeps the positive side of the plate supply from flowing to the grid but allows the high frequencies to pass during the period that the tube is oscillating. Furthermore, when the grid receives a positive potential as a result of the voltage drop across C_2 the blocking condenser C_3 will tend to make the grid slightly negative and if the positive potentials are applied in rapid succession the grid will finally become so heavily charged with a negative potential that the plate current flow will stop, resulting in a cessation of the oscillations. To prevent this the grid leak R_2 is provided to allow this accumulation of electrons on the grid to gradually leak off at the proper intervals and thus maintain smooth oscillations.

The oscillations generated are, therefore, a direct result of the constant variation of the grid bias due to the capacities C_1 and C_2. Thus, the high frequencies generated by the tube through C_1 and C_2 also discharge through the inductance L and circuit resistance R_1 (load circuit), and the value of these constants determines the frequency of the oscillations (wave length).

The intensity of the grid excitation depends upon the value of the grid-condenser capacity as can be readily seen if we consider the voltage drop as being the determining factor. Thus, if the value of the grid-excitation condenser is small, the greater will be the voltage drop and the greater the grid excitation.

For different power capacities of transmitting tubes, the value of the grid excitation will vary in accordance with the tube characteristics.

For example, if two 250-watt tubes are connected in parallel (500 watts), then the values of the capacity and inductance should be such that with 500 watts dissipated in the circuit, the total voltage between points A and B in Fig. 2 would be 3,750 volts. The correct grid excitation for these tubes would be near 500 volts, and, therefore, the values of C_1 and C_2 are determined by the relation C_2/C_1, or 3,250/500. This means that the capacity value of C_2 equals 6.5 that of the plate excitation condenser C_1, and, therefore, if the value of C_2 is 6.5 times greater than the plate condenser C_1, then the voltage drop across the condenser C_2 will be 1/6.5 of the drop across C_1, which will give 500 volts across C_1, thus giving a voltage of 3,750 across the two condensers at points AB.

Ques. 8. What kind of waves are generated with a vacuum-tube transmitter?

Ans. This depends upon the character of the plate supply in the oscillator-plate circuit. If a pure direct current such as is delivered by batteries and accurately designed direct-current generators and filters is applied to the plate of the tube, continuous waves (CW) are generated. If, on the other hand, an alternating current is applied to the plate, an interrupted continuous wave (ACCW) will be produced. It is, however, also possible to produce an interrupted-continuous wave with pure direct current on the plate by using a chopper system to break up the oscillations into interrupted groups. In tube circuits using alternating current on the plate, the wave groups in the antenna system may be in two forms, *i.e.*, full-wave ACCW or half-wave ACCW. This depends upon the number of tubes used. For example, if two tubes are used and the plate of one tube is connected to one end of the plate power transformer and the other to the opposite end and both connected into the oscillatory circuit, then full-wave interrupted-continuous waves will be produced, but if only one tube is used, the radiated waves will be of half-wave character. Systems using alternating-current on the plates are called full wave or half wave as produced by the above methods.

Ques. 9. If a transmitting vacuum tube fails to oscillate, where would you look for the trouble?

Ans. Failure of a transmitting vacuum tube to oscillate may be traced to one or more of the following causes:

1. Fuses blown.
2. High-potential plate supply circuit open (burned-out radiofrequency choke, poor plate connection on the tube, burned-out generator-filter condenser and choke, improperly fitted brushes on the generator commutator, broken leads).
3. Oscillatory circuits not adjusted properly. Improper values of plate and grid inductances or capacities.
4. Burned-out grid leak or grid choke.
5. Plate or grid blocking condenser open or shorted (the latter may produce serious overheating of the tube).
6. Plate potential too low.
7. Filament potential too low.
8. Aerial or ground circuit open.
9. Transmitter improperly tuned to resonance with the radiating system.
10. Filament deactivated.
11. Sagging filament touching the grid.
12. Loose, dirty, or corroded connections, especially in the oscillatory circuit.
13. Poor tube-socket connections.

Ques. 10. How may the frequency of a vacuum-tube transmitter be stabilized?

Ans. The frequency of a vacuum-tube transmitter may be stabilized by the use of a carefully balanced oscillatory circuit or a piezoquartz-crystal oscillator.

Ques. 11. How can you tell if a transmitting tube is overloaded?

Ans. This can usually be determined by the color of the plate of the tube during operation. The plate current should never exceed the value which produces a dull cherry-red color on the plate.

Another method most commonly used is the plate-ammeter indication method. If the plate ammeter indicates the normal number of milliamperes for the given tube as specified by the maker or the instruction sheet, the tube is operating under normal load conditions and is not overloaded.

It is, therefore, important to observe the plate meter and the tube-plate color to determine overloading in transmitting tubes.

Ques. 12. Draw a diagram of a fundamental vacuum-tube oscillator and explain its theoretical operation.

Ans. Figure 3 illustrates a fundamental vacuum-tube oscillator. The theoretical action of a vacuum-tube oscillator may be clearly understood by referring freely to the figure and the following explanation: The moment the filament switch *Sw* is closed and the direct-current generator is running, the filament emits electrons which bombard the plate. A plate current will then flow from *P* to *F* through coil L_1 back to the negative terminal of the generator, completing the circuit and resulting in a steady flow of current in the plate circuit.

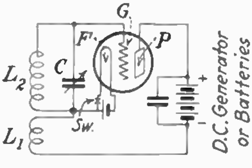


Fig. 3.—Fundamental vacuum-tube oscillator.

This would indicate that a magnetic field must be present about coil L_1. The field would appear to be steady because the flow of plate current is assumed to be constant. The moment the switch *Sw* was closed, however, the magnetic field about the coil L_1 expanded, which, according to the electromagnetic law would cut the coil L_2, due to its inductive relation, and would, consequently, induce an e.m.f., or difference of potential, across it. If then, the coils are wound in a direction in which L_2 would receive a positive potential at the top end and a negative potential at the bottom end, the grid which is connected to the positive end of the coil would receive a positive charge. This immediately partly neutralizes the space charge between F and P and allows more current to flow in the plate-circuit PFL_1 generator. This results in a greater expansion of the field about L_1 and, consequently, a greater induction into L_2, resulting in a greater charge upon the grid. Again the plate current increases and a heavier charge will again be placed upon the grid. This action will continue up to a certain point, depending upon the characteristics of the tube and the resistance of the circuit.

As soon as the plate current ceases to increase, the potential upon the grid drops to zero. Thus, as the increase made the grid positive by the inductive action of coil L_1 upon L_2, then a sudden decrease in the plate current will result in making the grid negative. Thus, if the positive charge on the grid increases the plate current, it is quite apparent that a negative charge upon the grid will tend to decrease it. The plate current will, when the grid is negative, decrease to a point below normal, just as it will increase above normal when positive. In other words, the plate current will decrease to a certain point in which there will be no further change in the grid potential. Then the complete cycle will be reversed and the operation will be completed all over again. Thus, the plate current will rise and fall with a definite frequency, the period of which depends upon the values of the inductance and capacity in the circuit.

Ques. 13. What are the various types of power supply used in vacuum-tube transmitters?

Ans. 1. Direct-current generator with suitable filters.

2. Alternating current with transformer and tube rectifiers.

3. Storage batteries with suitable ampere-hour capacity.

4. Alternating current with transformer but without tube rectifiers (raw alternating currents).

5. Alternating current with transformer and synchronous rectifier.

Ques. 14. What is the function of a grid leak in a vacuum-tube transmitter? What is its usual value?

Ans. The grid leak allows the accumulation of electrons on the grid to leak off gradually, to prevent a blocking action of the plate current, should the grid become excessively charged negatively.

In practically all transmitting circuits there is a condenser placed in the grid or plate-excitation circuits to block the high voltage from the grid and allow the radiofrequency variations to pass. When the tube is oscillating and the grid potential is constantly changing from positive to negative at high frequency, the positive charges attract electrons to the grid, and, due to the blocking action of the grid condenser, these electrons are trapped on the grid. If, therefore, the electronic accumulation becomes too heavy, the plate current will decrease and finally choke and stop the tube from oscillating properly. If a grid leak of a value between 2,000 and 10,000 ohms is connected between the filament and the grid, the charges will leak off and dissipate, enabling the tube to oscillate steadily. The value of the grid leak is usually not very critical.

Ques. 15. What is the function of a radiofrequency choke coil in a vacuum-tube transmitter?

Ans. Radiofrequency choke coils are connected in the power-supply and grid-leak circuits to prevent the high frequencies from passing through them. If radiofrequency chokes are not provided, the high frequencies passing through the generator circuits will prevent the tube from oscillating satisfactorily, or extremely unstable oscillating conditions will result.

Furthermore, in circuits where the tube acts as an amplifier, such as in master oscillator systems, the choke coils in the grid circuits also tend to prevent the tube from being set into self-oscillations at extreme frequencies.

Extremely high frequencies may be generated in a tube transmitter circuit due to small oscillatory currents having a high-frequency period being set up due to inductance in the connecting wires, distributed capacity, and choke coils. The generation of these extremely high frequencies is prevented by the insertion of small resistances or choke coils in the grid leads of the tube.

The above effect is known as *parasitics*, and the resistances connected in the grid circuits to prevent this action are called *parasitic resistances.*

In general, the radiofrequency choke tends to maintain the radiofrequency currents through the circuits of lowest high-frequency reactance and thereby maintains a maximum signal amplitude and, consequently, an increase in efficiency.

Ques. 16. What are three types of oscillating systems? Draw diagrams and explain the theoretical operation of each type.

Ans. Three oscillating systems are illustrated in Fig. 4, *i.e.*, Hartley, Colpitts, and tuned-plate, tuned-grid.

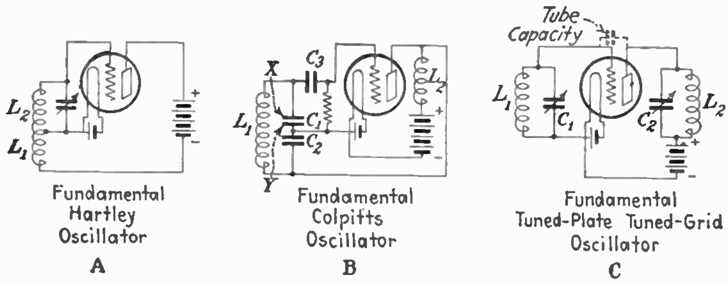


FIG. 4.—*A.* Hartley, *B.* Colpitts, and *C.* tuned-plate, tuned-grid oscillators.

The theoretical operation of the Hartley circuit is, in principle, the same as that of the fundamental oscillator explained in Ques. 12.

The Colpitts system differs from the above in that the grid receives its potential variations through a capacitive arrangement instead of an inductive one, but is the same in principle.

The theoretical operation of the Colpitts oscillatory system is as follows:

When the filament-switch and plate-supply circuits are closed, a steady current flows in the plate circuit through the choke coil L_2 and the plate supply and from the plate to the filament through the tube. The plate condenser C_2, which is connected in shunt to this circuit, acts as load due to a displacement current in the condenser dielectric which results in a voltage drop across the condenser. Now, if the condenser C_1 is connected to the grid of the tube, the voltage drop across C_2 will also produce a drop across C_1 at the points X and Y which will result in an e.m.f. being impressed on the grid. Thus, the potential applied to the grid due to the voltage drop will result in a voltage difference between the filament and grid, which will consequently produce a like change between the plate and filament, which will result in a change in plate-current flow and a further change in grid potential due to voltage changes across C_2 and C_1. This action applies alternating-potential variations to the grid resulting in oscillations (refer to the fundamental tube oscillator Ques. 12).

The condenser C_3 is placed in series with the grid to prevent the positive potential of the plate supply from being applied directly to the grid through the load inductance L_1, which would result in a constant positive bias on the grid and would produce a tremendous increase in plate current and a consequential overloading of the tube. The blocking condenser C_3, however, will tend to keep the grid negative, and when the alternating-potential variations are applied to the grid, during the positive cycle, there will eventually be a decrease in the plate current to a point where the tube will stop oscillating. To insure against this, a resistance is connected between the grid and the filament to allow the negative charges to leak off when they become too high, thus allowing an even rise and fall of grid-potential variations and maintaining a steady rise and fall of radiofrequency oscillations that are being generated.

The choke coil L_2 is inserted to keep the high frequencies from flowing through the plate power-supply system.

The tuned-plate tuned-grid system generates continuous oscillations by a similar capacitive feed-back system, but instead of providing separate plate- and grid-excitation condensers, the tube capacitance is used for producing the grid-potential variations and oscillations as follows:

If both the plate and grid inductances and capacities are adjusted to resonance with each other, or nearly so, an e.m.f. will be impressed upon the grid through the tube capacity as soon as the filament is lighted and a plate current is flowing. This will result in a reinforcing action upon the grid and a corresponding change in the plate current which will produce continuous oscillations the same as the fundamental oscillator in Fig. 3.

In all of the above transmitting circuits the frequency (wave length) is determined by the values of the oscillating constants of the circuit, *i.e.*, inductance and capacity.

Ques. 17. What are piezo-electric resonators and oscillators?

Ans. These are bodies which become electrically charged when they are submitted to mechanical pressure; and, oppositely, become mechanically strained when subjected to an electrostatic field pressure.

It has been found that certain crystals such as quartz and Rochelle salts can be electrically charged by placing them between two metallic plates and applying a pressure to them. Similarly, if an e.m.f. is applied to the two metal plates the crystal will either contract or expand, depending upon the polarity of the applied e.m.f. Thus, if an alternating e.m.f. is applied to the metal plates the crystal will be subjected to pressure reversals which will cause it to vibrate, or in other words, it will expand and contract at the excitation frequency, provided the mechanical vibrating frequency is equal to the applied excitation frequency. The frequency at which the crystal will oscillate depends upon its thickness; *i.e.*, the thicker the crystal the lower the frequency of vibration and *vice versa.* A very thin crystal may vibrate at frequencies near 7,000,000 cycles if extreme care is taken in providing that the applied potentials are small, to prevent it from cracking or chipping. Rochelle salts are vigorous oscillators but are not used because of their fragility, and, therefore, a more substantial material such as quartz is used. At extremely high frequencies, however, even a thin quartz plate might be very easily broken and, therefore, is seldom used.

In cases where it is desired to use the crystal-oscillator method at very high frequencies, the vibrating period of the crystal is usually kept low by using a crystal of thicker structure (lower frequency). Then, in order to produce oscillations at the extreme frequencies, a series of vacuum-tube amplifiers, functioning as harmonic producers, will generate oscillations at one of the harmonic periods of the crystal.

Now, if a quartz crystal is placed between two metallic plates and connected to the grid and filament circuit of a vacuum tube, as in Fig. 5, and the inductance and capacity in the plate circuit adjusted to the vibrating frequency of the crystal, an e.m.f. will be impressed between the grid and the filament. This will, in turn, build up a high potential e.m.f. (due to resonance in both the grid-to-filament and plate-to-filament circuits) resulting in an oscillating current of continuous character being generated, due to the contraction and expansion of the crystal, the frequency of which is dependent upon the oscillatory constants, *i.e.*, plate inductance and capacity and the vibrating frequency of the crystal.

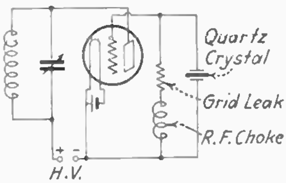


FIG. 5.—Piezo-electric oscillator.

The theory of the generation of oscillations is the same as the tuned-plate, tuned-grid system in Fig. 4, with the crystal forming the grid-oscillatory circuit instead of the grid inductance and capacity, L_1C_1.

The crystal-oscillator system of frequency control provides greater stabilization and standardization of frequency than any other form of oscillator and is now being used throughout the world as a frequency standard controlling device.

Ques. 18. What tests may be made to ascertain whether or not a transmitting tube is oscillating?

Ans. 1. If a wavemeter, having a suitable high-frequency indicating device such as a lamp, neon tube, or radiofrequency ammeter, is placed in an inductive relation to the oscillating system and adjusted to the wave length (frequency) at which the transmitter is to oscillate, it will have a high-frequency oscillating current induced into it at resonance which will produce an indication in one of the above indicating devices and thereby show that the tube is oscillating.

2. If an ammeter is connected in the plate-supply circuit of a tube a certain amount of current will flow through it depending upon the plate potential and tube characteristics. If the circuit is oscillating, the reading on the plate ammeter will read less than the normal operating reading and, therefore, will serve as an oscillation indicating method.

3. If a neon tube or a high-frequency ammeter is connected in the high-frequency portion of the plate circuit, an indication on either device will serve as an oscillation indicating method.

4. Similarly, if a high-frequency indicating device is connected in the grid circuit, an indication will result if the tube is oscillating.

Thus, if a neon tube or radiofrequency ammeter (thermo-coupled or hot wire) is connected in any portion of the oscillatory circuits, either in the grid or the plate circuits, a reading will occur when the tube is oscillating.

Ques. 19. What are some of the causes for failure of a tube transmitter to radiate?

Ans. 1. Tube not oscillating.
2. Defective antenna ammeter.
3. Defective antenna insulation.
4. Circuits not in resonance.
5. High antenna resistance.
6. Poor connections on the antenna inductance.
7. Improper coupling.

An antenna-ammeter reading does not necessarily indicate that an antenna is radiating. It is merely used as a means of indicating resonance with the excitation circuit.

Ques. 20. How would you decrease the power of a tube transmitter?

Ans. Decrease the plate e.m.f. by increasing the generator-field resistance, or insert a resistance in series with the plate supply.

Ques. 21. Draw a diagram of a commercial tube transmitter using the master-oscillator and power-amplifier systems of transmission. Explain briefly its theoretical operation.

Ans. Figure 6 illustrates a typical commercial tube transmitter using this principle.

The oscillations in the transmitter are generated by a tube using the Colpitts system of oscillation generation. These oscillations are then passed to two tubes which function as power amplifiers (not oscillators). These oscillations are then induced into the antenna circuit by a suitable means of coupling and then radiated in the form of continuous (CW) or interrupted-continuous waves (ICW), as may be desired.

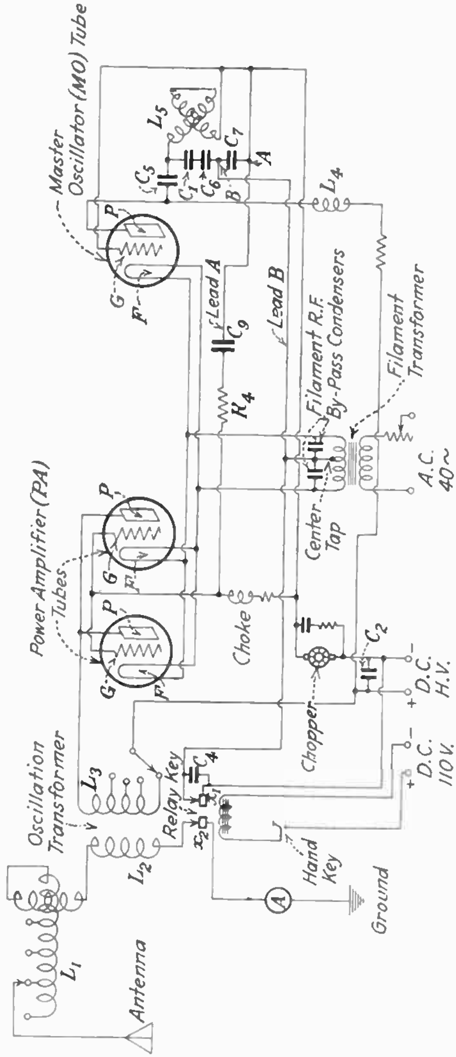


FIG. 6.—Wiring diagram of vacuum-tube transmitter (master-oscillator type).

For higher-power transmitters using this principle, two or more master-oscillator tubes may be used and as many as six or eight amplifier tubes.

The theoretical operation of this type of transmitter is, briefly, as follows:

When the motor-generator system is started, a high-voltage direct-current potential is applied to the plates of the tubes, and the filaments are lighted through the medium of a filament step-down transformer. The transformer is operated by a 40-cycle alternating current obtained from an alternating-current armature excited by the motor field winding.

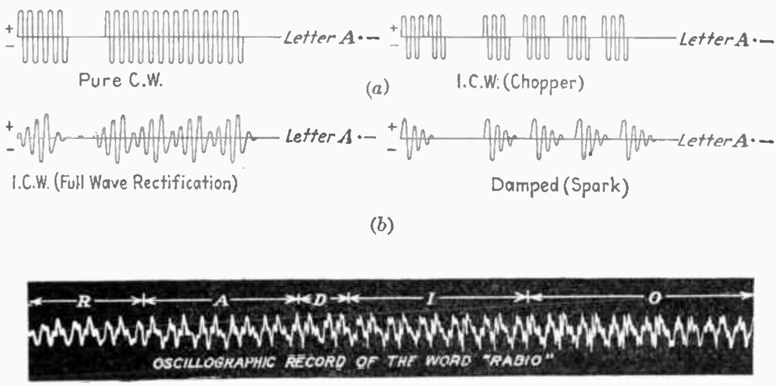
When the hand-key circuit is closed, a solenoid is energized which operates a relay key and closes the contacts X_1 and X_2 which allows a plate current to flow from the plate to the filament circuits in the power amplifier tubes *PA* as follows: $HV+$, L_3, P, F, center tap, X_1, $HV-$, and in the master oscillator circuit $HV+$, P, F, center tap, $HV-$, which completes the plate-current flow in all the tubes.

It has been seen that when a plate current is flowing in a tube circuit designed for the generation of high-frequency oscillations (in this case, the *MO*, master oscillator, is of the Colpitts type), there will be a voltage drop across the plate-excitation condensers C_1, C_6 and, consequently, across the grid-excitation condenser C_7. This results in the excitation of the grid of the *MO* tube which results in a change in the plate circuit (see Fundamental Oscillator, Ques. 12) which generates oscillations through the plate high-frequency circuits P, C_1, C_5, C_6, filament center tap, through the radiofrequency-bypass condensers, to the filament and thence to P, thus completing the high-frequency plate circuit. The grid high-frequency current flows: G, C_7, filament center tap, through the radiofrequency-bypass condensers, thence to F and G. The variometer L_5 which is shunted across the plate and grid-excitation condensers acts as an inductive load and thereby controls the frequency of the circuit.

Thus, the oscillations generated by the *MO* tube are dependent upon the frequency constants, as in any oscillatory circuit, *i.e.*, inductance and capacity. In this circuit, the frequencies can be varied over a band depending upon the variable range of L_5.

Now, assuming the *MO* tube to be oscillating, it will be seen that the two leads *A* and *B* connected across the grid-excitation condenser C_7 will have a high-frequency potential variation across them, and since lead A is connected to the grids of the PA tubes through the coupling condenser C_9 and feed resistance R_4 and the lead B is connected to the filaments through the filament radiofrequency-bypass condensers, this same high-frequency potential variation will be present between G and F of the PA tubes.

Now the steady plate-current flow in the PA tubes will be varied at the frequency of the grid-potential variations which



(c)

Fig. 7.—Characteristics of radio waves.

(a) (*left*) Class A, type 1 continuous waves; (*right*) Class A, type 2 continuous waves.
(b) (*left*) Class A, type 2 continuous waves; (*right*) Class B, damped waves.
(c) Class A, type 3 continuous waves.

will result in a high-frequency current flow in the plate circuit P, L_3, C_2, C_4, filament center tap, filament bypass condensers, F and P, completing the high-frequency plate-current flow.

Hence, the high-frequency field about coil L_3 will be transferred to L_2 if the latter is critically adjusted to resonance by the variometer L_1 and the inductance taps, provided, of course, that contact X_2 is also closed.

The above explanation covers pure CW transmission but if it is desired to break up the continuous oscillations into groups, as illustrated in Fig. 7, then the chopper wheel must be put into operation.

Ques. 22. What are the characteristics of the various types of waves emitted from various transmitters?

Ans. The various emissions are divided into two main classes: *A*. Continuous waves. *B*. Damped waves.

Class *A* includes the following types of waves:

Type 1.—Unmodulated continuous waves, arc, oscillating-tube generators, and high-frequency alternators.

Type 2.—Continuous waves modulated at an audible frequency; continuous waves the amplitude or frequency of which are varied in a periodic manner at an audible frequency and combined with telegraphic keying.

Type 3.—Continuous waves modulated by speech or music the amplitude or frequency of which is varied according to the wave-variation characteristics of speech or music.

Figure 7 illustrates the various wave forms under the above three types.

Ques. 23. Draw a diagram of a complete commercial installation including a receiver employing a regenerative detector with one step of audio amplification. A tube transmitter provided with a radiophone attachment. The transmitter is to be operated by storage batteries. Show charging equipment to be used with both emergency batteries and receiver batteries. State in watts or kilowatts the power used. Ampere-hour capacity. Include the motor generator and an automatic starter.

Ans. Figure 7*B* illustrates a complete diagram of the above parts.

Ques. 24. Draw a diagram of a complete commercial radiophone transmitter.

Ans. Figure 7*D* illustrates a complete diagram of a radiophone transmitter.

Ques. 25. What is the break-in system?

Ans. This is a system which enables an operator at the transmitting station to listen in during the period that he is transmitting a message. With an arrangement of this kind, the operator sending a message may be stopped at any point of the message by the receiving operator by the latter's holding down the key at the point where he missed a letter or word. This method is of great advantage in cases where long messages are being sent, because it permits the receiving operator to halt the transmitting operator the moment he misses a letter and thus save considerable time. In modern tube-transmitter installations, this system is utilized by using a special relay key operated by a solenoid which is excited by the ship's power and controlled by the regular small Morse hand key. This device consists of two pairs of contacts, one pair being connected with the low-potential end of the antenna system and the other pair in the key circuit of the transmitter. Whenever the antenna contacts are open, the radio receiver is connected through the antenna inductance, and when they are closed automatically, they short circuit the receiver, thereby protecting against high-voltage surges. During the period that the key circuit of the transmitter is closed, the receiver contacts must close a fraction of a second before to insure against a possible *burn-out* of the receiver. This is accomplished by carefully adjusting the contact spring on each pair so that the spacings on the antenna contacts are about ⅛ inch less than the key contacts. When the proper spacing adjustment is obtained, a slight spark will occur at the key contacts and a slightly larger one at the antenna contacts. If a relay key is not provided, then a break-in system may be arranged by using a separate antenna for the receiver. Figure 6 illustrates a master oscillator-tube transmitter equipped with a break-in relay.

Ques. 26. How would you transmit signals if your entire transmitter became inoperative?

Ans. Figure 21 illustrates a simple emergency transmitter. If, however, no power is available, then, in cases of extreme emergency, the receiver may be used as a small transmitter by adjusting it to 600 meters and then varying the tickler coil until the tube oscillates. The key is then connected in series with the B battery lead for signalling.

Ques. 27. How are harmonics suppressed?

Ans. Harmonics in a vacuum-tube transmitter may be effectively suppressed from being radiated by using a trap circuit capable of absorbing the undesirable harmonics being radiated. Careful adjustment of the coupling between the antenna and exciting circuits will, in most cases, suppress the radiation of harmonics. Various other factors such as proper antenna design and the breaking up of guy wires with insulators are also important items in harmonic suppression.

Ques. 28. How can it be determined if a transmitting tube is soft?

Ans. A soft transmitting tube usually shows a blue haze between the filament and the plate and further manifests itself by very erratic operation. A careful observation of the plate-current ammeter will usually indicate a soft tube by an excessive current reading. In many cases where a tube suddenly becomes soft, the plate becomes white hot, and a heavy increase in plate current will result.

Ques. 29. Of what use is a plate milliammeter in the plate circuit of a tube transmitter?

Ans. A milliammeter in the plate circuit of a tube transmitter enables the operator to observe the following:

1. The proper plate-current flow for a given tube at its rated voltage.
2. Improper bias voltage.
3. Tube overloading.
4. Unsteady oscillation.
5. Soft tube.

Ques. 30. What are the indications that a tube transmitter is not operating?

Ans. No radiation, no plate-current flow, no grid-current flow, filament not lighted, no plate voltage. If, on the other hand readings are obtained on all meters but are of improper values, see if the following adjustments have been satisfactorily made:

1. Adjust generator-field rheostat to proper tube voltage.
2. Adjust filament rheostat for the proper filament voltage.
3. Adjust the oscillatory plate and grid taps on the inductances.
4. Adjust the antenna circuit to resonance.

Ques. 31. How would you find a defective transmitting tube?

Ans. A defective oscillator tube can usually be determined by the transmitter's failing to oscillate, that is, provided all other parts of the circuits are not defective. In amplifier circuits, a defective amplifier tube may be located by replacing it with a spare. In cases where more than one tube is used as an amplifier, then one tube must be taken out and replaced with a spare, and so on with the other tubes until the defective one is found.

Perhaps the simplest method for detecting defective tubes is to note carefully the readings on the plate, grid, and antenna ammeters. In all modern tube transmitters, the correct values of plate current and grid current flow are usually indicated in the instruction sheets for the specific types and number of tubes in use.

Other symptoms of a defective transmitting tube are as follows:

1. The color of the plates exceeding a dull cherry red.
2. A blue haze between the filament and the plate.

Ques. 32. How would you key a high-power tube transmitter?

Ans. In the majority of the commercial-tube installations where direct current is applied to the plates of the tubes, the key is usually connected in series with the low-potential side of the plate lead, or in the case of the ACCW tube transmitters the key is in the primary circuit of the power transformer. In the former system, a small hand key cannot be used because considerable arcing would result which would produce sticking and would, therefore, make accurate transmission impossible.

In many of the commercial-tube installations, a heavy contacted relay key is used operated by a solenoid in series with a small Morse hand key and excited by the ship's power. Some of these keys are also equipped with additional heavy contacts to open and close the radiating circuit for break-in operation.

Ques. 33. What is the effect of an improper bias on a transmitting tube?

Ans. An improper bias will, in most cases, cause unstable operation. The proper bias in oscillator tubes will aid the circuits in oscillating properly and will, therefore, help to produce stable operation.

In power-amplifier tubes such as are used in the master-oscillator systems, they must have a proper grid bias to prevent overloading or self-oscillation.

It is important to remember that the proper operation of any tube either as an oscillator or as a power amplifier must have a certain negative potential on the grid (negative bias) so that the tube will effectively function on the proper point of the plate-characteristic curve.

All tubes designed for transmitting purposes usually have a certain value of negative potential on their grids for a specific plate voltage. Hence, in order to obtain maximum efficiency, it is always necessary to apply the proper negative bias for each change in plate potential. These values are usually specified by the tube manufacturer and if no grid values are supplied it is then an indication that the grid bias is not critical.

Ques. 34. Tell two ways in which alternating current may be used as a power supply for vacuum tubes.

Ans. Figure 7A illustrates two ways in which alternating current may be used as a power supply for vacuum tubes.

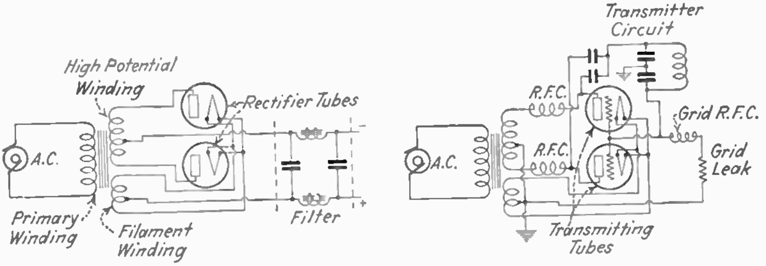


FIG. 7A.

Ques. 35. How would you reduce the power of a tube transmitter in order to work a nearby station?

Ans. Decrease the plate voltage by increasing the resistance at the generator-field rheostat. If the generator-field rheostat is burned out and cannot be repaired, then connect a salt-water rheostat in series with the plate-supply lead or field circuit.

Ques. 36. What methods are used to prevent overloading of transmitting tubes?

Ans. Transmitting tubes are protected from overload by fuses, properly adjusted circuit breakers, and proper adjustments such as proper plate voltages, proper grid bias (usually a grid leak), carefully adjusted oscillatory circuits, proper number of turns in the plate inductance, and good electrical connections, especially in the high-frequency circuits.

Ques. 37. State three principle causes of trouble encountered with tube transmitters.

Ans. 1. Poor electrical connections, especially in the high-frequency circuits. This is a very common trouble on shipboard due to the salt water's oxidizing and corroding all unsoldered contacts.

2. Low radiation due to dirty or leaky insulators (assuming that the circuits are properly resonated).

3. Overloading due to defective bias resistance or grid leak, circuit not oscillating, defective oscillator tubes, defective amplifier tube (as in master-oscillator power-amplifier circuits), improper number of plate turns.

Ques. 38. What substitute could be used for a burned-out grid leak?

Ans. In oscillator circuits, a resistance of approximately 5,000 ohms. This may be constructed by cutting off a 12-inch piece of hose filling it with salt water, and plugging at both ends. Then pierce a wire into each end so that it makes connection with the water. In power-amplifier systems, the burned-out grid leak may be replaced by a 60-watt lamp.

Ques. 39. Tell of four different sources of plate current.

Ans. Motor generator, rectified alternating current, raw alternating current, and battery supply.

Ques. 40. Tell three ways of interrupting continuous waves.

Ans. Chopper, audio oscillator, and microphone.

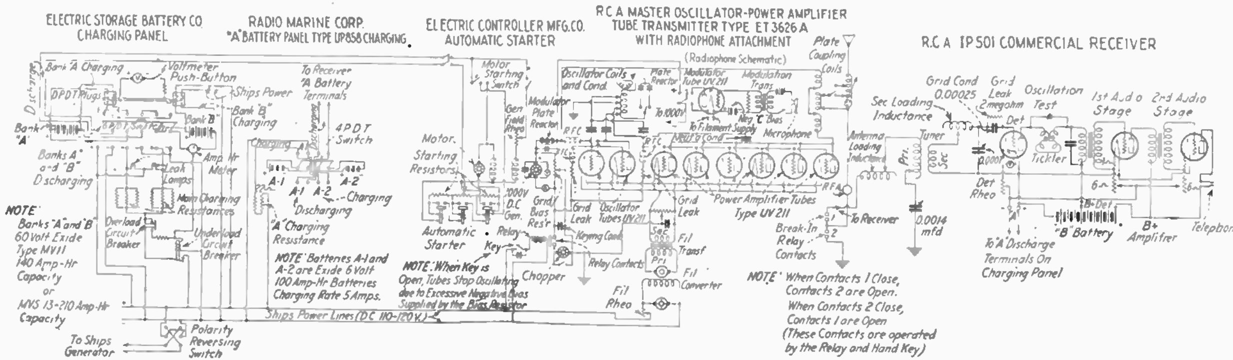

ELECTRIC STORAGE BATTERY CO CHARGING PANEL
RADIO MARINE CORP. "A" BATTERY PANEL TYPE UP858 CHARGING
ELECTRIC CONTROLLER MFG.CO. AUTOMATIC STARTER
R C A MASTER OSCILLATOR-POWER AMPLIFIER TUBE TRANSMITTER TYPE ET 3626 A WITH RADIOPHONE ATTACHMENT
(Radiophone Schematic)
R.C A IP 501 COMMERCIAL RECEIVER
Bank 'A' Charging
Voltmeter Push-Button
DPDT Plugs
Discharge
Bank "A"
Banks A' and 'B' Discharging
Leak Lamps
Amp Hr Meter
Main Charging Resistances
Overload Circuit Breaker
Underload Circuit Breaker
NOTE: Banks 'A' and 'B' 60 Volt Exide Type MVII 140 Amp-Hr Capacity or MVS 13-210 Amp-Hr Capacity
To Ships Generator
Polarity Reversing Switch
Ships Power Lines (DC 110-120 V.)
To Receiver 'A' Battery Terminals
Ships Power
Bank 'B' Charging
4 P D T Switch
A-1
A-2
Charging
Discharging
'A' Charging Resistance
NOTE: Batteries A-1 and A-2 are Exide 6 Volt 100 Amp-Hr Batteries Charging Rate 5 Amps.
Motor Starting Switch
Motor Starting Resistors
Automatic Starter
Gen Field Rheo
1000 V D.C Gen.
Relay
Key
NOTE: When Key is Open, Tubes Stop Oscillating due to Excessive Negative Bias Supplied by the Bias Resistor
Chopper
Oscillator Coils and Cond.
Modulator Plate Reactor
Plate Reactor
Modulator Tube UV 211
Modulation Trans.
To 1000 V
To Filament Supply
Neg. 'C' Bias
Microphone
RFC
Grid Bias Res'r
Grid Leak
Oscillator Tubes UV 211
Keying Cond
Relay Contacts
Power Amplifier Tubes Type UV 211
Fil Transf
Sec
Pri
Fil Converter
Fil Rheo
Plate Coupling Coils
RFA
Antenna Loading Inductance
To Receiver
Break-In Relay Contacts
0.0014 mfd
NOTE: When Contacts 1 Close, Contacts 2 are Open. When Contacts 2 Close, Contacts 1 are Open (These Contacts are operated by the Relay and Hand Key)
Sec Loading Inductance
Tuner
Grid Cond 0.00025
Grid Leak 2 megohm
Det
Oscillation Test
Tickler
Det Rheo
1st Audio Stage
2nd Audio Stage
"B" Battery
B+ Amplifier
Telephones
To 'A' Discharge Terminals On Charging Panel

Fig. 7B.

Ques. 41. Where in a vacuum-tube transmitting circuit would you install a chopper to modulate continuous waves? Show by diagram.

Ans. See Fig. 6.

Ques. 42. Why is it necessary to maintain the proper filament voltage on a transmitting tube?

Ans. If the filament voltage on a tube is not properly adjusted, either there will be a decrease in the plate current due to improper emission and a consequential inoperation, or an excessive emission will decrease the life of the filament in a very short time and thus render the tube useless. This is true with both the oxide and the thoriated filaments, especially the latter. Hence, if the voltage is too low, the tube will not function properly and if too high will in a short time ruin the tube.

Ques. 43. Draw a complete diagram of a commercial tube transmitter with a radiophone attachment.

Ans. Figure 7*B* illustrates a complete wiring diagram of a commercial tube transmitter with a radiophone attachment.

Ques. 44. Describe a two-button carbon microphone. Explain the theory of operation.

Ans. See Ques. 388.

Ques. 45. Draw a diagram of a filter capable of being used with a high-power vacuum-tube transmitter and explain the operation of the filter.

Ans. Figure 7*C* illustrates a typical filter system used in high-power tube transmitters.

The object of this filter system is to smooth out the current variations produced by the generator commutator so that a steady current will flow in the plate-to-filament circuit. The operation of this filter is briefly as follows: The current variations produced by the generator are known as commutator *ripples*. These ripples rise and fall at a certain frequency, depending upon the number of commutator segments and the general design of the armature. Now, as soon as these variations are impressed

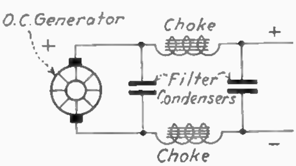


FIG. 7C.

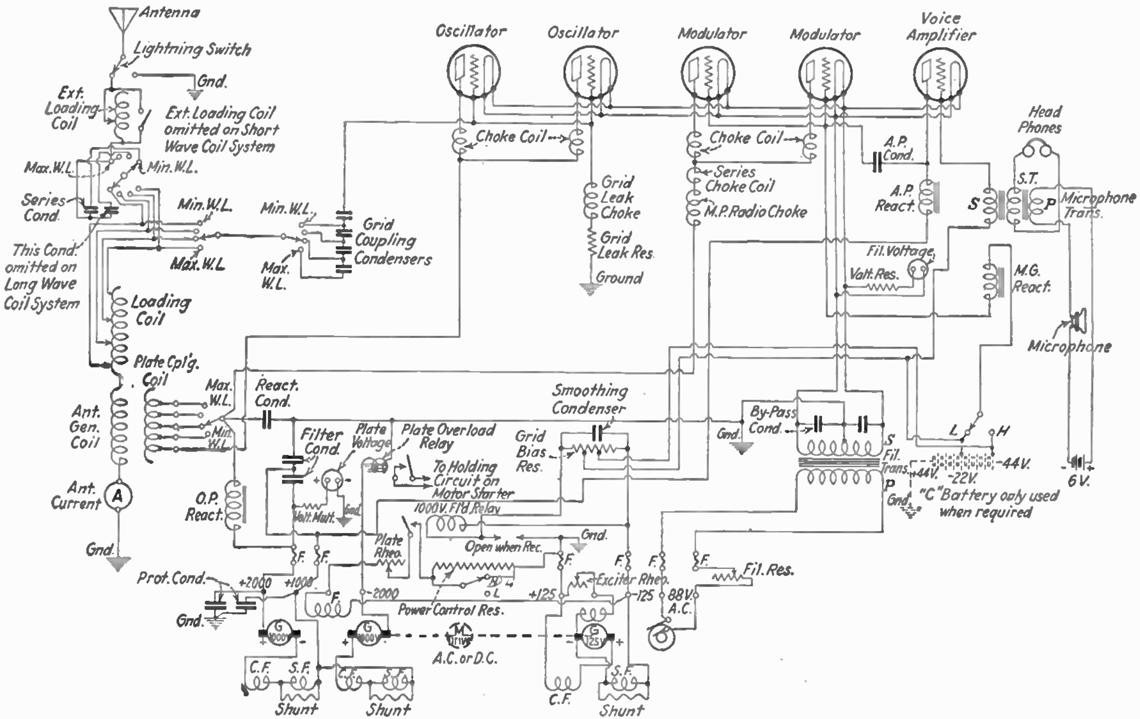

Antenna
Lightning Switch
Gnd.
Ext. Loading Coil
Ext. Loading Coil omitted on Short Wave Coil System
Max. W.L.
Min. W.L.
Series Cond.
This Cond. omitted on Long Wave Coil System
Min. W.L.
Max. W.L.
Min. W.L.
Max. W.L.
Grid Coupling Condensers
Loading Coil
Plate Cpl'g. Coil
Ant. Gen. Coil
Ant. Current
Gnd.
Oscillator
Oscillator
Modulator
Modulator
Voice Amplifier
Choke Coil
Grid Leak Choke
Grid Leak Res.
Ground
Choke Coil
Series Choke Coil
M.P. Radio Choke
A.P. Cond.
A.P. React.
Head Phones
S.T.
S
P
Microphone Trans.
Fil. Voltage
Volt. Res.
M.G. React.
Microphone
Max. W.L.
Min. W.L.
React. Cond.
Filter Cond.
Plate Voltage
Plate Overload Relay
To Holding Circuit on Motor Starter
Volt. Mult.
1000V. Fl'd Relay
O.P. React.
Smoothing Condenser
Grid Bias Res.
Gnd.
By-Pass Cond.
Fil. Trans.
L
H
-44V.
+44V.
-22V.
"C" Battery only used when required
6V.
Plate Rheo.
Open when Rec.
Gnd.
Power Control Res.
Exciter Rheo.
Fil. Res.
88V. A.C.
Prot. Cond.
+2000
+1000
-2000
+125
-125
Gnd.
F.
M Drive
A.C. or D.C.
C.F.
S.F.
Shunt
Shunt
C.F.
Shunt

Fig. 7D.

across the *choke* coils, their high inductance will tend to oppose this varying effect in such a manner that the current on passing out of the choke coils to the plates of the tubes will have steadied down to a practically non-varying flow. This depends of course upon the design of the filter. Hence, the high self-inductance tends to prevent a change of the current flow and, in conjunction with the condensers, smooths out the undesirable current variations. Here the condensers function as a sort of reservoir to absorb the voltage changes across the chokes, and thus they help to prevent varying potentials from being applied to the plates of the tubes.

Brief Bibliography

NILSON and HORNUNG: "Practical Radio Telegraphy," McGraw-Hill Book Company, Inc.

MORECROFT: "Principles of Radio Communication," John Wiley & Sons, Inc.

LAUER and BROWN: "Principles of Radio Engineering," McGraw-Hill Book Company, Inc.

PLATE I.—Two-kilowatts Federal arc installation. (*Courtesy*, Federal Telegraph Company.)

PART III

ARC TRANSMITTERS

Ques. 46. How would you proceed to place an arc transmitter into operation? Explain fully.

Ans. To place a 2-kw. Federal arc back-shunt system into operation, proceed as follows:

1. Close the main line D.P.S.T. switch on the arc-control panel.

2. Place the send-ground-receive switch on *send.* This should start the water pump and excite the generator field. Make certain that the water is circulating properly.

3. Start the motor generator by first closing the circuit breaker on the motor-starting panel and then bringing the motor up to speed by slowly advancing the starting arm from the *off* to the *on* position.

4. Adjust the voltage of the generator to about 300 volts by using the generator-field rheostat and observing the voltmeter on the arc-control panel.

5. Start the flow of alcohol, allowing it to drip rather rapidly. If the transmitter is provided with a magnetic alcohol container, the flow of alcohol is automatically started when the send-ground-receive switch is thrown to *send.* Turn the arc-adjusting knob on the cathode until it has about $\frac{1}{32}$-inch motion when the carbon holder is pushed inward to strike the arc flame; $\frac{1}{32}$ inch is about the right length of gap to use on starting the arc-converter unit, and it is advisable to make sure that this is right, before connecting the circuit to the generator.

6. Close the arc-main-line switch 1 (circuit breaker) on the arc-control panel by pushing the handle downward until the switch locks.

7. Strike the arc flame by pushing inward on the arc-adjusting knob. The carbon holder is held out against the stop by a spring inside the cathode. By pushing inward on the carbon

holder the force of this spring is overcome and the electrodes are brought together for starting the arc flame. The arc flame should be struck by pushing inward on the carbon holder and quickly allowing it to recede. Too much force should not be used, otherwise the electrodes may become damaged.

It may be necessary to strike the carbon holder several times before the arc is ignited. It may also be necessary to shorten the arc gap by turning the arc-adjusting knob. As soon as the arc flame starts, it should be drawn out slowly and adjusted until oscillations start. When oscillations start, the antenna ammeter will indicate that there is current in the antenna circuit. The arc flame should then be adjusted for a maximum indication of the ammeter.

8. Close the arc-starting resistor switch 2 on the arc-control panel by pushing the handle down until it locks. This short-circuits the main arc resistance. Adjust the arc flame for a maximum and steady indication of the antenna ammeter (between 8 and 9 amperes).

9. Signals may now be transmitted by using the Morse hand key.

The iron-plate resistor may now be adjusted for balance. For example: If the reading on the radiofrequency ammeter is 8 amperes when the arc is oscillating in the back-shunt circuit, and the reading changes when the key is pressed, then the iron-plate resistor must be varied until the radiofrequency ammeter reads the same when the key is up as when it is down. Care must be taken that this adjustment be made carefully so that both readings will be steady.

If it is desired to transmit with the chopper and compensating loop, then short-circuit the Morse hand key by the short-circuiting switch, and put the chopper into operation using the auxilliary hand key for signalling.

Make certain that the inductance is adjusted to the proper wave length by noting the position of the variable-inductance lead and the wave marker.

Ques. 47. Draw an elementary diagram of an arc transmitter. Explain fully its operation.

Ans. For an elementary diagram of an arc, see Fig. 8.

The arc is fed by a direct current varying in pressure from 200 to 1,200 volts, depending upon its size. To this source of supply is connected the arc converter where the supply current is converted into high-frequency, undamped oscillations in the following manner:

a. The arc is struck, and the high-potential current across the terminals begins to charge the condenser, made up of antenna and ground. This condenser, therefore, takes some of the current away from the arc, and the voltage across the arc increases until the condenser is fully charged.

b. When the condenser is fully charged, the current through the arc rises to normal value; this causes the voltage across

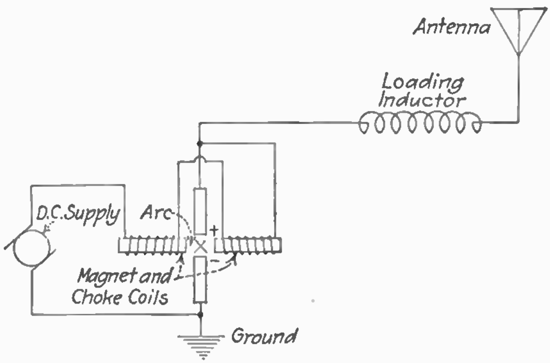


FIG. 8.—Elementary wiring diagram of arc transmitter.

the arc to drop. The condenser, however, is still fully charged, and its voltage value is now higher than that of the arc. It, therefore, discharges across the arc.

c. Due to the fact that the discharge takes place through a circuit having oscillatory characteristics, undamped oscillations are produced.

d. At each oscillation the voltage rises and falls periodically, giving a constant source of energy. As long, therefore, as the voltage is present the oscillations continue.

In order to signal with this system, it is necessary to provide some means of breaking the oscillations of the antenna circuit into code groups. This may be done, as shown in Fig. 12, with a compensating loop and key in inductive relation to the antenna inductance, in which position it absorbs the generated oscillations of the arc when the key is pressed and in this way changes the frequency of the emitted wave. The receiving operator must tune to the wave length (frequency) of the emitted wave when the key is depressed. This system is practically obsolete, although not entirely out of use.

NOTE.—For a complete diagram of a modern arc-signalling system see Fig. 10.

Ques. 48. Explain how to obtain maximum voltage across the arc.

Ans. This is accomplished by carefully adjusting the arc length and voltage, by turning the electrode adjusting handle, and by means of the field rheostat. It is also necessary that the electrodes be in good condition.

Ques. 49. Describe the construction of the positive electrode of the arc.

Ans. The positive electrode of the arc is copper. It consists of a copper tip which is fastened to a brass holder. It can be

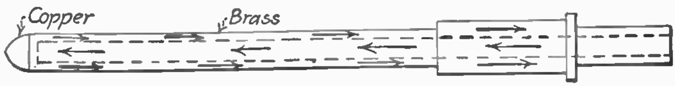


FIG. 9.—Water-cooled arc electrode.

removed from the holder when it has burned low. The tip is so constructed that water can flow through it, thereby keeping it cool. Figure 9 shows the water circulation and general construction of the positive electrode. On the more recently designed arc sets, both positive and negative electrodes are of copper and are water cooled as the one here shown (see Ques. 52).

Ques. 50. How would you adjust the flow of water to the cooling chamber?

Ans. The flow of water can be adjusted by regulating a valve near the water tank.

Ques. 51. What is an arc?

Ans. The Committee on Standardization, Institute of Radio Engineers, defines the arc as the passage of an electric current of relatively high density through a gas or vapor, the conductivity of which is mainly due to the electron emission from the self-heated cathode. Under present practical conditions, the phenomena takes place near atmospheric pressure. A transmitting system using an arc for producing the undamped oscillations is sometimes referred to as an *arc* or an *arc set.*

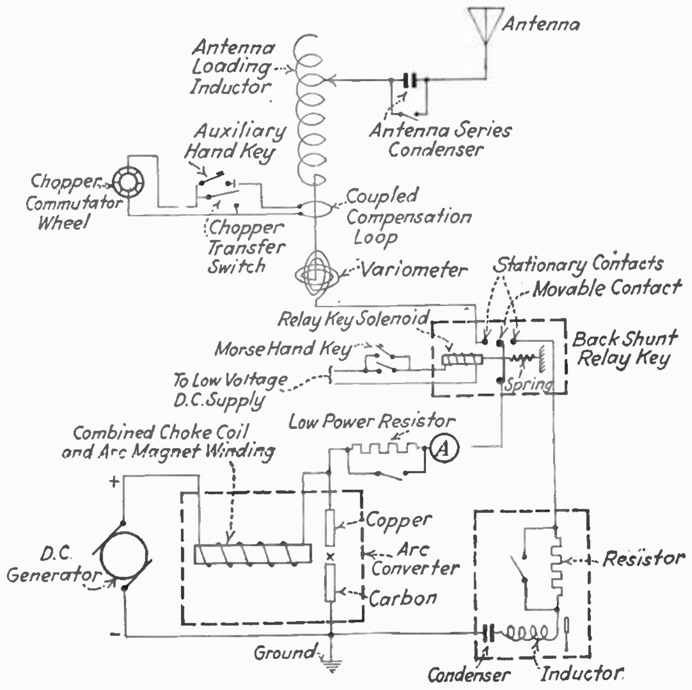


FIG. 10.—Wiring diagram "back-shunt" arc signalling system.

Ques. 52. Of what material are the negative and positive electrodes made?

Ans. Usually the positive electrode is made of copper and the negative electrode is made of carbon. A later type of arc manufactured by the Federal Telegraph Company has a copper positive electrode and a copper negative electrode, both of which are water cooled. This latter type is called the *metal-electrode arc.*

Ques. 53. What is the function of the choke coils in an arc chamber?

Ans. 1. They smooth out the generator irregularities due to the commutator ripples.

2. They prevent the high frequencies from passing through the generator windings and thus function as a radiofrequency choke.

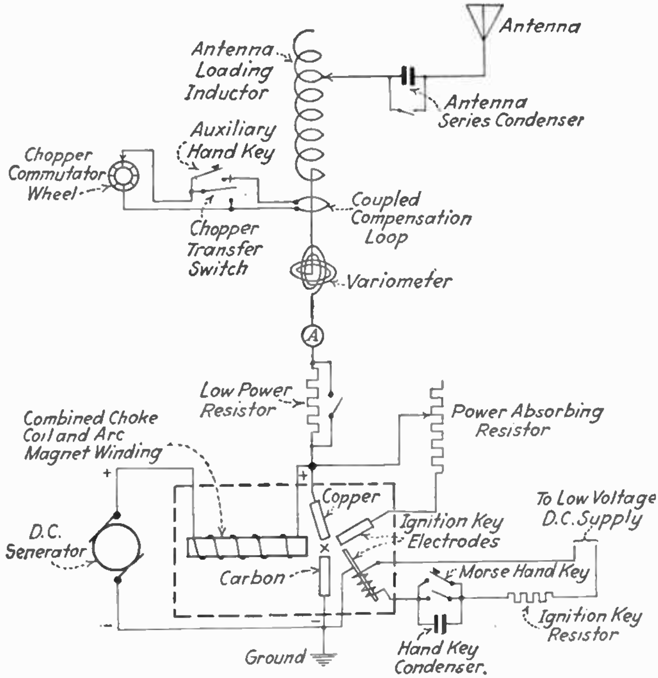


FIG. 11.—Wiring diagram "ignition-key" arc signalling system.

3. They maintain a steady magnetic field across the arc flame which tends to stabilize the arc by deionization and thus acts as an indirect method of cooling.

Ques. 54. What are the various arc-signalling systems?

Ans. Back-shunt relay; ignition key; chopper and compensating-loop systems. Figures 10, 11, 12 illustrate the above systems.

Ques. 55. Why is the negative electrode slowly rotated?

Ans. So that the carbon, which is deposited by the hydrocarbon gas, may become deposited evenly. The cathode, due to this formation, will in time have a mushroom-like shape.

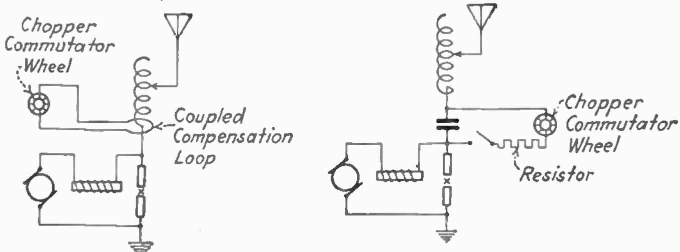


FIG. 12.—Wiring diagram "compensating-loop" and "chopper" arc signalling systems.

Ques. 56. What two means are provided for keeping the electrodes of an arc transmitter cool? Explain fully.

Ans. The copper electrode is hollow, and water is circulated through it. The arc chamber is also provided with an exhaust path for allowing the carbonized hydrogen gas in the arc chamber to escape. These characteristics in the design of the arc tend to keep the electrodes cool.

The water is circulated through the anode, upper and lower units of the arc chamber by means of a centrifugal pump with the necessary hose and tank attachments.

Another method of cooling is the thermosiphon system. Here is applied the theory of water rising to a higher level when heated. Thus, when the water in the anode becomes heated, it will rise into the tank (provided, of course, that the water tank is at a higher level) and cause a circulation of water during the period in which the arc is burning. The blower magnets might also be referred to as an indirect-cooling system due to the deionizing effect of the magnets on the arc while it is in operation.

Ques. 57. What kind of vapor is emitted between arc electrodes?

Ans. An ionized vapor stream resulting from an electronic emission after the two electrodes have been struck and gradually moved apart.

This stream is due to the intense heat generated between the electrodes. The positive ions heavily bombard the negative electrode (cathode) which results in a breaking up of the molecular structure of the electrode into electrons and positive ions. These electrons then move to the positive electrode (anode) to form an electronic path of current, or, conventionally, a flow of electricity from the anode to the cathode.

If, however, the ionization is increased further by dripping alcohol or kerosene upon the arc flame and generating a hydrocarbon gas, then a greater arc current will flow and the arc flame will be considerably "fatter."

This increase in arc current is due to a decrease in the arc resistance as a result of the electrons bombarding the gas atoms and breaking them up into ions and electrons. This increases the electronic flow to the anode causing an increase in the conventional flow from the anode to the cathode. This action of the breaking up of the gas atoms is known as *ionization due to collision.*

Ques. 58. How would you determine the proper spacing of arc electrodes? Explain fully.

Ans. Before striking the arc, ascertain the distance between the anode and cathode by pushing in the cathode. This should be done until the distance between the electrodes is approximately 1/32 to 1/8 inch. Place the arc into operation and adjust the spacing to a point of maximum stability as indicated by a steady reading on the main-power ammeter and radiofrequency ammeter. If the adjustment of spacing does not produce a steady arc, increase the alcohol flow or vary the voltage.

Ques. 59. Explain the relay back-shunt system of arc signalling.

Ans. Figure 13 illustrates the wiring diagram of the 2-kw. Federal-arc back-shunt system.

The back-shunt relay is actuated by a solenoid excited from the ship's direct current and controlled by a small Morse hand key in series with the solenoid.

When the key is *open,* the back-shunt relay arm is connected to a closed or absorption circuit into which the arc oscillates.

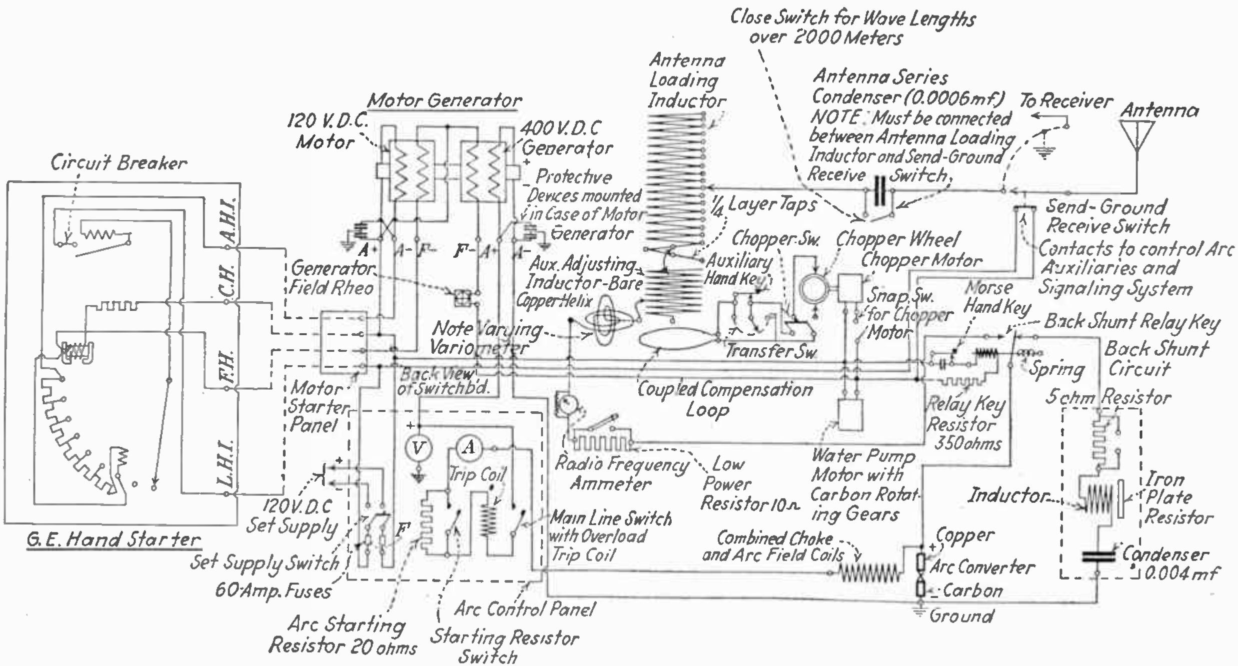


FIG. 13.—Complete Wiring diagram of a two-kilowatts Federal arc (back-shunt system).

When the key is *closed,* the arc is transferred to the antenna oscillatory system.

This results in a uniwave signal emission and enables the operator to adjust the arc for maximum stability when the key is *open* and eliminates unnecessary adjustment interference.

Ques. 59*a*. If the arc fails to start, what are some of the possible troubles? State briefly.

Ans. If the motor generator is running, the cause of the trouble may be any of the following: fuses blown; all switches not in correct position; break in some circuit; no generator current; improper gap adjustment, trouble with alcohol drip; poor tips; improper voltage adjustment; antenna partly or fully grounded.

Ques. 59*b*. If the arc flame goes out while the arc is working, what may the trouble be?

Ans. The trouble may be any of the following: improper gap adjustment; arc grounded through antenna or 500 volt circuit; arc jumping to electromagnet pole tips; cathode not revolving; water leak in arc chamber; improper alcohol feed; break in power circuit.

Ques. 59*c*. If the arc does not radiate, what may the trouble be?

Ans. Failure to radiate or poor radiation may be due to any of the following causes: poor insulation somewhere in the oscillating circuit; improper alcohol feed; gap improperly adjusted; weak magnetic field; break in antenna circuit; improper power adjustment; gas leak in arc chamber or feed; water leaks; dirty electrode holders due to carbon; loose connections.

Ques. 60. Draw a diagram of a commercial-arc transmitter, showing the following parts: hand starter, motor generator, charging panel including an arrangement for charging the receiver batteries, regenerative detector and two stages of audio-frequency amplification, and state the ampere-hour capacity of the batteries. State the name and type of the transmitter.

Ans. Figure 13*A* illustrates the diagram of a commercial-arc installation.

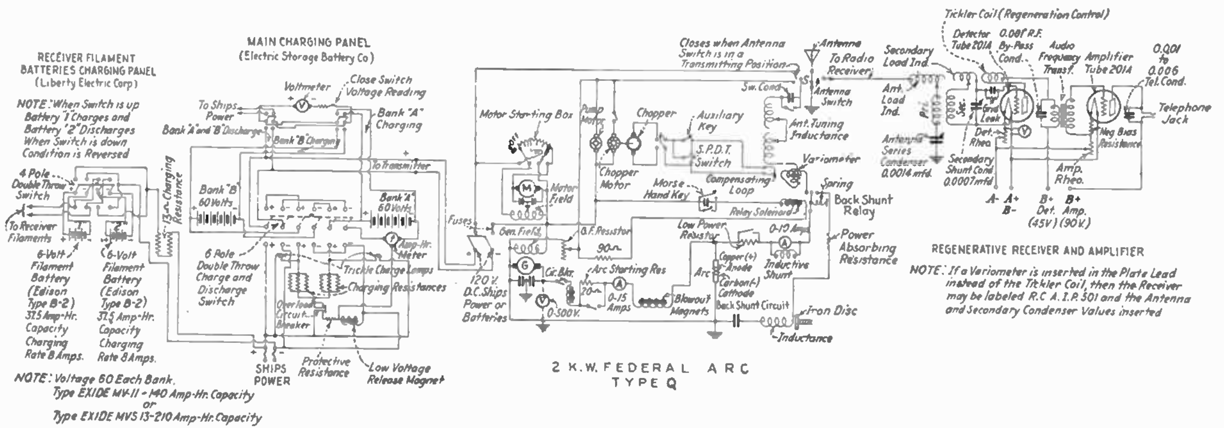

RECEIVER FILAMENT BATTERIES CHARGING PANEL
(Liberty Electric Corp)
NOTE: When Switch is up Battery "1" Charges and Battery "2" Discharges When Switch is down Condition is Reversed
4 Pole Double Throw Switch
To Receiver Filaments
6-Volt Filament Battery (Edison Type B-2) 37.5 Amp-Hr. Capacity Charging Rate 8 Amps.
6-Volt Filament Battery (Edison Type B-2) 37.5 Amp-Hr. Capacity Charging Rate 8 Amps.
13Ω Charging Resistance
NOTE: Voltage 60 Each Bank, Type EXIDE MV-11 - 140 Amp-Hr. Capacity or Type EXIDE MVS 13-210 Amp-Hr. Capacity
MAIN CHARGING PANEL
(Electric Storage Battery Co)
Voltmeter
Close Switch Voltage Reading
To Ships Power
Bank "A" Charging
Bank "A" and "B" Discharge
Bank "B" Charging
To Transmitter
Bank "B" 60 Volts
Bank "A" 60 Volts
Amp-Hr. Meter
6 Pole Double Throw Charge and Discharge Switch
Trickle Charge Lamps
Charging Resistances
Overload Circuit Breaker
SHIPS POWER
Protective Resistance
Low Voltage Release Magnet
Fuses
120 V. D.C. Ships Power or Batteries
Motor Starting Box
Motor Field
Gen. Field
G.F. Resistor
90Ω
Ct. Bkr.
Arc Starting Res
20Ω
0-15 Amps
0-500V.
Blowout Magnets
Pump Motor
Chopper
Chopper Motor
Auxiliary Key
S.P.D.T. Switch
Morse Hand Key
Compensating Loop
Relay Solenoid
Low Power Resistor
0-10 Amps
Arc
Copper (+) Anode
Carbon (-) Cathode
Inductive Shunt
Back Shunt Circuit
Iron Disc
Inductance
Power Absorbing Resistance
Back Shunt Relay
Spring
Variometer
Ant. Tuning Inductance
Sw. Cond.
Closes when Antenna Switch is in a Transmitting Position
Antenna
To Radio Receiver
Antenna Switch
2 K.W. FEDERAL ARC
TYPE Q
Tickler Coil (Regeneration Control)
Secondary Load Ind.
Detector Tube 201A
0.001 R.F. By-Pass Cond.
Audio Frequency Transf.
Amplifier Tube 201A
0.001 to 0.006 Tel. Cond.
Telephone Jack
Ant. Load Ind.
Pri.
Sec.
Grid Leak
Det. Rheo
Neg Bias Resistance
Antenna Series Condenser 0.0014 mfd.
Secondary Shunt Cond 0.0007 mfd
Amp. Rheo.
A- A+ B-
B+ Det. (45V)
B+ Amp. (90V.)
REGENERATIVE RECEIVER AND AMPLIFIER
NOTE: If a Variometer is inserted in the Plate Lead instead of the Tickler Coil, then the Receiver may be labeled R.C.A. I.P. 501 and the Antenna and Secondary Condenser Values inserted

Fig. 13A.

Ques. 61. Explain the fundamental operation of an arc transmitter.

Ans. See Ques. 47.

Ques. 62. What is the purpose of the magnetic field across an arc flame?

Ans. The purpose of a powerful magnetic field across the arc electrodes is to clear the heavily ionized field produced by the arc's burning in the hydrocarbon atmosphere and thus assist in the rapid deionization at the proper intervals. Without this magnetic field the arc resistance would remain practically constant and, therefore, would not oscillate.

This magnetic field is usually referred to as a transverse magnatic field and is said to act upon the arc flame as an indirect cooling system.

Ques. 63. How would you maintain a clean and even arc flame so that a clear note will be transmitted?

Ans. Adjust the spacing of the electrodes very carefully, adjust the voltage, make certain that the proper amount of hydrocarbon gas is generated by adjusting the alcohol drip, make certain that the arc chamber is airtight, make certain that the water is circulating properly, and, finally, make certain that all high-frequency connections are well made. After all this has been done, start the arc and adjust the voltage and electrode spacing until the main-power and radio-frequency ammeter read steadily. Then it is important to watch the meters during transmission and immediately adjust the spacing again if the meter readings begin to vary.

The quality of the arc signal can then be determined by listening in on the receiver and the arc adjusted until it clears up into a clean-cut note without any ragged tone effects.

Ques. 64. How would you take care of an arc converter for suitable operation?

Ans. 1. Clean the arc chamber frequently from moisture, soot, and dust.

2. Keep the gaskets fitting snugly to prevent leakage.

3. Keep the alcohol chamber filled with clean alcohol.

4. Keep the water-circulating hose free from clogging (avoid sharp bends).

5. Make sure that the anode tip is not bent from hard striking.

6. Keep the cathode evenly formed; if irregular, insert a new one.

7. Keep the centrifugal pump in good condition.

8. Make sure that the cathode is tight in its holder.

9. Keep all electrical connections in good condition.

10. Make sure that water circulates through the anode and the upper and lower units of the arc chamber.

11. Give considerable attention to all high-frequency circuit connections.

Ques. 65. Give a detailed theoretical explanation of an arc generator for the production of high-frequency oscillations. Show the necessary graphs and scheme of connection.

Ans. The theory of the Poulsen arc generator is herewith fully described.

An arc consists of a gaseous conductor of definite length and cross-section, the cross-section being made up of ions which are

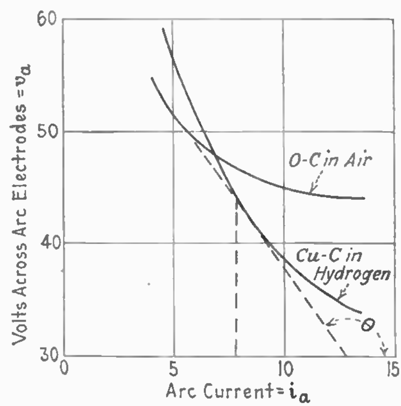


FIG. 13*B*.

greater in number than the current. In the Poulsen arc generator the electrodes are a hollowed copper anode cooled by circulated water and a carbon cathode which is slowly rotated insuring an even burning. One of the characteristics of such an arc is that its resistance does not follow Ohm's law as does metals but has what is known as *negative resistance, i.e.*, the resistance decreases with the rise in current flow, due to the fact that for a greater current flow the number of ions in the arc space is increased. The static-characteristic curve of the arc is shown in Fig. 13*B*. This curve would be obtained by allowing given values of current to flow through the arc and computing the resistances of the arc for these values and the voltage necessary to force such values of current through ionized space. These readings would be taken allowing sufficient time to elapse after a given value of voltage has been impressed for the arc current to come to rest. Two curves are shown in this figure: The first, or C-C curve is that for two electrodes of carbon in air, and the other, or Cu-C curve, is that for a carbon and copper arc immersed in a hydrocarbon atmosphere. It is to be noted that such a combination gives a much steeper curve.

In radio operation, however, the changes in arc current occur at radio frequencies, and, therefore, the resistance of the arc no longer follows the static-characteristic curve but a curve such as shown in Fig. 13*C*. This curve is known as the *kinetic-*

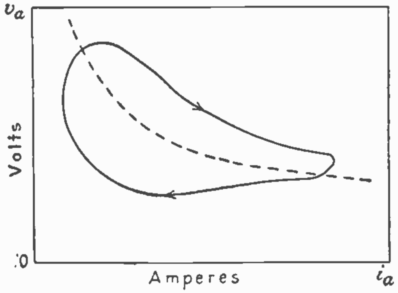


FIG. 13*C*.

characteristic curve, because when the current has reached its maximum value and commences to decrease, the electrodes are hot and the conductivity is still good, so that the arc-potential difference remains low until the current is nearly zero, and then a cooling of the electrodes causes a slight rise of current, followed by a fall to zero, then a reversal and a rapid increase in the negative direction. It is due to this characteristic that it is possible to generate high frequencies with an arc. Thus, in order to obtain oscillations of a high frequency and appreciable energy from an arc, it is necessary to provide the following:

1. The arc must burn in an atmosphere of hydrogen vapor.
2. The arc must burn in a water-cooled chamber.
3. The positive electrode (anode) must be of copper and suitably cooled.
4. The arc flame must be subjected to a powerful transverse magnetic field to clear the ionized path as soon as possible.
5. If a carbon negative electrode is used, it must be rotated so that the carbon deposit from the hydrocarbon gas becomes deposited evenly.

NOTE.—In some of the later types of arcs, the negative (cathode) electrodes are also of copper and, therefore, must be water cooled the same as the anode electrode.

The theoretical action of an arc in an oscillating condition is as follows:

Refer freely to Fig. 13*D*, which illustrates the various current

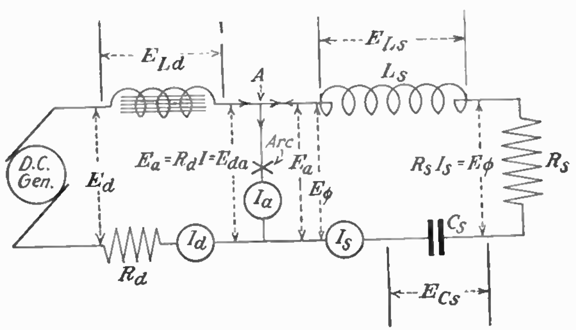


FIG. 13*D*.

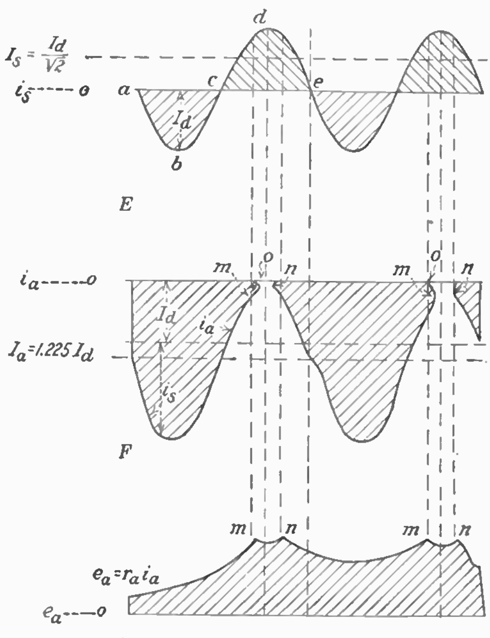
and voltage components in the arc-generating circuit. Note, also, the complete cycle of operations in Fig. 13*E*.

The arc-radio-frequency cycle may be divided into two halves. The first is that during which the radio-frequency energy I_s is circulated by an e.m.f. set up by energy stored in the inductance *L* and the capacity *C*. The second is the energy-adding period during which I_s is circulated by an e.m.f. set up by the energy from the direct-current circuit. This may be referred to as the *charging period*.

Hence, with the starting of the generator potential, the condenser C_s is charged to the potential E_d. Then, when the arc is struck, direct current I_d flows through it in the direction of the arrow, forming one component of the arc current I_a. The other component is the discharge current I_s from the condenser C_s, which may be expressed thus:

$I_d = i_a - i_s$ (these are only instantaneous values)

Due to the fact that arc-flame conductivity is dependent upon gas ionization, it is dependent upon gas temperature and, hence,



FIGS. 13E, F, G.

I_a, the current through the arc. Thus, as i_s and i_a increase as shown in Figs. 13E and 13F, the conductivity of the arc flame is raised. This causes a further increase in i_s until, finally, the peak of the i_s curve is reached at b. At this point, the energy, which at the beginning of the cycle was stored in C_s as potential energy, has been completely changed to kinetic energy stored in the magnetic field of the inductor L_s. The condenser charge is, therefore, zero, and the currents i_s and i_a are a maximum.

The magnetic field of L_s now begins to collapse. This continues to make current flow in the same direction. The process continues until the point *c* (Fig. 13*E*) is reached. Condenser C_s is now fully charged in the polarity opposite to its initial charge, and the energy in the oscillatory circuit is once again in the potential form.

The condenser now begins to discharge, and the second half of the radio-frequency cycle begins. During this half cycle, energy from the direct-current circuit is supplied to the oscillatory circuit. Current leaving the condenser does not pass up through the arc, forming a portion of I_a, as in the preceding half cycle, but passes through the direct-current circuit in accordance with the equation

$$I_d = i_a + i_s \text{ (instantaneous values)}$$

As i_s increases toward *d*, Fig. 13*F* shows that i_a approaches zero, and at *m* it has been reduced to such a low value that the stream of ions forming the arc flame starts to rupture under the influence of the magnetic field. This continues to the point *o*, at which the arc is completely extinguished and i_a is zero. Thus:

$$I_d = i_s \text{ (instantaneous values)}$$

The next instant i_s decreases from *d* toward the point *n*. There is, therefore, a slight reduction in I_d which induces an e.m.f. E_{Ld} between the terminals of the inductance I_d in the direct-current circuit. This surge has a much steeper wave front than the sinusoidal radio-frequency oscillations and is unable to force its way beyond the first few turns of L_s. The resultant increase in voltage across the arc is sufficient to jump the gap between the electrodes and reestablish i_a. This occurs at *n*, and more I_d is shunted off through the i_a path as i_s approaches zero at *e*.

The point *e* is at the beginning of a second cycle identical with that just described, with the exception that, whereas at *a* the potential E_c across C_s was only that of *Ed*, at *e* it has been augmented by the discharge of L_s, also. Thus, when the arc is first started, there is a transient period extending over several cycles, during which the peak of E_c for each succeeding cycle is constantly increased until a stable condition is reached, which depends solely upon the resistance of the radio-frequency circuit, all other conditions remaining constant. Thereafter, the effective value of E_c may be computed by the well-known equation

$$E_c = \frac{I_s}{2\pi f C_s}$$

The Arc Voltage E_a.—Although I_s is sinusoidal and I_a is a sinusoidally pulsating unidirectional current, the voltage across the arc, E_a, has a jagged wave form. When i_s is at a and the arc is struck by bringing the electrodes together, e_a takes a certain value, as shown. Due to the drop in arc-flame resistance produced by increasing current and because the flame resistance drops at a rate greater than the first power of the current, e_a, which equals $r_a i_a$, decreases with an increase in i_a, as previously described. This is the reason for the dip in the e_a curve and illustrates the well-known falling characteristic of the arc. As i_a approaches zero, e_a increases up to the extinction point m. Then comes reignition at n and e_a drops as gap ionization increases. The cycle then repeats itself.

Brief Bibliography

NILSON and HORNUNG: "Practical Radio Telegraphy," McGraw-Hill Book Company, Inc.

"Manual for Radio Operators:" Federal Telegraph Company.

STONE: "Elements of Radio Telegraphy," D. Van Nostrand Company.

ROBISON: "Manual of Radio Telegraphy and Telephony," U. S. Naval Institute.

PART IV

SPARK TRANSMITTERS AND TRANSMITTERS IN GENERAL

Ques. 66. What are the four main circuits of a spark transmitter?

Ans. 1. Low-frequency, low-potential circuit consisting of all apparatus from alternating-current generator to primary of power transformer.

2. Low-frequency, high-potential circuit consisting of secondary of power transformer and condensers.

3. High-frequency, high-potential closed oscillatory circuit consisting of the condensers, spark gap, and primary of oscillation transformer.

4. High-frequency, high-potential open oscillatory circuit consisting of antenna, loading inductance, secondary oscillation transformer, and ground.

Ques. 67. Describe fully how you would proceed to adjust a spark transmitter to a given wave length.

Ans. It is well to remember in answering a question of this kind that a spark transmitter has two independent circuits, namely, the closed oscillating circuit consisting of the condensers (capacitance), the primary turns of the oscillation transformer (inductance), and the spark gap; and the open oscillating circuit consisting of the secondary of the oscillation transformer, antenna tuning inductance (loading coil), radiofrequency ammeter, antenna, and ground. A variation of the capacitance or inductance value in either of these circuits affects the radiated wave. First, tune the closed circuit to the desired wavelength by closing the key and causing the spark to jump the gap. Situate the wavemeter in inductive relation to the circuit and take a reading. Resonance on the wavemeter will be indicated, according to the type of wavemeter used, by a maximum sound in the telephone, a maximum reading of a hot-wire or thermocouple ammeter or the brightness of a glow lamp. Whichever device is used, resonance will be indicated by a maximum indication.

If the wave length reads high, reduce the number of turns of inductance, if too low, increase the inductance by adding turns. It is not necessary to adjust the capacitance (condensers), as this is usually fixed.

While it is not absolutely necessary, it is always best when calibrating the closed circuit that all of the various pieces of apparatus comprising the open circuit be disconnected one from the other and the secondary drawn away from the primary coil to the position of minimum coupling. This is done so that minimum mutual induction will take place between the circuits thereby eliminating any broadening effect of the measured wave.

When the closed circuit has been tuned to the given wave length, the open circuit is reconnected, and the coils of the oscillation transformer (coupler) brought in close relation. Inductance is then added or subtracted from the secondary or antenna inductance (open circuit) until the antenna ammeter indicates resonance by a maximum indication. This shows that the open circuit is now tuned to the same wave length as the closed circuit, and the set is ready for operation.

In order, however, that the purity and sharpness of the wave may be checked up, the radiated wave should be measured while the transmitter is in actual operation. If two or more waves are present, the coupling and inductance values of the secondary and antenna loading coil should be so proportioned that the energy in any of the lesser waves shall not exceed 10 per cent of the energy in the desired wave.

A decrement reading should then be taken. The decrement must not exceed two-tenths for ordinary operation. In view of the fact that it is not necessary to measure for decrement to tune a set to a desired wave length, an explanation of this operation is omitted in this answer (see Ques. 352*a*).

Ques. 68. Draw a diagram of an antenna switch with connections.

Ans. See Fig. 14.

Ques. 69. To measure wave length, what instruments must be available?

Ans. To measure the wave length of a transmitter a wavemeter is necessary. (Figs. 70, 71, 72.) An antenna ammeter must be in the transmitter circuit to indicate resonance.

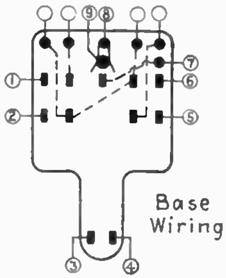


FIG. 14.—Antenna switch with connections.

Contact	Circuit
1 and 2.	Motor starter
3 and 4.	Generator field
5 and 6.	Transformer primary
7.	Antenna terminal for receiver
8.	Antenna
9.	Transmitter oscillation transformer secondary
	Blank terminals are extras.

Ques. 70. What is meant by the fundamental or natural frequency of an antenna?

Ans. The lowest resonant frequency of an unloaded antenna, *i.e.*, without added inductance or capacity. Practically, this means antenna flat top (if any), lead-in wire and ground lead.

Ques. 71. Describe an oscillation transformer. What immediate advantage is obtained from employing such a device?

Ans. An oscillation transformer (range 300 to 1,000 meters, 1,000 to 300 kilocycles) may consist of two spirally wound coils, one of which is the primary and the other the secondary. The primary and the secondary coils usually consist of about 13 turns of copper-ribbon conductor having a large surface area.

An oscillation transformer is useful because it allows a very flexible degree of coupling between the open and closed oscillating circuits with no direct conduction of energy from one circuit to the other. This makes it possible to adjust for a wave of low decrement as well as for a pure wave. When using an oscillation transformer, the resistance of the spark gap is not in the antenna circuit. This tends to keep down the decrement of the radiated wave. It is sometimes the practice to decrease the coupling of the oscillation transformer when it is desired to decrease power transmitted, but with the newer types of apparatus this method of decreasing power is unnecessary as this is usually done by increasing the generator-field resistance.

Ques. 72. Show, by sketch, the changes from 800 to 600 meters (375 to 500 kilocycles).

Ans. See Fig. 15.

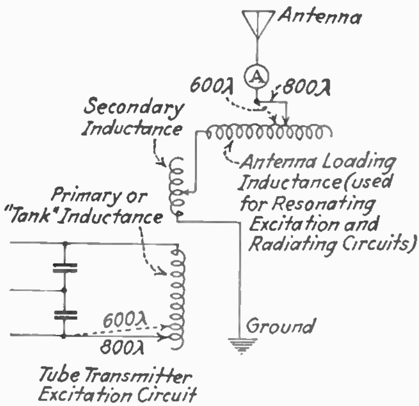


FIG. 15.—Sketch showing changes from 800 to 600 meters.

Ques. 73. How may the radiation of a quenched-gap transmitter be increased?

Ans. Generally speaking, the radiation of a quenched-gap transmitter may be increased by increasing the number of gap units in use and carefully varying the coupling between the open and closed oscillating circuits. It is, of course, possible to use too many units of the quenched gap at once, thereby endangering the insulation of the set as a whole. The correct number for maximum radiation with a particular set may best be found by experiment. Increasing the input to the primary of the power transformer will increase the radiation, but care must be taken not to overload the set by using too high power.

Radiation in the antenna circuit may be seriously decreased if the gap sparking surfaces are dirty or if the gaps are not sufficiently airtight due to a leaky insulation gasket. It has also been found that the radiation and tonal qualities can be improved by carefully adjusting the generator and motor-field rheostats for each change in the number of gaps used. The coupling must also be adjusted to the point of highest radiation.

Ques. 74. How do you increase radiation with a synchronous rotary spark transmitter?

Ans. If the current to the step-up power transformer is fixed, the radiation in the open oscillating circuit of a transmitter equipped with a synchronous rotary spark gap may be increased by carefully manipulating the angular adjustment of the stationary electrodes and critically varying the coupling between the open and closed oscillating circuits. A variation of the speed of the motor generator will also effect the radiation, causing it to increase or decrease depending upon various conditions in the apparatus. When adjusting for increased radiation, the antenna ammeter should be carefully watched. Increasing the input to the power transformer will usually result in increased radiation on any type of transmitter.

Ques. 75. What would be the effect of throwing a synchronous spark gap out of synchronism?

Ans. The note would become very ragged and distorted. The condensers would also be subjected to excessive strain, and the quenching properties of the gap would be seriously impaired. It would decrease radiation.

Ques. 76. How would you reduce power without affecting the frequency of the generator?

Ans. By increasing the resistance of the generator-field rheostat, thereby decreasing field excitation. Decrease the number of gap units in use, if using a quenched gap.

Ques. 77. What causes a spark transmitter to emit more than one wave?

Ans. Retransference of energy due to tight coupling and improper quenching of the gap circuit.

Ques. 78. What happens to a poorly sealed quenched-gap unit?

Ans. If air is continually present in the gap when the spark is discharging, an oxide will deposit on the gap surface and ultimately short-circuit the gap. In certain models of the quenched gap this oxide leads the spark over to the insulating gasket, and the gasket is soon rendered useless.

Ques. 79. Describe two spark gaps in general use on shipboard.

Ans. The two types of spark gaps used on shipboard are the rotary synchronous and the quenched.

The synchronous gap consists of a disc mounted on the shaft of the generator with a number of studs corresponding to the number of field poles in the generator. This disc is enclosed in a metallic drum for muffling the noise. On the top of the drum two insulated bushings are inserted for the two stationary sparking electrodes. This drum may be moved in an arc around the rotating disc when the gap is in motion for the proper adjustment to synchronism. After the proper adjustment has been found, the drum may be locked by a setscrew to prevent shifting.

Great care must be taken to have the spacing between the stationary and rotary electrodes as close as possible without touching. Otherwise, it will be impossible to obtain a clear musical note. The main adjustments for the proper functioning of this gap is, therefore, dependent upon the electrode spacing and the proper drum-electrode position with respect to the rotating disc. For determining the correct adjustment of a synchronous gap, press the key and rotate the drum with the hands very slowly until a clear spark discharge is obtained. If the note is ragged and distorted, it will be a sure indication that the gap is out of synchronism. This will considerably impair the quenching properties and general efficiency of the gap and, consequently, the radiation.

A common type of quenched gap, consists of a series of gap units. The number of units used in a gap depends upon the amount of power used. A switching arrangement and rack is provided for cutting in or out the number of gaps desired, *i.e.* the greater the power, the more gaps used.

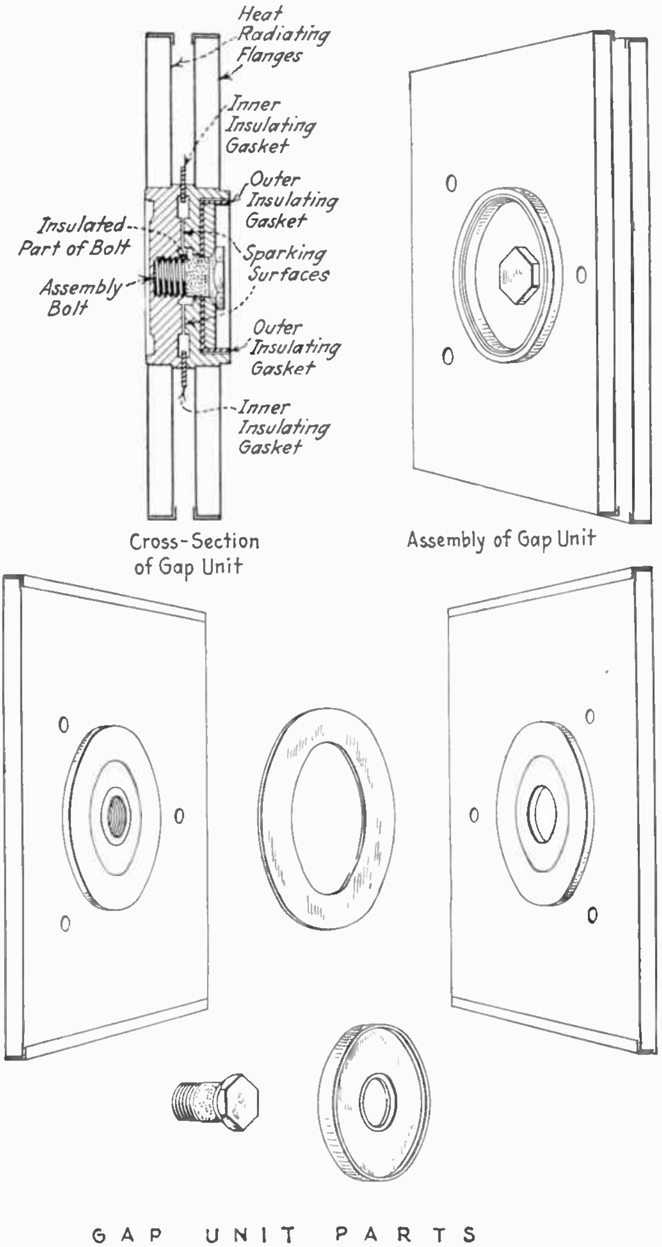


Fig. 16.—Quenched spark gap.

One of the most efficient types of quenched gaps is the Lowenstein gap. Each gap is made up of a number of individual units, one of which is shown in Fig. 16. The quenched-gap unit consists of two silver-plated, circular sparking surfaces with heat-radiating flanges. The two silver-plated surfaces of each unit are separated by a fiber insulating washer to prevent a short circuit of the two plates and also to maintain an air tight sparking chamber. The two plates of each unit are held together by a bolt, which enables rapid repairing in case the unit becomes defective during operation.

The actual space between the sparking surfaces is usually 0.010 inch for each unit, with 10 to 15 units in series.

The flange arrangement of the plates permits rapid radiation of the heat and thereby aids in the rapid deionization of the gap after each spark discharge. The space between the radiating flanges is much greater than the space separating the sparking surfaces, which prevents the spark from jumping across the outside of the gap. The distribution of the sparks into small groups by the series of gap-units arrangement minimizes heat and oxidization on the sparking surfaces and thereby aids the quenching properties of the gap.

Ques. 80. On a ship, how is the ground connection made?

Ans. On shipboard, the ground connection is made to the steel hull, or, if it is a wooden vessel, a large copper plate several square yards in area is fastened to the hull below the water line and a connection made thereto.

Ques. 81. In the open radiating circuit of a ship's transmitter, where (on the oscillation transformer) is the ground connected?

Ans. In transmitting systems, the ground connection is made to the center of the oscillation transformer (pancake type) because the free end of the coil is the high-voltage end. This puts the center of the coil at ground or zero potential and thus maintains a better degree of stability.

Ques. 82. Describe a conductively coupled transmitter. Draw a diagram.

Ans. Figure 17 illustrates a conductively coupled transmitter. The oscillations produced in the primary section of the inductance are induced by direct induction or conduction into the secondary section of the inductance and are radiated in electromagnetic form.

In a direct or conductively coupled transmitter, the coupling is loosened by decreasing the number of turns common to both circuits as indicated by the dotted lines.

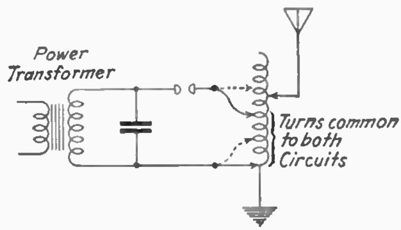


Fig. 17.—Conductively coupled transmitter.

Ques. 83. Name and describe four types of transmitting condensers.

Ans. 1. Glass plate (now practically obsolete).

2. Leyden jar (now practically obsolete).

3. Compressed air (now practically obsolete).

4. Mica.

1. The glass-plate condenser consists of a number of plates of high-grade glass about ¼ inch thick, coated on both sides with a tin or copper foil to within about 2 inches of the edge. The foil may be put on either by shellacking the foil to the glass or by an electroplating process. The individual plates are then placed in racks, the number depending upon the capacity of the condenser desired.

For very high potentials, the plates are usually submersed in oil to prevent brush discharge or creepage losses (corona effect).

2. The Leyden jar is similar in construction to the glass plate, with the exception that the glass dielectric is formed into a jar instead of a plate.

The jar, which was used in the old-type commercial installations, is about 1½ feet high and about 4 inches at the base. A high grade of glass ⅛ inch thick, coated on the outside and interior with a heavy copper foil, is used. This coating is brought up to within about 4 inches of the top of the jar. These jars are placed in racks with a metallic base for parallel connection with the outer foil coating. The interior connections were made with a lead weight or soldered connection.

One advantage of the Leyden jar is that there is only one edge where brush discharge may occur.

3. The compressed-air condenser consists of interleaved plates enclosed in a cylindrical tank in which one set of plates are

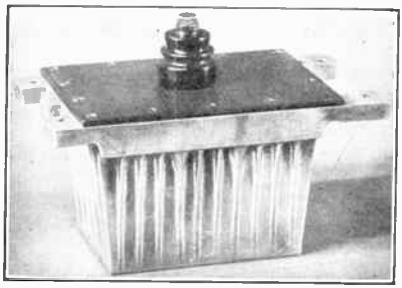


FIG. 18.—Mica transmitting condenser. (*Courtesy,* Dubilier Condenser Corporation.)

brought out to an insulated bushing and the other set of plates directly connected to the steel tank.

The dielectric in this condenser is of air and is maintained at a high dielectric constant by a 250 to 300-pound pressure of air. This will enable the condenser to withstand exceptionally high-voltage pressures without rupturing, provided, of course, that the tank is made airtight to maintain the air pressure constant. If the dielectric breaks down, due to a leaky air chamber, the tank must be resealed and pumped up again to the proper air pressure.

4. The mica condenser is the most common and the most efficient in use today.

The mica transmitting condenser (Fig. 18) used in commercial transmitters consists of hundreds of alternate layers of mica and copper foil enclosed in an aluminum casing. Into this casing a specially prepared adhesive composition having the required dielectric properties is inserted to eliminate vacuum pockets, air, and moisture. The air and moisture are first expelled, and then the layers of mica are covered with a thin layer of this adhesive; a pressure plate is then placed on the topmost section or unit of the condenser, and melted wax is

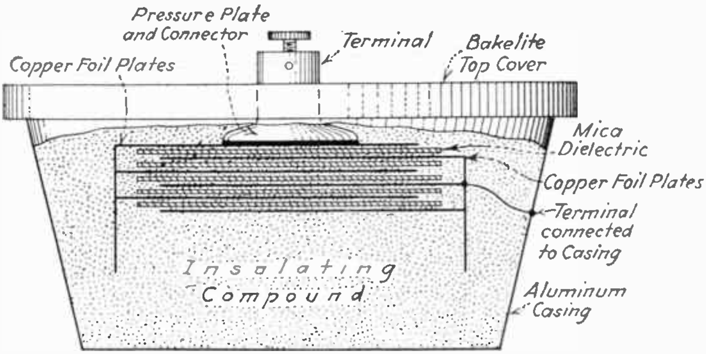


FIG. 19.—Cross-section of mica transmitting condenser.

poured into the casing. When this hardens, the condenser plates are rigidly held together, thus preventing a change in the spacing of the foil and the mica and maintaining a constant capacity.

When the condenser dielectric is excessively strained and a puncture results, the small spark through the punctured mica

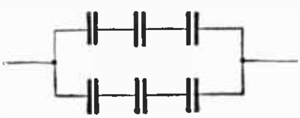


FIG. 19a.—Condensers in series parallel.

heats up the special composition which, as soon as the circuit in which the condenser is connected is opened, cools and fills up the puncture and acts as a self-healing device.

In the high-voltage condensers of this type, there are usually several condenser units in the one casing which are connected in series to distribute the voltage strain, thus making it possible to use the condenser for extremely high voltages.

All transmitting condensers are fitted with safety gaps. (See Fig. 20.)

Figure 19 illustrates a cross-sectional arrangement of the mica transmitting condenser.

Ques. 84. Under what conditions would you change the wave length of a mobile station to other than normal?

Ans. If another wave length is available, the normal wave of 500 kilocycles per second (600 meters) must not be used for the transmission of long radiograms in regions where radio traffic is heavy. The ship station shall follow the instructions of the coast station with which it is in communication.

In the case where a ship receives no reply to a distress call on a 500-kilocycles per second (600 meters) wave, the ship may shift to any other wave on which attention might be attracted.

It may be necessary to change to another wave-length when obtaining radiocompass bearings or if, for any reason the length of the aerial was changed.

Ques. 85. Why are the closed and open oscillatory circuits so called?

Ans. The closed circuit is so called because very little energy produced in it is able to get out of it. It might be likened to a closed tank from which nothing could get out. This circuit is, therefore, a very poor radiator.

On the other hand, the open circuit radiates (loses) much of its energy just as an open tank would lose much of its water through radiation. The open circuit is, therefore, a good radiator of electromagnetic waves.

For a description of the makeup of these circuits, see 3 and 4 of Ques. 66.

Ques. 86. What is the most common cause of a breakdown in a condenser?

Ans. When using a quenched-gap set, care must be taken not to use too many gap units, as many small gaps in series are equivalent to one large gap, and an excessive voltage would be required to jump the gap space in use. In other words, an abnormally widened spark gap might result in condenser breakdown.

Occasionally, condensers will break down due to hysteresis in the dielectric, caused either by a poor quality of dielectric material or by the application of voltages beyond the normal rating of the material. In high-potential condenser systems, a safety gap is usually provided to protect the condenser from puncture.

In tube circuits, the heavy oscillating voltages used often weaken the dielectric of the condensers, and breakdown results.

Ques. 87. How would the high-potential condensers of a transmitting set be protected from puncture?

Ans. Connecting condensers in series divides the voltage between them. It also decreases the capacitance. It is possible

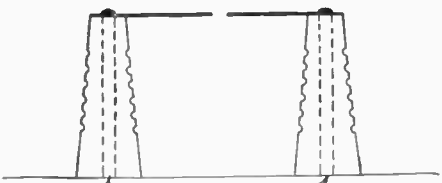


FIG. 20.—Protective safety spark gap.

then to protect high-potential condensers by connecting several units in series, but in order to maintain the total capacitance at a given value, it is necessary to connect an equal number of such groups in parallel. The series-parallel connection as shown in Fig. 19*a* is, therefore, used.

Another method to protect high-potential condensers from puncture is to fit the unit with a safety spark gap (Fig. 20) which is set just below the puncture voltage. This affords a path for the current to take should an overload value be reached, and, therefore, no damage is done to the condenser.

Ques. 88. Why does a series connection of condensers decrease the voltage strain? What effect has this upon the total effective capacity?

Ans. When condensers are connected in series, the voltage strain is decreased, due to the increase in the thickness of the dielectric material, and, consequently, there is a reduction in the total effective capacity; the greater the distance between two plates, the lower the capacity.

Ques. 89. What constitute the principal losses in transmitting condensers?

Ans. Brush-discharge losses (corona effect) due to creepage. Dielectric losses due to hysteresis (molecular friction).

Ques. 90. How would you adjust a quenched-gap set for a clear note and high radiation?

Ans. In order to operate properly, a quenched gap must have clean sparking surfaces, airtight units, and be in good mechanical and electrical condition. The alternating-current voltage, frequency, and number of gaps in use, and the coupling of the set must be carefully adjusted. The note may be listened to through the receiver of the station, while the eye watches the radiation meter and the hands adjust coupling and gap units.

Ques. 91. Describe the principles of operation of the thermo-coupled ammeter.

Ans. This meter operates on the principle that if two dissimilar metals are welded together at a junction point (called the thermo-junction) and subjected to a heat, an e.m.f. is set up between them, hence the name *thermo* (heat) *couple* (coupling of two metals).

Some of the common metals which will produce a thermo-electric effect if two of them form the thermo-junction are as follows: bismuth, platinum, copper, lead, silver, antimony.

Ques. 92. What causes the breakdown of antenna insulators? How would you remedy this trouble?

Ans. Antenna insulation may break down if the antenna voltages or currents are of an excessive value.

Breakdown may also be the result of insulators which have accumulated large quantities of dirt, soot, and moisture.

The remedies in most cases are obvious.

1. Dirty insulators may be cleaned when the operator notices a decrease in radiation due to this effect.

2. If the insulator is badly charred, a new one should be inserted

3. If no new ones are available, and all those in use are defective, a piece of marlin rope soaked in oil may temporarily be used with success.

Ques. 93. Why may the radiation of a transmitter on shipboard, which is tuned while the ship is at dock, change when the ship leaves the dock?

Ans. The dock, another ship close by, or any other large structure may affect the capacity of the ship's antenna. When the ship leaves the dock, these structures are removed, and the oscillating characteristics of the antenna circuit are changed, throwing the set out of tune. A slight adjustment of the coupling or antenna inductance will usually bring back high radiation.

Ques. 94. Why is an antenna switch called a change-over or transfer switch? What is its object?

Ans. The antenna change-over switch is used for transferring the antenna from either the transmitter to the receiver or *vice versa*. The antenna switch also serves as a protective device when receiving by disconnecting various circuits of the transmitter such as the generator-field winding and the transformer-primary winding. The opening of the field circuit greatly decreases the generator induction during reception and, therefore, does not necessitate stopping the motor. It also acts as a safeguard in that, if the key is accidentally pressed when the switch is in receiving position, the transmitter will not function (see Fig. 14).

Ques. 95. Of what use is a hot-wire ammeter in tuning a transmitter?

Ans. A hot-wire or thermocouple ammeter can be used to determine conditions of resonance between the primary and secondary circuits of a transmitter.

Ques. 96. Of what use is a motor blower in a transmitting system?

Ans. The motor blower is sometimes used in quenched-gap systems to cool the gaps so that rapid deionization takes place and to insure good quenching properties and thus produce low damping in the open or radiating circuit of the transmitter.

Ques. 97. Of what use is an antenna-tuning inductance in connection with a radio transmitter?

Ans. The antenna-tuning inductance, or *loading coil*, as it is more generally termed, is used in the open oscillating circuit of a radio transmitter for obtaining wave lengths beyond the range of the oscillation transformer alone. It is also used for critical adjustment of resonance for various wave-length or frequency changes. Whenever the wave length or frequency of the primary circuit is changed, the secondary must be adjusted to it to maintain conditions of resonance. This is usually accomplished in commercial transmitters by varying the loading inductances instead of the secondary of the oscillation transformer.

Ques. 98. Of what use is an induction coil in a transmitter?

Ans. An induction coil is used as an auxilliary transmitter in many of the commercial tube installations for emergency

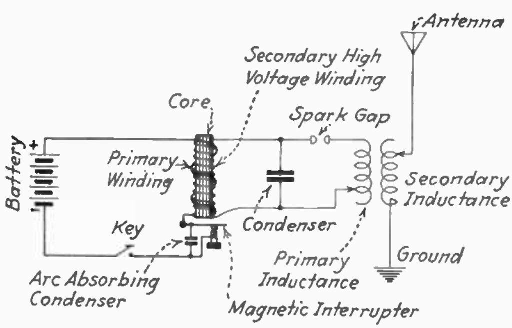


FIG. 21.—Induction-coil transmitter.

transmission if the tubes become inoperative and no spares are available or in cases where the tube equipments are dependent entirely on ship's power.

An induction coil may also be used as a plain aerial exciter for testing antenna insulation or for determining the fundamental wave length of an antenna and ground system.

An induction-coil transmitter is shown in Fig. 21.

Ques. 99. Explain the action, in the closed oscillatory circuit of a transmitter, when the key is pressed.

Ans. When the key is pressed, current flows from the alternating-current generator through the primary of the step-up power transformer, setting up a magnetic field around it. The rising and falling of the magnetic lines of the primary cut the secondary windings inducing an e.m.f. therein and raising it to a very high voltage. The high-potential condensers are charged to the breakdown potential of the gap, resulting in a discharge. The circuit through which the discharge takes place, having capacitance and inductance, has oscillatory characteristics, and the spark discharging through it sets up oscillations. The oscillations, in turn, have a wave length or frequency depending upon the capacitance and inductance of the closed circuit. The oscillations in the closed circuit induce oscillations in the open oscillating circuit at the wave length or frequency to which this circuit is tuned. The oscillations in the open circuit are radiated out into space in the form of electromagnetic waves.

Ques. 100. Describe three or more ways of producing high voltages for radio purposes.

Ans. Induction coil; transformer; high-frequency alternator; high-voltage generators.

Ques. 101. What makes a spark gap conductive?

Ans. The ionization which takes place just prior to the condenser discharge through the gap. The ionization is a result of the breaking up of the air particles between the gap electrodes due to the strain exerted across the gap when it is connected across a charged condenser.

Ques. 102. What is the effect of connecting a spark gap in parallel with the secondary of a power transformer?

Ans. See Fig. 22. If the spark gap is connected directly across the secondary of the step-up transformer, with a condenser and primary inductance in parallel, the power transformer is short-circuited through L, and the circuit would not operate. The two standard methods of connecting are shown in B and C of the same figure, of which B is the most commonly used.

Ques. 103. What occurs in the closed or gap circuit of a spark transmitter just prior to spark discharge?

Ans. The immediate vicinity of the gaps become highly strained. This results in a breaking up of the air particles between the gap, known as *ionization.* This ionized path increases the gap conductivity and allows the condenser to discharge through it.

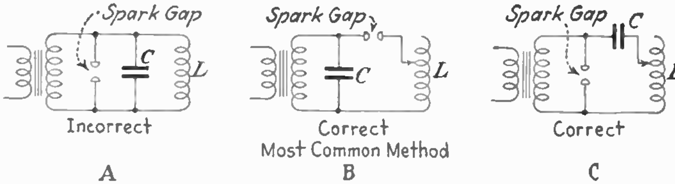


FIG. 22.—Correct and incorrect method of connecting spark gap and condensers to transformer.

Ques. 104. What effect has the height of an antenna on the range of the station?

Ans. The higher an antenna is erected the better radiator it is because of the larger dielectric between the antenna and ground, which results in a greater electromagnetic field being radiated or lost from the antenna circuit.

Ques. 105. What effect has poor insulation of the antenna on the range of the station?

Ans. The antenna current decreases rapidly with poor antenna insulation, and, therefore, the range of the transmitter as a whole is decreased.

Ques. 106. Describe the nature of an oscillatory discharge of a condenser through a spark gap and an inductance.

Ans. Figure 23 illustrates the cycle of events in the discharge of a condenser. From 0 to 90° of the charging cycle, the condenser charges. Electrostatic lines of force are gradually increasing. As the charging cycle approaches 90°, excessive strain is manifested in the vicinity of the spark gap, which results in the breaking up of the air particles between the electrodes into ions. This is called *ionization* (see Ans. 103).

From 90 to 180°, the condenser discharges through the gap and the inductance. Now the electrostatic energy is converted into electromagnetic energy, which, due to the condenser inertia, charges the condenser, in the opposite direction, to a decreased amplitude. Here the loss, is due to dissipation of energy in the form of heat when the condenser made its first discharge through the gap and the inductance.

From 180 to 270°, the same action as from 0 to 90° takes place, with the exception that the charge on the condenser is

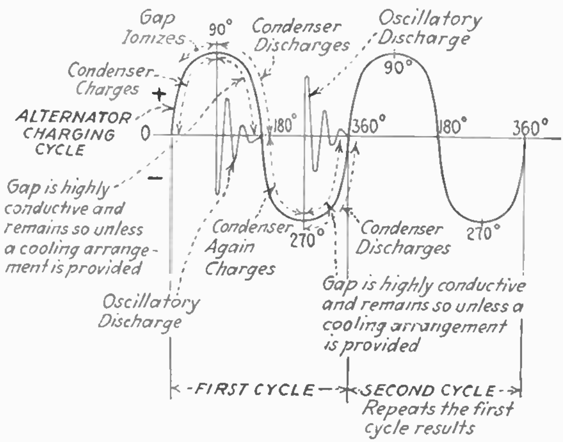


FIG. 23.—Cycle of events in the discharge of a condenser.

reversed due to the reversal of the charging e.m f. The energy involved has continued to decrease due to heat and light losses.

From 270 to 360°, the same action as from 90 to 180° takes place. These cycles of discharge continue back and forth until all of the energy is dissipated in heat.

It can be seen from this explanation that the spark gap functions as a trigger or valve, and, therefore, if the coil is inductively coupled to the secondary coil of the open radiating circuit and both oscillatory circuits resonated, then the alternating field about the primary coil will cut the secondary and induce into it an e.m.f. which will set the antenna into oscillation and radiate waves in electromagnetic form of a damped character.

If the proper discharge is to be obtained, the gap spacing must be carefully adjusted.

If the gap electrodes are too close, the condenser will not receive a full charge and may discharge before 90° of the charging cycle. On the other hand, if the gap electrodes are too far apart, then the condenser dielectric will be subjected to abnormal strain which will result in a puncture of the dielectric.

The period of damping in a circuit of this type is another important factor. For example, if the type of gap used does not radiate the heat quickly (deionize), then the oscillations will not die out very rapidly (low damping) and, consequently, will not permit a wave of low decrement to be emitted from the antenna system. This is due to reaction of the primary and secondary circuits on account of the high conductivity of the gap circuit.

Hence, for every discharge of the condenser through the spark gap and the inductance the electrostatic energy is really converted into electromagnetic energy about the inductance and the connecting wires, and, since the oscillations are of a high-frequency character and of a constantly changing polarity, the magnetic field about the inductance will be rising and falling at a definite frequency depending upon the values of the inductance and the capacity in the circuit.

Ques. 107. Where are the protective condensers usually located in transmitting apparatus? Explain fully, giving their purpose.

Ans. Protective condensers are installed, as indicated in the diagram (Fig. 1):

1. Across terminals of armature of alternator.
2. Across terminals of field of alternator.
3. Terminals of shunt field of motor.

Protective devices are also placed across the terminals of the armature of the blower motor on a quenched-gap set. The purpose of the protective device is to protect the apparatus to which it is connected from puncture of insulation, should a high voltage kick-back occur from the high-frequency circuits. A photograph of one of the latest types of protective condensers is shown in Fig. 24.

Ques. 108. Describe a wave changer. What is its function?

Ans. The wave changer is an automatic switching arrangement which permits the operator to select and change quickly the wave length of the transmitter without affecting its efficiency. This switch automatically selects and connects the proper

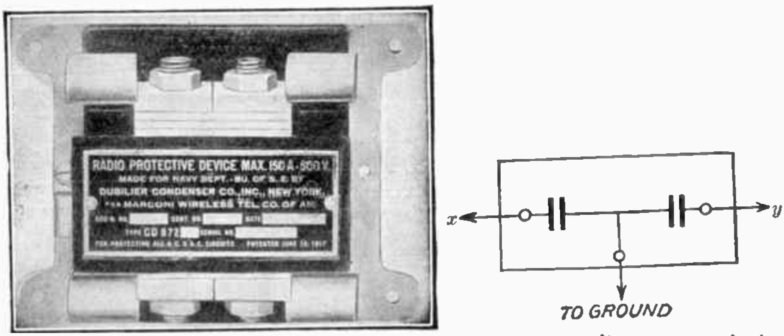


FIG. 24.—Protective condensers: (*left*) photo; (*right*) wiring diagram, terminals x and y connect to apparatus to be protected.

inductance and capacity values for certain predetermined and measured waves. The change in wave length may be made by the operator with a single movement of the wave-changer handle. It is usually provided that 3 wave lengths are available by the use of this switch. After the wave changer has been thrown to the desired wave length, it is sometimes necessary also to adjust the coupling to bring the set to maximum radiation.

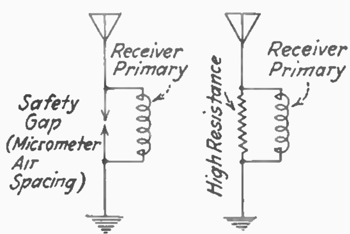


FIG. 24*a*.—Protective devices on receiver.

Ques. 109. Explain four kinds of protective devices for high electrical surges and lightning.

Ans. 1. Lightning switch for disconnecting the antenna from the receiving tuner (see Fig. 1).

2. Safety gap (lightning arrestor) connected across the primary winding of the receiving tuner (see Fig. 24*a*).

3. High resistance connected across the primary winding of the receiving tuner (see Fig. 24*a*).

4. Protective condensers for protecting power equipment from high-frequency kick-backs and surges (see Fig. 1 and Ques. 107).

Ques. 110. What method is used to measure the antenna current? What would you use in its place in case none was provided?

Ans. Hot-wire or thermocouple ammeter in series with antenna circuit.

Substitute methods:

1. Small series gap in antenna circuit.
2. Small lamp in series with antenna circuit.
3. Small lamp shunted across one or more feet of the antenna lead-in wire, the shunt depending upon the amount of power used.

Ques. 111. Draw a diagram and explain the construction and electrical functioning of a closed-core transformer.

Ans. Figure 25 illustrates one of the most common types of closed-core transformers, the shell type. This type of transformer is used for both step-up or step-down purposes. Only the step-up type will be discussed here.

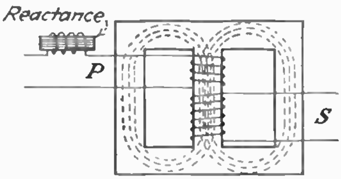


FIG. 25.—Closed-core transformer (shell type).

The magnetic core is usually made up in a rectangular shape of a highly permeable magnetic material to minimize the molecular friction (hysteresis) due to the alternating-current reversals when the transformer is in use. This material is usually made up of an alloy of silicon steel or any other form of highly permeable magnetic material. The core is made up of sheets of this steel in the form of laminations to minimize the setting up of small whorls of currents in the iron, known as *eddy currents.* Each sheet of steel is carefully treated with a high grade of insulating varnish to prevent rusting. All of the sheets are then piled together and bolted to form the core. A layer of mica or empire cloth is then wrapped over the assembled core, and the windings are wound over it.

The primary winding in the step-up transformer is usually made up of a heavy insulated copper wire, approximately No. 12 gage, depending upon the power design.

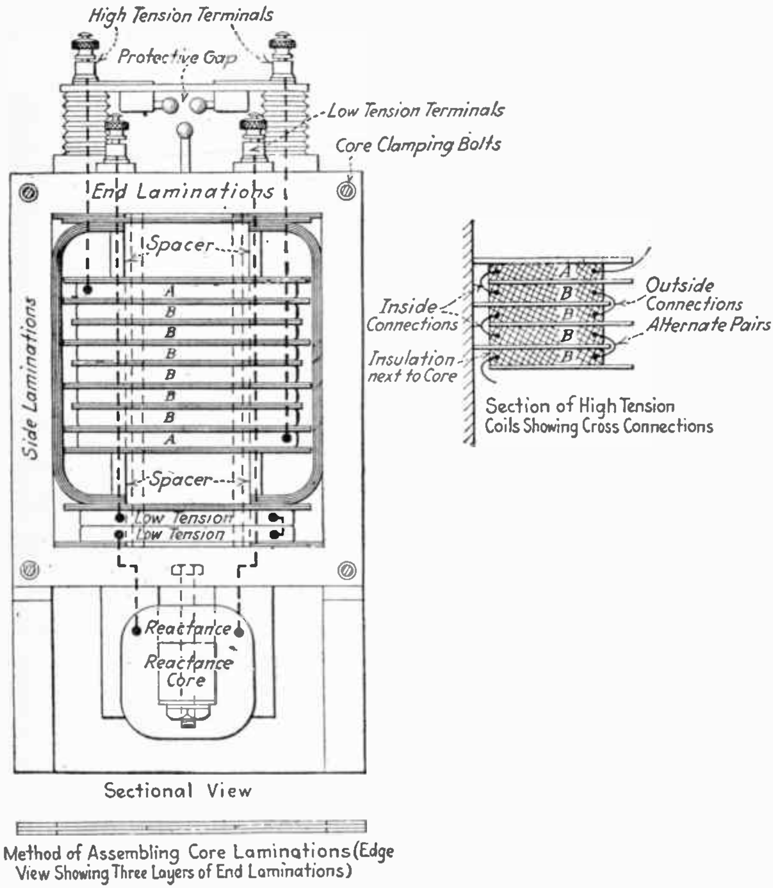


FIG. 26.—Assembly of a transformer.

The secondary is made up of many thousands of turns of very fine wire to give the desired step-up ratio. This winding is not made up in one continuous string but consists of a series of coils, each separately insulated in the form of pancakes or pies, as illustrated in Fig. 26. The entire core and winding system is then enclosed in a steel or iron case with the high-potential leads passing through a high-insulating bushing to prevent brush-discharge leakage across the casing.

The primary winding is then connected to an alternating-current supply of the proper frequency, and the secondary to the load or transmitting circuit.

The theoretical operation of a closed-core transformer is as follows: The low-potential, low-frequency current passes through the primary winding of the transformer, which sets up a rising and falling magnetic field at a definite frequency. This rising and falling of the magnetic field magnetizes the core and cuts the secondary winding, which induces an e.m.f. therein, depending upon the number of turns compared with the primary. For example, if the primary consists of 800 turns and the secondary of 40,000 turns, the ratio of transformation would be 50, or, in other words, the voltage would be stepped up fifty times. Thus, if the primary voltage is 200, the secondary voltage would be fifty times as great, or 10,000 volts. The frequency, however, would remain the same in both cases.

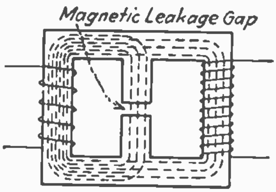


FIG. 27.—Closed-core transformer with leakage gap.

In high-potential transformers for spark transmission, the core design is a very important factor due to the inductive effects when the transformer is under load. For example, if the secondary winding is connected to a heavy load circuit, the current flow in the secondary winding will produce a magnetic field in opposition to the primary winding, which will decrease the inductive reactance of the primary and allow a heavy rush of current through the winding which may seriously overheat or burn out the primary winding. This effect would be practically the equivalent of a short-circuited secondary, and, therefore, the core must be suitably designed to prevent an overload condition from damaging the winding.

The two methods used in transformer design to prevent excessive current flow in the primary are the magnetic-leakage-gap and reactance-coil methods.

Figure 27 illustrates a magnetic-leakage core design. Here the magnetic-leakage gap prevents a change in the self-inductance of the primary winding when under load, and, therefore, the current flow in the primary winding will remain practically constant.

If the shell type of transformer is used, a resistance or reactance coil is usually connected in series with the primary winding to limit the rush of current during overload and thus protect the winding from burning out. See Fig. 25.

Ques. 112. Describe the open-core transformer.

Ans. An open-core transformer has a core made of soft iron in strip or wire form. To decrease losses the individual wires or strips that constitute the core are shellacked. An insulation wrapping is wound around the core, and the primary winding of a comparatively few heavy turns is wound around it. A heavy insulation is placed over this winding, and the secondary winding of many turns of fine wire is wound thereon in pancake form. The path of the magnetic field in an open-core transformer is open, as will be seen by referring to Fig. 28. It is seen that the field path is completed through the air.

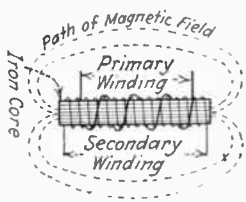


FIG. 28.—Open-core transformer.

Ques. 113. What are the principal losses in a power transformer?

Ans. The principal losses in power transformers are iron and heat losses due to hysteresis and eddy currents. Hysteresis losses are minimized by constructing the transformer core of a type of magnetic material known as *silicon steel, Ajax metal,* or *Permalloy.*

Other serious heat producers are the small eddy currents set up in the core in the form of whorls which tend to oppose the magnetizing forces of the core to such an extent that a considerable loss results. To reduce these losses, the core is made up in the form of a number of sheets of metal. This is called a *laminated* core (see Ques. 111, which describes construction of a transformer).

Ques. 114. How would you test for an open in either the primary or the secondary of a power transformer or an induction coil?

Ans. If an ammeter, or a lamp, connected in the transformer-primary circuit does not register when the circuit is closed, the primary winding is open. Another test such as a battery and telephones connected in series with the primary or secondary winding would indicate an open if no click is heard. In testing the secondary winding, the click intensity will be considerably weaker than the primary, due to the higher resistance of the winding. If no click is heard in the secondary winding, there is probably an open in one of the pancake sections. The open section can then be very easily located by connecting a battery in series with a pair of telephones and the various sections, called *pies,* and the open pie either short-circuited or, preferably, removed from the magnetic field and the transformer operated at reduced power.

Ques. 115. What is the advantage of a 1,000 or 500-cycle note over a 60-cycle note in so far as it relates to receiving apparatus?

Ans. The 1,000 or 500-cycle note can be more easily copied through atmospherical interference.

The human ear usually responds much better to a high note.

Ques. 116. What effect has the closed circuit of a transmitter upon the frequency?

Ans. The closed oscillatory circuit greatly increases the frequency of the high-voltage alternating current supplied from the secondary of the step-up transformer. This is necessary in order to produce radio waves to travel over long distances. In any spark transmitter, the closed circuit may, for example, increase the frequency as high as 600,000 or more cycles per second.

Ques. 117. What effect has the transmission of energy by a power transformer on the impressed frequency?

Ans. None.

Ques. 118. What is meant by ratio of transformation of the step-up transformer?

Ans. By ratio of transformation we compare the primary input volts with secondary output volts. The ratio of transformation is the ratio of the number of turns of wire on the secondary to the number of turns on the primary. If, for instance, a transformer steps up the voltage from 100 to 5,000 volts, the ratio of transformation would be 50, or, in other words, the voltage is stepped up fifty times. Now let us assume that the primary of the transformer has 400 turns. In order to step up the impressed voltage fifty times, it would be necessary to have fifty times as many turns on the secondary as are on the primary, or 20,000 turns.

Ques. 119. Describe three types of antenna systems and give their effects.

Ans. Three types of antenna systems (transmitting) are the inverted L (˥), the T, and the umbrella. Figure 29 illustrates these three types.

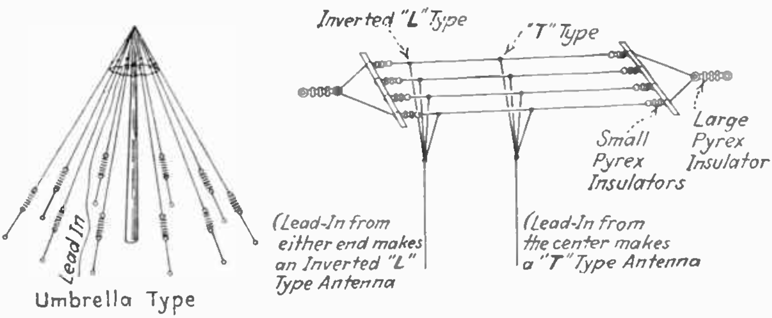


FIG. 29.—Antenna systems.

In the inverted-L (˥) type of antenna system, radiation is fairly equal in all directions, excepting that, if the horizontal part greatly exceeds the vertical part, the antenna will have considerable directional properties in the direction opposite the free end. Furthermore, in the inverted-L (˥) type of antenna, a considerable amount of energy is also radiated in a direction perpendicular to the horizontal wires. The natural wavelength of an inverted L antenna is approximately 4.2 times the length of the ground lead, lead-in and flat top.

The T type of antenna has no directional tendencies and is more favorable to radiation in all directions. There is, however, a difference in wave length compared with an inverted L of the same physical dimensions, due to the neutralization effect of the inductance in the horizontal portion. The natural wavelength of the T antenna is approximately 4.4 times the length of the lead-in plus one half the flat top, if the lead-in is taken from the center. If the lead-in is not taken from the center of the flat top, the flat top should be measured as being from the point at which the lead-in connects, to the most distant end of the flat top. This length plus the lead-in times 4.4 give the approximate natural wavelength of the antenna.

The umbrella type of antenna radiates energy evenly in all side directions but practically zero upward. The efficiency of this type of radiator depends upon the slope of the vertical wires and their distance from the earth. If the wires come too close to the earth, the electric field is practically enclosed, and, therefore, very little energy is radiated. It is, therefore, necessary to keep the wires as far away from the earth as possible to obtain desirable radiation. This necessitates high elevation and large area expansion, which makes this type of antenna impractical for ordinary purposes.

Ques. 120. What types of antenna are used on shipboard and what are their differences in wave length?

Ans. Two types, the inverted L and the T. The inverted L has a higher wave length than a T of the same physical dimension. This is caused by the neutralization effect of the inductance in the two halves of the horizontal part of the T antenna, due to the high-frequency current reversals when the antenna is oscillating.

Ques. 121. What is meant by impact excitation?

Ans. This phenomenon is also termed *shock excitation* and designates a method of producing free alternating currents in an excited circuit in which the duration of the exciting current (the impact) is short compared with the duration of the current in the excited circuit. In a circuit of this kind there is very little reaction between the circuits, and, consequently, it produces a lowly damped wave train.

A typical impact transmitter is the Cutting & Washington type 4-A, explained in Ques. 123 below.

Ques. 122. What is the difference between an impulse- and an impact-excitation transmitter?

Ans. According to the standardization report of the Institute of Radio Engineers, *impulse excitation* is a term applied to any type of transmitter in which the oscillations of the primary circuit are rapidly damped out and the secondary allowed to oscillate freely at its own natural period without any appreciable reactance between the circuits.

Impact or shock excitation, on the other hand, means that the gap quenches out the oscillations of the primary before one or two half cycles of oscillation have taken place. Any well-designed quenched-gap transmitter, therefore, might be termed an impulse-excitation transmitter, whereas "impact excitation" would imply a set designed like the one described in the following question.

Ques. 123. Describe some form of impact-excitation transmitter.

Ans. A wiring diagram of a commercial type of impact-excitation transmitter is shown in Fig. 30.

Motor Generator.—The motor is connected to the regular source of direct-current supply, and the alternator delivers 250 volts at 500 cycles frequency.

Transformer.—The transformer is a highly efficient one, of the closed-core type wound as an autotransformer with a ratio of 5.6:1 and has practically no leakage.

Condenser and Primary Inductance.—The total capacitance of the condenser on the ½-kw. set is 0.16 microfarads, and the inductance value is approximately 1.2 microhenries. This shows that the ratio of capacitance to inductance in an impact-excitation transmitter is high. This fact is one of the chief characteristics necessary to get impact or shock excitation.

Spark Gap.—The spark gap used with this type of transmitter consists of two electrodes each made of a sparking surface of thin tungsten welded to copper backs and operated in air. The gaps have a micrometer adjustment, and the sparking distance may be varied to the thousandth part of an inch. The gaps are provided with cooling fins and locking nuts.

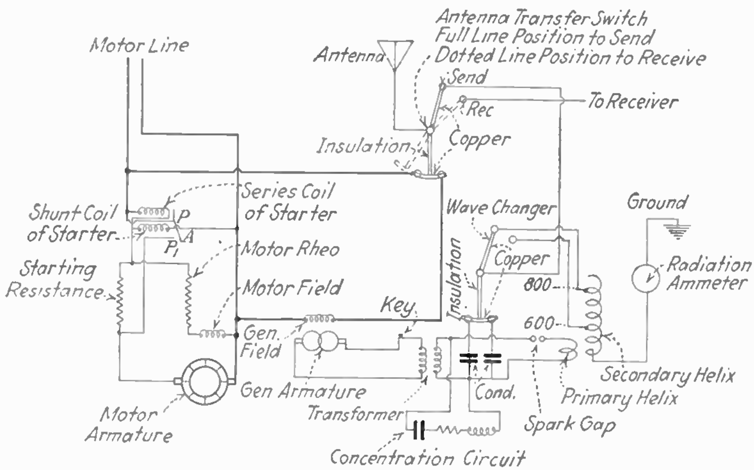


FIG. 30.—Wiring diagram of an impact transmitter.

Concentration Circuit.—This circuit has a period three times that of the alternator. It absorbs the first third of the alternator wave, discharges into the primary condenser along with the current of the secondary of the transformer during the middle

FIG. 31.—Graph of concentration-circuit effect.

third, and absorbs the last third of the wave. Its function is to concentrate the discharges into concrete groups so that the tone envelope will have approximately equal periods of activity and inactivity, thus giving maximum telephone efficiency. In other words, without the concentration circuit the emitted wave is similar to incompletely modulated continuous waves.

Figure 31 illustrates the concentration-circuit effect.

Oscillation Transformer.—The primary consists of a single turn of copper tubing and has an inductance value of 1.2 microhenries, as explained before. The secondary consists of 30 turns of edgewise-wound strip having a total inductance value of 320 microhenries. The amount of inductance in use, however, will depend upon the size of the antenna.

The term oscillation transformer as applied to impact-excitation transmitters is in itself questionable, as there are no oscillations in the primary circuit.

A wave-changing switch is also attached which is used for changing the wave length, and this automatically connects in the proper value of capacitance and inductance.

Theoretical Operation.—The condenser charges up to a potential sufficient to break down the gap and discharges through

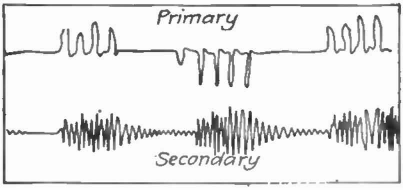


FIG. 32.—Impact-oscillations graph.

the gap. Owing to the low persistence of the primary circuit, the non-volatile nature of the electrodes, the ratio of periods between the primary and secondary circuits, and the pressure wave generated due to the viscosity of the gas, this discharge consists of only a half cycle. This half cycle sets the antenna into oscillation. The condenser then recharges, and when it has reached a potential almost sufficient to break down the gap, the back e.m.f. from the still oscillating antenna adds an increment to the voltage across the gap sufficient to break the gap down so that this second discharge comes in the proper phase to increase the amplitude of the antenna oscillations. This process continues throughout approximately the middle third of each pulse of the charging current. Figure 32 gives a fundamental idea of the oscillations in the primary and secondary circuits and shows that there is no appreciable reaction between the circuits. Figure 33 shows an impact excitation transmitter.

A set of the above description can be tuned very quickly and radiates a pure and sharp wave of pleasing tone characteristics.

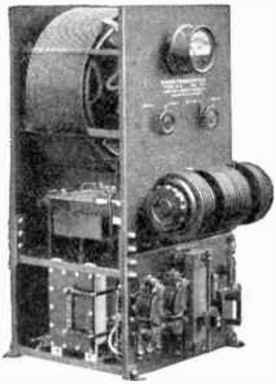


FIG. 33.—Cutting and Washington impact excitation, ½-K. W. transmitter.

Ques. 124. How would you clean a quench gap?

Ans. See Fig. 16. When the gap is opened as shown, clean the sparking surfaces with a very fine grade of sandpaper. Be sure to place the sandpaper so that all portions of the sparking surfaces are evenly cleaned. Then polish with a piece of chamois or cloth. Inspect the insulating gasket before assembling and see that it is free from rough edges or other irregularities. Screw together very tightly so as to make the sparking chamber practically airtight.

Ques. 125. A 500-cycle transmitter employing a quench gap is coupled too close to the antenna circuit. What will be the effect?

✓ *Ans.* If the coupling is too close, an interaction between the primary and secondary circuits will result which will cause an emitted wave of highly damped character. No matter how efficient the damping of the primary circuit of a quenched transmitter, there is always a possibility of some reaction between the two circuits if the coupling is too close.

Ques. 126. What end of the antenna will have the highest potential?

Ans. The free end of the antenna always has an excessive voltage strain and must, therefore, always be heavily insulated.

Brief Bibliography

NILSON and HORNUNG: "Practical Radio Telegraphy," McGraw-Hill Book Company, Inc.

"Principles Underlying Radio Communication—U. S. Signal Corps," Supt. of Documents, Govt. Printing Office, Washington, D. C.

STANLEY: "Textbook on Wireless Telegraphy," Longmans Green and Co.

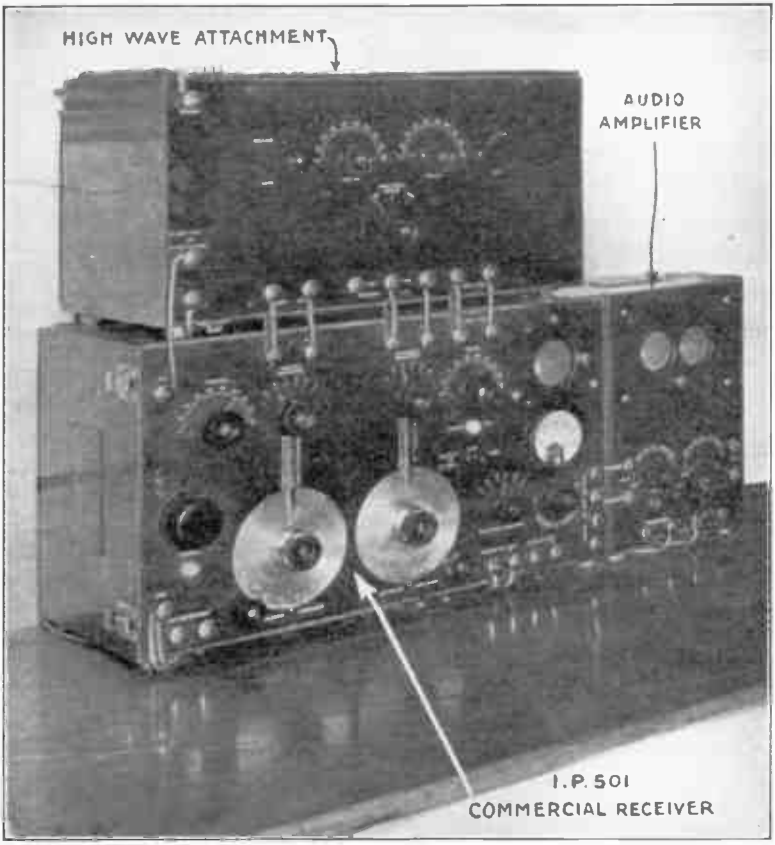


PLATE II.—Modern ship-receiver installation. (*Courtesy*, Radio Corporation of America.)

PART V

RECEIVING APPARATUS AND RADIOCOMPASS

Ques. 127. Name some crystal detectors.

Ans. Galena, silicon, carborundum, cerusite, iron pyrites zincite-bornite, and molybdenite.

Ques. 128. Tell how you would receive wave lengths higher than the fundamental of your antenna?

Ans. By inserting a loading coil in series with the antenna or primary inductance or shunting a capacity across the primary winding. The former method is the more efficient.

Ques. 129. What is the usual resistance of head phones used in radio reception?

Ans. 2,000 to 3,000 ohms per pair.

Ques. 130. To what advantage can a buzzer be used in a receiving station?

Ans. 1. A buzzer can be used to adjust the crystal to a point of maximum sensitivity.

2. To locate open circuits in low-resistance coils.

3. To test for short-circuited condensers.

4. In conjunction with a wavemeter, the buzzer can be used as a small transmitting system to calibrate a receiving set.

5. For exciting the antenna system to determine the fundamental wave length of the antenna.

Ques. 131. Give a diagram of three different types of detectors and explain their operation.

Ans. Figure 34 illustrates three types of detector circuits. The crystal detector rectifies the high frequencies into unidirectional impulses. These rectified pulsations are impressed across the telephone bypass condenser. In other words, the rectified signal voltage charges the condenser until the condenser voltage or potential is higher than the applied signal voltage, and then the accumulated charges discharge through the telephone windings and produce a click. If, therefore, 1,000 wave trains per second were producing this effect upon the telephone windings, then there would be 1,000 clicks, and a resultant musical note would be heard. Another type of crystal detector is the battery-operated type, of which the carborundum-crystal type is the most prominent. Theoretically, it functions the same as the non-battery-operated type of crystal detector. It is provided, however, with a battery and voltage divider (potentiometer) to improve its rectifying properties.

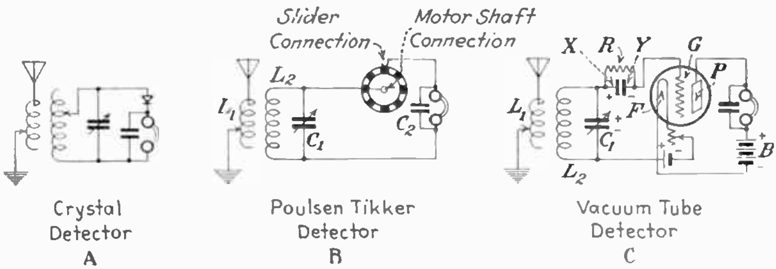


FIG. 34.—Three types of detector circuits.

Another type of detecting element is the Poulsen tikker, used when continuous waves are to be received. This is explained in Ques. 132. The most efficient of all detectors is the three-element vacuum tube, and it will, therefore, be explained in detail.

When the filament in Fig. 34c is heated to incandescence, an emission of electrons will result. If the plate is connected to a positive potential, the electrons (negative particles of electricity) will move from the filament to the plate through the B battery circuit and back to the filament. This constitutes a steady flow of direct current from F to P and from B to F.

Conventionally this direction of flow is reversed and referred to as a flow of current from the plate to the filament, *i.e.*, *BPFB*. It is a generally accepted theory that the B battery flow is from $B+$ to P; then to F; and finally to $B-$. To prevent confusion, therefore, this latter theory will be used in the following explanation:

In the immediate vicinity of the filament there is ever present a cloud of electrons which tend to create a negative field (or space charge) even though a great number are moving toward the plate. If this space charge could be controlled by neutralization, then a considerable increase in electronic movement to the plate would result, obviously increasing the plate current *BPFB*. For example, if a third element (grid) is inserted between *P* and *F* and charged with a positive potential, then a portion of the space charge would be broken up or neutralized, which would allow more electrons to move toward the plate, resulting in an increase in plate current. If, on the other hand, the grid is charged with a negative potential, then the space charge would be increased by the repelling effect of the grid and, consequently, reduce the plate current below normal. The amount of plate-current increase or decrease depends upon the amount of positive or negative potential applied to the grid. It must be clearly understood that if the grid potential is made alternatively positive and negative a corresponding rise and fall in the plate current will result at whatever rate the grid is varied. If an alternating current of 60 cycles is applied to the grid, then the plate current will vary at the same frequency but will be of greater amplitude due to the relay action of the tube.

With this in mind, let us assume a high-frequency signal voltage variation applied to the grid of a tube by means of the coupling device $L_1L_2C_1$. When the side X on the condenser is positive, side Y will be negative. The grid being connected to this point will likewise be negative. From the previous explanation, this action would tend to indicate that the negative charge on the grid would decrease the plate current due to the repelling action of the grid against the filament space charge. Now, as the alternating potential changes side X of the condenser to negative and Y to positive, the grid will receive a positive charge. This positive charge will tend slightly to neutralize some of the space charge and increase very slightly the plate current. With the next potential change, the grid will again be made negative, which will again increase the space charge and reduce the plate current. At this instant, the plate current is reduced to a slightly greater degree than at the first cycle due to the accumulation of electrons on the grid from the previous positive charge. This is caused by the blocking action of the grid condenser. This sequence of events occurs for each cycle, so that each cycle contributes its quota toward the negative charge on the grid. When, therefore, the oscillations cease at the end of each wave train, (assuming a damped or modulated wave train), the grid will remain at the negative potential it has reached due to the blocking action of the grid condenser.

If, therefore, the insulation of the side *Y* is perfect, then this negative charge on the grid may be sufficient to prevent any appreciable plate current from flowing, and a "blocking" or "choking" action of the tube will result. To prevent this, the resistance *R* is connected across the grid condenser so that when the grid becomes too heavily negative the charges may leak off

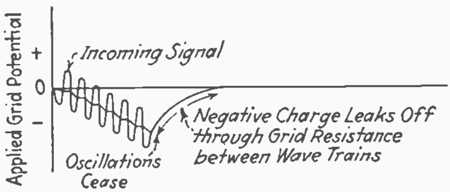


FIG. 35.—Graph showing grid rectification.

and dissipate through the resistance. The slope in the curve in Fig. 35 illustrates the effect of the signal variation due to the grid leak. If the resistance *R* is omitted, a more desirable slope or "dip" is obtained due to the constant accumulation of negative charges on the grid, but as this will eventually choke the plate current and, consequently, the signal, this method cannot be used, and, therefore, the resistance *R* is necessary for stable operation of the tube.

It will be noted by the curve that when a cessation of oscillations results, the net potential will be much less than before and will eventually become zero, depending upon the value of *R* through which the negative charge dissipates. This is an altogether desirable state of affairs because the negative charge can be sufficient to decrease the plate current without choking the tube, while the time of the discharge can be such that when the next series of oscillations commence, the grid will have returned to its normal potential. If, therefore, the time interval between the dots and dashes (or voice oscillations) is longer than it takes the grid to return to its normal potential, then the resultant effect upon the plate current and, consequently, across the telephone bypass condenser will be a charging of the bypass-telephone condenser until the condenser voltage is higher than the applied or signal voltage; then the accumulated charges discharge through the telephone in the form of a pulse which produces an audible click or sound, depending upon the tone or spark frequency of the incoming wave train.

Thus, if 1,000 wave trains per second were impinged on the grid, the telephone diaphragm would produce 1,000 clicks, and a resultant musical note of high pitch would be heard.

Ques. 132. Draw a diagram of a Poulsen tikker. Explain fully its operation.

Ans. The theoretical operation of the Poulsen tikker, illustrated in Fig. 34, is as follows:

When receiving undamped waves, continuous high-frequency oscillations are induced into the secondary circuit L_2C_1. The tikker, when placed in motion, will allow these high-frequency currents to flow to the telephone condenser C_2 at regular intervals, depending upon the speed of the motor and the number of segments on the wheel. It will be seen that the construction of the wheel permits the current to flow into the condenser only when the brush touches the conducting section and breaks the current when the brush is on the insulated portion. Thus, if the wheel is so designed as to permit the condenser C_2 to receive a charge at a rate within the audible range of the human ear, then, during the instant that no current flows, the condenser will discharge the accumulated energy from the preceding pulse through the telephone. If, therefore, these discharges come at a rate of one thousand times per second, an audible sound will be heard in the telephone corresponding to the discharge frequency. The tone pitch can then be varied to suit the listener by increasing or decreasing the speed of the wheel as may be desired.

Ques. 133. Describe fully the action of an inductively coupled tuner. Draw a diagram.

Ans. Oncoming electromagnetic waves cut the antenna and pass down through the primary winding of the inductively coupled tuner to the ground, and *vice versa.* This action sets up an electromagnetic field of an oscillating character around the primary winding of the tuner. If, now, the secondary oscillatory circuit is adjusted to resonance with the primary circuit, an e.m.f. will be induced in the secondary winding of the tuner due to the inductive relation between primary and secondary windings. This is accomplished by the careful adjustment of the secondary inductance with the secondary shunt or main tuning condenser and the primary tuning inductance (if variable) and the antenna series condenser. When both circuits have been carefully adjusted to resonance the selectivity of the circuits may be increased by loosening the coupling between both circuits and readjusting the secondary shunt variable condenser. For general listening-in purposes, however, the coupling is usually kept fairly tight to insure a maximum reaction between primary and secondary coils or broad tuning.

The high-frequency potentials across the secondary coil and condenser at resonance must then be rectified into low-frequency pulses to make the signals audible.

This is accomplished by using either a crystal or a vacuum-tube rectifier in which the high-frequency variations are converted into audible vibrations by the rectifying property of the crystal or the tube. (For tube operation see Ques. 131.)

The telephone receiver is then actuated by this rectifying action aided by a small fixed condenser shunted across the telephone windings which act as a radiofrequency bypass to the high-frequency variations across the high impedance of the telephone-receiver winding.

This condenser charges for the duration of nearly 1 wave train, and when its accumulated charges are higher than the applied signal voltage, it discharges through the telephones and produces a click. The pitch of the sound emitted from the telephone will depend upon the number of clicks produced in a second of time (see Fig. 34*A* for a diagram of an inductively coupled tuner with a crystal detector).

Ques. 134. Name some crystal detectors with which a potentiometer is used.

Ans. Carborundum, zincite-bornite, and silicon.

Ques. 135. What coupling is used for listening in? Why?

Ans. Tight coupling, to enable reception over a wide band of wave frequencies. This is necessary for general listening-in purposes so that no calls will be missed.

Ques. 136. What is the usual plate voltage employed to function a vacuum-tube detector?

Ans. The usual plate voltage is between 22.5 and 45 volts and is usually supplied by a standard 45-volt dry battery.

Ques. 137. What means are usually provided on shipboard for supplying filament current for the successful operation of a vacuum-tube detector?

Ans. Dry cells, storage batteries, and line-voltage reducers.

Ques. 138. What happens if the telephones lose their magnetism?

Ans. The loss in magnetism in the permanent magnets results in an increase of the magnetic reluctance, and, therefore, the signal variation through the telephone winding will not produce sufficient diaphragm vibration. Consequently, the signal volume will be considerably decreased.

Ques. 139. How would you adjust a receiving system employing a vacuum-tube detector to the given wave length of a transmitter?

Ans. To adjust a vacuum-tube detector receiver to a given wave length, light the filament by closing the filament circuit switch. Care must be taken not to burn the filament too brightly as the strength of the signals do not always increase with filament current, and the life of the tube is reduced.

The rheostat should be adjusted until the voltage reads about 5 volts if the standard storage-battery type of tube is used, and 3 volts if the dry cell type is used.

Vary the antenna and secondary inductances until a maximum signal is heard. Then carefully resonate for a maximum signal by adjusting the antenna and secondary condensers. Adjust the telephone condenser knob (this condenser is used on modern commercial receivers) until the signal is at a maximum. Then, for sharp tuning, loosen the coupling and again vary the antenna and secondary condensers with the vernier.

For continuous wave reception, the tickler coupling should be as loose as possible. The tuner coupling must also be loosened a little more than with spark reception. Then proceed carefully to resonate both circuits by again adjusting the primary and secondary-condenser verniers in the same manner as before.

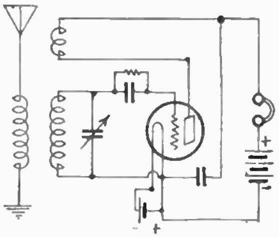


FIG. 36.—Inductively coupled tuner. Self heterodyne oscillator and detector.

The tickler coil must be adjusted until a slight click is heard as the condenser passes through resonance. The best tone will be heard just slightly above or below the resonance point.

Ques. 140. Explain two methods of receiving undamped signals?

Ans. Heterodyne and tikker.

The heterodyne method is one in which a local current of radiofrequency is superimposed upon an incoming frequency of

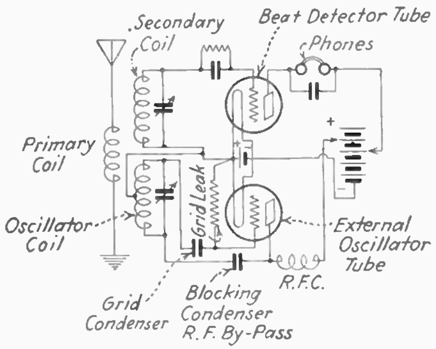


FIG. 37.—Heterodyne (external-oscillator type).

electromagnetic waves, resulting in a frequency equal to the difference between the incoming and the superimposed frequencies. For example, if the incoming radiofrequency is 100,000 cycles per second and the local frequency 99,000 cycles, then the resultant note will have a frequency of 1,000 pulses per second. Figures 36 and 37 illustrate two circuits capable of producing this effect.

The tikker method of undamped-wave reception is explained under Ques. 132.

Ques. 141. What means are provided in a receiving system to protect it from injury by signals transmitted on high power in the nearby vicinity?

Ans. A safety gap of very short length is connected between the antenna and the ground on receiving equipment at the point where the antenna lead and the ground lead make connection to the apparatus. Strong signals will discharge across the gap and form a short path to the ground and in that way they are prevented from passing through the receiving apparatus and can do no damage to it. Some types of receivers are fitted with a very high resistance conductor which is connected directly across the antenna and ground. Such a protective device allows currents of such value as to be of a damaging nature to pass directly to the earth. It is, of course, possible in inductively coupled types of apparatus to quickly decrease the coupling and in that way the mutual induction between the circuits is decreased so that the high-potential current does not flow through the secondary circuit where it might do damage (see Fig. 24*a*).

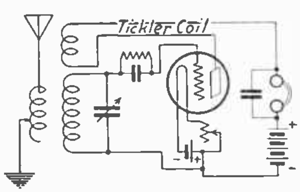


FIG. 38.—Detector circuit.

Ques. 142. Draw a diagram of a receiving system employing vacuum tubes (a) as a detector, (b) with one step of amplification, (c) with two steps of amplification.

Ans. See Figs. 38, 39, and 40.

Ques. 143. How could you determine if a vacuum-tube receiver is adjusted for the reception of continuous waves?

Ans. In order to receive continuous waves, the receiver must consist of a suitable feed-back arrangement such as a "tickler coil" to produce oscillation (see Ques. 139, 140 and 153, heterodyne oscillator and beat detector).

Two practical methods of ascertaining if the tube is oscillating are the "coupling test" and the "finger test."

In the coupling-test method, a click will be heard when the tickler coupling is increased to a point of oscillation. This click has a sound similar to the plucking of a loose violin string.

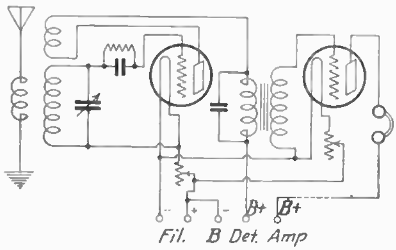


FIG. 39.—Detector circuit with one stage of amplification.

The finger test is one of the best methods for determining if a vacuum-tube receiver is oscillating. For example, if the finger is touched to the grid terminal of a detector tube, a distinct click will be heard, and, when removed, another click of equal intensity. If, however, a more pronounced click is heard upon

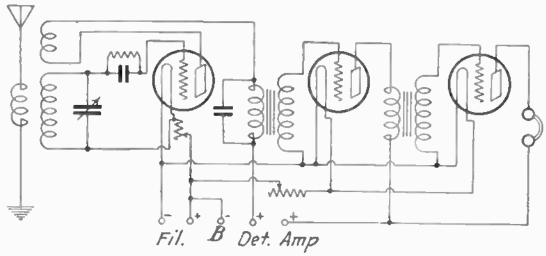


FIG. 40.—Detector circuit with two stages of amplification.

touching the grid than upon releasing, then the tube is not oscillating, and no continuous waves can be received.

Ques. 144. Draw a diagram of a standard receiving system employing a crystal detector and potentiometer.

Ans. See Fig. 41.

Ques. 145. What is the difference between a Fleming valve and an audion (three-element vacuum tube) detector?

Ans. The Fleming valve has two elements, a filament and a plate, and the audion has three elements, the filament, the grid, and the plate.

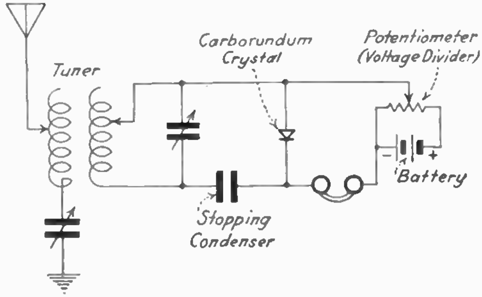


FIG. 41.—Receiving circuit with crystal detector.

Ques. 146. What instrument is used to regulate the current to the filament, and what is the purpose for such regulation?

Ans. The filament current in a vacuum tube is regulated by a low-resistance rheostat. The reason for such regulation is that the sensitiveness of the tube is increased by careful regulation of the filament current. The filament-current rheostat also prevents a recuperated battery from burning out the filament when it is first lighted.

Ques. 147. Explain the construction of the shielded-grid (four element) vacuum tube; what is the purpose of the fourth element; how may this tube be used in the receiving circuit?

Ans. This tube has four elements, filament, plate, control grid, shield grid. It has the customary four prong base which holds terminals as follows; two filament, one plate, one for the shield grid. A metal cap fits to the top of the tube which is the terminal for the control grid.

The purpose of the shield grid, when the tube is used as a radio frequency amplifier, is to prevent oscillation resulting from the feed-back of energy from the plate circuit to the grid circuit. This is accomplished by using the shield grid to neutralize the plate-grid capacity which will cause oscillation even when all external sources of feed-back have been eliminated. When the tube is so used it is called a screen-grid tube.

This tube may also be used as an audio amplifier and when it is so used it is called a space-charge-grid tube. The shield grid now serves to increase the mutual conductance of the tube by lowering its plate resistance. The result is a higher amplification gain per stage.

As indicated above the four element tube may be used either as a radio or audio frequency amplifier. In the United States, however, it is most commonly used as a radio frequency amplifier and will so be used in modern commercial receivers.

Ques. 148. Show, by diagram, two means of connecting a test buzzer to a crystal detector. Explain their advantage and connection fully.

Ans. See Fig. 42. A test buzzer connected as in this figure, if connected inductively or directly, is of advantage in testing

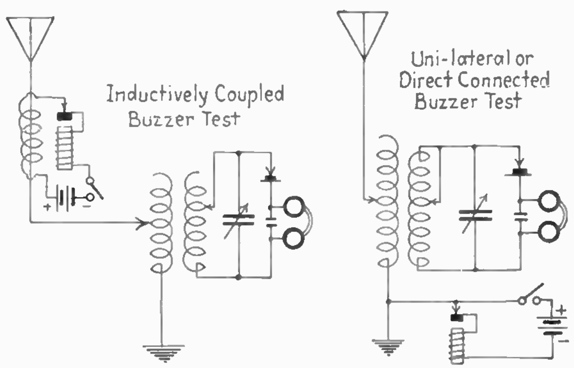


Fig. 42.—Test-buzzer connections to crystal receiver.

to ascertain whether or not the receiving apparatus as a whole is in working condition. This function can be performed by a test buzzer because it generates electromagnetic waves which have an effect upon the receiving circuit similar to the radio waves received from a distant transmitter. A test buzzer is of very great value when a crystal detector is used, as it is the only absolute method of making sure that the detector point is on a sensitive spot on the crystal.

Ques. 149. How do you proceed to calibrate a receiving set with a wavemeter?

Ans. To calibrate a receiving set, the wavemeter must act as a transmitter. This is accomplished by means of a buzzer as shown in Fig. 43. First start the buzzer and tune the wavemeter to the lowest wave length to which the receiving set is to be tuned. Tune the primary circuit of the receiver to resonance with the wavemeter by varying any movable inductance or capacity handles in the circuit, and note the final positions on a sheet. The secondary or closed circuit may then be adjusted until the loudest signal is heard. This is done by moving inductance switches and condenser handles. The final positions of each can be noted on a sheet. The wavemeter may now be tuned to the next higher wave length, and a similar operation gone through. These operations are to be repeated for each successive wave length or frequency.

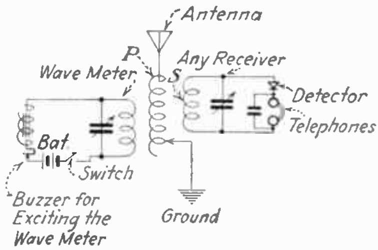


Fig. 43.—Tuning receiver with a wavemeter.

Wave Length	Primary	Primary Cond.	Secon-dary	Secondary Cond.	Coupling
200					
250					
300					
350					
400					
450					
500					
550					
600					
650					
700					
750					
800					
850					
900					
950					
1000					

Fig. 44.—Tuning chart for receiver.

The wavemeter must be placed in close proximity to the receiver and coupled to it as shown in the diagram. A sample tuning sheet is shown in Fig. 44.

Ques. 150. Draw a diagram of a "stand-by" circuit.

Ans. See Fig. 45.

Ques. 151. What is the meaning of the term "stand-by" circuit in connection with a receiving system?

Ans. A "stand by" circuit is one that is tuned broadly. With a circuit of this kind, a wide range of wave lengths can be heard, and for this reason it is valuable for general listening-in purposes.

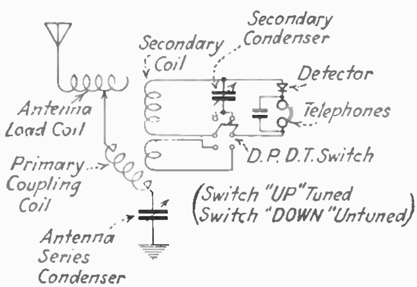


FIG. 45.—"Stand-by" circuit.

Ques. 152. Why is it necessary to employ a diaphram in connection with head receivers?

Ans. It is the vibration of the diaphram that produces the sound in the head receiver. The diaphram is acted upon by the magnets in the receiver and vibrates at a certain speed depending upon the frequency of magnetic attraction exerted by the magnets. These vibrations set up a wave motion in the air particles which act upon the ear diaphram producing sound.

Ques. 153. Draw a diagram of a regenerative detector and explain the theory of regeneration.

Ans. Before reading the theory of regeneration, refer to the explanation on a vacuum-tube detector with a grid leak and condenser on pages 70 to 73.

It will be remembered that the rectifying action of the tube, due to the grid condenser and leak, resulted in a low and high-frequency current flow in the telephone-plate circuit in which the low-frequency pulse passed through the telephone and the high-frequency was bypassed through the telephone condenser.

In a regenerative system it is this radiofrequency current in the plate circuit which can be used for radiofrequency amplification of the received signals by a feed-back arrangement of either an inductive or capacitive connection.

Figure 46 illustrates a typical regenerative circuit in which the coil L_3 is used to feed back the signal radiofrequency variations in the plate circuit to the grid to produce an increased signal variation and, consequently, a louder signal response in the telephones.

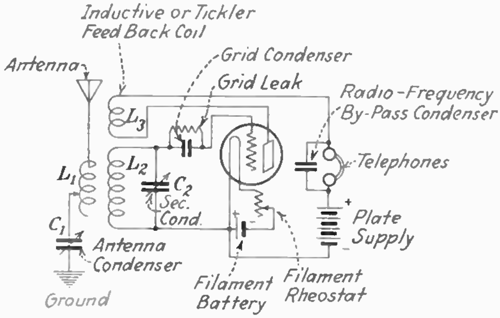


FIG. 46.—Wiring diagram of regenerative receiver.

The reason for this action is as follows:

In the high-frequency grid circuit L_2C_2, where the damped-signal variations are fed to the grid, after they have been induced by conditions of resonance from L_1C_1, there is always present a certain amount of ohmic resistance which results in a loss of some of the signal energy and, consequently, an increase in the signal damping. This loss, due to the circuit resistance, is called the *positive resistance* of the circuit.

When the signal variations are applied to the grid of the regenerative receiver, there will be a resultant high-frequency plate-current component which will flow through the coil L_3 and the radiofrequency-bypass condenser. Now, if the coil L_3 is inductively related to L_2, an e.m.f. will be induced across L_2C_2 which will be in phase with the high-frequency e.m.f. set up in the same circuit due to the incoming signal. If then the coil L_3 is so wound as to provide a negative feed-back coupling between the plate and grid circuits, the negative resistance will partly neutralize the positive ohmic resistance of the circuit which will result in a decrease of damping and, therefore, a higher amplitude of the signal variations and, consequently, a louder signal response in the telephones.

It is important to note that the neutralization effect increases as the feed-back coupling L_3 is made closer, and a point may be reached where the damping is so small, due to the neutralization of the positive resistance, that the circuit may start oscillating. A modulated or damped signal would then be of such a sharply tuned character that the signal would become heavily distorted and possibly inaudible.

It can thus be seen that a regenerative system will give increased amplification of damped and modulated signals only up to a certain point, *i.e.*, a little below the oscillating point.

This circuit can, however, be used for the reception of continuous waves by actually setting the tube into oscillation through tight coupling. This is called a *self-heterodyne oscillating system* and operates in principle the same as the circuit in Fig. 36, with the exception that the one tube functions as both an oscillator and a detector.

Ques. 154. Describe the electrical and magnetic phenomena in connection with the proper functioning of the head receiver.

Ans. In order clearly to understand the working of a telephone receiver it is necessary to know the principal parts of which

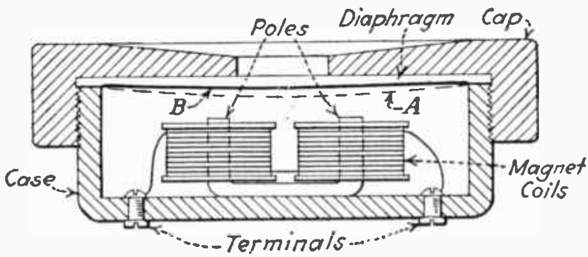


Fig. 47.—Cross-sectional view of telephone receiver.

it is composed. Figure 47 shows a side cut of a watch-case type such as is used in radio work.

Note that the diaphragm is placed so that it will be affected by the magnets. The magnets are permanent electromagnets, and the magnetism in them has a holding effect on the diaphragm. A more pronounced movement of the diaphragm, however, toward and away from the pole pieces takes place when a pulsating e.m.f. is applied to the coils. When no current is flowing in the magnet coils, the position of the diaphragm is as in position *B*, which is normal.

When the current flows through the coils, a magnetic field is set up which draws the diaphragm toward the pole faces, position *A*. When the current stops, the diaphragm returns to normal position. It is seen that every time the diaphragm moves from

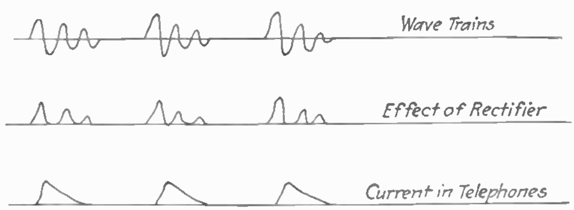


Fig. 48.—Wave train to telephone, current curve.

normal position to the position nearest the pole faces and back to normal a click is produced. If these clicks are made to occur in rapid succession a continuous sound is produced. A study of the graphs (Fig. 48) will show the relation of the radio oscillations to the final telephone current.

If the spark frequency is steady and the sparks discharge across the gap at regular intervals, the note in the head phone will be smooth. If, on the other hand, the intervals between the sparks are uneven, an uneven note will be heard in the head receiver.

Ques. 155. Why are permanent magnets used in head telephones?

Ans. Permanent magnets produce a greater response for a given current than is obtained with soft iron magnets, due to the constant pull upon the telephone diaphragm, thereby providing a constant path of low magnetic reluctance for the current variations through the telephone windings.

Ques. 156. Describe magnetic coupling. Describe electrostatic coupling.

Ans. *Magnetic coupling* is any coupling which takes place by means of magnetic lines of force. The autotransformer is used to give direct magnetic coupling, and the oscillation transformer gives inductive magnetic coupling. Both are types of magnetic coupling (see Fig. 49). The term *electromagnetic coupling* is used synonymously with magnetic coupling.

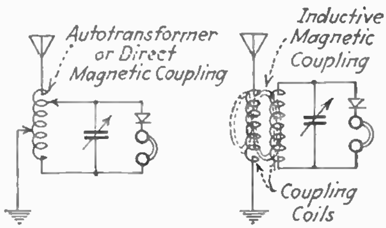


FIG. 49.—Magnetic coupling.

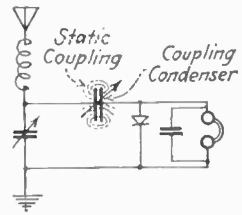


FIG. 50.—Static coupling.

Electrostatic coupling takes place through a condenser, as shown in Fig. 50. Here, the energy is passed from the antenna circuit to the rectifier in electrostatic form by means of the coupling condenser. The lower the capacity of this condenser, the looser will be the coupling, and the greater the capacity, the tighter the coupling.

Ques. 157. Describe the operation of the slipping-contact detector.

Ans. *A slipping-contact detector* consists of a grooved brass wheel mounted on a motor shaft. A wire brush is so arranged as to make slipping contact with the wheel when it rotates. The wheel and brush connections are connected in place of the crystal detector. The theory of operation is that the slipping contact is one of variable resistance and, therefore, causes variable charges to accumulate in the telephone condenser. The note in the head telephones will vary in accordance with the speed at which the wheel rotates.

Ques. 158. Why is it necessary to employ detecting elements to render radio signals audible?

Ans. Radio waves have a frequency far above the audible range. Frequencies above 10,000 cycles are ordinarily inaudible. If the head telephones were energized by this frequency direct and the diaphragm vibrated at this high frequency, nothing would be heard, as it is above audibility. It is, therefore, necessary to rectify these high-frequency oscillations into a low-frequency pulsating e.m.f. which can be heard in the head phones. This rectification is shown graphically in Fig. 48.

Ques. 159. How would you test for a short circuit in an air-dielectric condenser?

Ans. A low-potential condenser with air dielectric may be tested for a short circuit in several ways. One of the simplest would be to connect the condenser under test in parallel to the head telephones, leaving one side of the circuit loose so that it can be connected and disconnected quickly. When radio signals are heard if the parallel condenser circuit is completed and the condenser is not shortcircuited, signals will be heard as before. This test can be used only where it is possible to receive loud signals, as the capacity of the condenser across the head telephones may render weak signals inaudible. Another and more simple test would be to insert a head phone and dry cell in series with the condenser, and, if short-circuited, a click would be heard in the telephones.

Ques. 160. Explain how you would tune in signals with an inductively coupled receiver.

Ans. A simple inductively coupled receiver is shown in Fig. 34. To receive signals, make sure that the antenna and ground connections are made. Set the crystal detector to a sensitive position, as determined with the aid of a test buzzer, or light vacuum tube detector. Set the variable condenser near the minimum value, and closely couple the secondary to the primary. Listen carefully and vary the primary contact until the maximum signal is heard. Next, vary the inductance value of the secondary by moving the contact until the signal strength is increased to a new maximum. The variable secondary condenser may now be varied for maximum signal strength. If interference from other stations is heard, the coupling should be decreased by moving the secondary away from the primary. It is well to remember that generally louder signals are obtained with a maximum value of secondary inductance and a minimum value of secondary capacity. To avoid interference from other stations, work with the smallest degree of coupling possible.

Ques. 161. What is the function of a fixed condenser in a receiving circuit?

Ans. The fixed condenser is usually connected in parallel to the telephones. In this position it provides a complete circuit for the oscillations in the secondary circuit without having to flow through the telephones, the high inductive reactance of which would tend to choke back the oscillations and possibly prevent their detection. In other words, the fixed condenser is primarily used to bypass the high-frequency variations across the high telephone impedance, to permit more of the high-frequency signal voltage to act on the crystal and, thereby, improve rectification. The condenser charges for the duration of nearly a wave train, and when its accumulated voltage is higher than the signal voltage, it discharges through the telephones.

Ques. 162. Explain how a buzzer tester may be used to locate faults in a receiving circuit.

Ans. If a certain part of the receiving apparatus is suspected of being open-circuited or short-circuited, a buzzer tester may be used to locate the trouble. To test for an open or a short circuit, connect the buzzer in series with the circuit under test. If the buzzer operates, the current path is complete; if it does not, the current path is open. An open circuit is indicated by lack of operation of the buzzer. A closed circuit is indicated by operation of the buzzer. The test may be applied to each piece of apparatus separately until the trouble or series of troubles is located.

Ques. 163. How should the receiving set be adjusted to a certain transmitting station during heavy static?

Ans. To receive in heavy static, extremely loose coupling is required. It is necessary when using loose coupling to tune very carefully, as a small variation from the proper position will tune most signals out. When using loose coupling on an inductively coupled set, it is necessary to vary critically the secondary capacitance and then carefully adjust the antenna series condenser.

Ques. 164. What is the advantage of a variable condenser across the secondary of a receiving transformer?

Ans. The secondary variable condenser permits accurate tuning of the secondary circuit to the antenna circuit. It also permits an increase of the wave length in the secondary circuit.

Ques. 165. What are the values of the A, B and C voltages used on the (UX 222) shielded-grid vacuum tube?

Ans. When the tube is used as a radio frequency amplifier the voltages may be as follows; A 3.3, B 135, C (control grid) −1.5, C (screen-grid) 45.

When the tube is used as an audio frequency amplifier the voltages may be as follows; A 3.3, B 180, C (control-grid) 0−¾−1½, C (space-charge-grid) 22.5.

Ques. 166. How is a ground connection made on a receiving system?

Ans. In the case of steel ships, the ground connection is made directly to the hull of the vessel. Care must be taken to have the paint well scraped before making the connection. In wooden ships, or sailing vessels, the ground connection is made to the crankcase of the propellor shaft or to a metal plate below the water line.

Ques. 167. (*a*) What would be the effect of reversing the plate battery on a vacuum-tube receiver; (*b*) the filament battery?

Ans. (*a*) No electrons would bombard the plate, and, therefore, no plate current would flow. The plate potential must always be maintained at a positive potential to obtain the proper results in a vacuum-tube receiver.

(*b*) If the filament battery is reversed a decrease in signal intensity might result. This depends upon the type of circuit used.

Ques. 168. Why are mechanically and electrically perfect connections necessary in radio receivers?

Ans. Mechanically perfect connections are absolutely necessary to prevent fading and swinging of signals. Electrically perfect connections are absolutely necessary to decrease the high-frequency resistance which would occur due to poorly soldered or unsoldered, corroded joints.

Ques. 169. Of what use is variable coupling in a receiving tuner?

Ans. A variable coupling between the primary and secondary of the receiving tuner enables the operator to tune the receiver either broadly or sharply. When listening in, using a stand-by circuit, the coupling is close or tight; while when working in traffic the coupling is kept loose, in other words, the primary and secondary are kept relatively well separated. The practice of using loose coupling while receiving messages not only cuts out existing interference but also prepares for any interference that may arise during reception. Tight coupling, on the other hand, enables the operator to hear calls and signals over a wide band of wave lengths. This does not apply to pure CW transmission.

Ques. 170. If your head phones suddenly became defective, where is the trouble most likely to be, and how would you remedy it?

Ans. The trouble is most likely in the phone cords, probably a disconnection at the metal tips or at the binding posts on the ear pieces of the phones. The remedy is to put on a new phone cord or solder the tips on the old one. If a new cord is not available, flexible wire may be used in its place. If the magnets have lost their magnetism it is sometimes possible to restore them by passing a current through the windings. The 110-volt direct-current line may be used with a 75-watt lamp in series with the headphones. Care must be taken so that the current passes through the magnet coils in the proper direction (in accordance with the right-hand rule for polarity of a solenoid) and that they do not overheat. A pair of extra head phones are required on all ships to meet any emergency.

Ques. 171. Describe a variometer to be used in connection with a receiving system.

Ans. A variometer consists of two coils, one of which is inside the other, connected in series. The outside coil is called the *stator*, and the inside coil the *rotor*. When a current is passing through both windings and the position of the rotor with respect to the stator is such that the magnetic fields of both coils are in the same direction, then both magnetic fields will interlink and a maximum of inductance will result. If, however, the rotor is turned so that a current flowing through both of the windings produces magnetic fields partially or fully

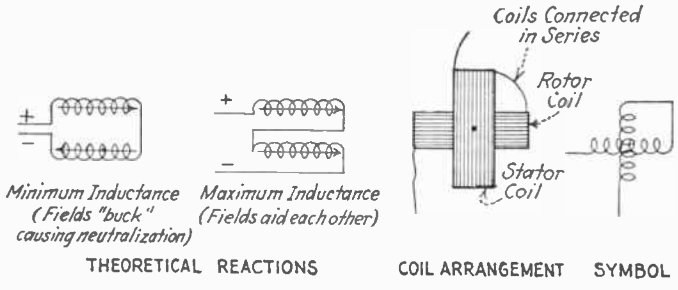


Fig. 51.—Variometer.

in opposition to each other, then the bucking effect of the two fields will result in a neutralization of the fields and a decrease in the inductance.

A variometer will thus permit a variation of inductance from a minimum to a maximum in accordance with the above explanation and will, therefore, enable a fine variation of wave length without the use of taps or condensers. It is, however, very difficult to obtain absolute-zero inductance unless the rotor is very close to the stator.

Figure 51 illustrates a wiring diagram of a variometer.

Ques. 172. What provision is made so that a receiver may be tuned below the natural or fundamental wave length of the antenna?

Ans. A variable condenser called a *short-wave condenser* is connected in series with the antenna circuit. This reduces the capacity of the circuit as a whole and, consequently, the wave length to which the set may be tuned.

Ques. 173. Why are low-resistance telephones not used with any type of modern detector?

Ans. Low-resistance telephones cannot be efficiently used with modern detectors, especially the crystal, due to their inability to create a sufficiently high amplitude of diaphragm vibration when feeble signal impulses are passing through the telephone windings. This is due to the lower number of turns and, consequently, a decrease in the magnetic-field density. For example, assume a coil to have 100 turns of copper wire wound on a permanent magnet and a current of 1 ampere passing through the winding. The strength of a magnetic field about a solenoid with an iron or steel core will depend upon four factors, the cross-sectional area and length of the magnet, the character of the magnetic material, the number of turns about the material, and the amount of current passing through the winding. In the modern telephone, the magnet is usually of steel and is permanently magnetized so that the diaphragm across it will be maintained in a strained condition. This also tends to complete the magnetic path of the telephone magnet and to provide a path of low reluctance which will consequently produce the desired signal effect. If, therefore, the magnetic field due to the permanent magnetic field has a certain flux density, then the 1 ampere flowing through the winding of 100 turns will increase the flux density and produce a greater strain on the diaphragm.

The flux density can be increased only up to a certain point known as the *saturation point.* This depends upon the permeability of the material, which, in turn, depends upon the character of the material and can be determined by plotting a graph showing the relation between the magnetizing force and the resulting flux density produced. This is known as the *magnetization* or $B{:}H$ ratio curve for magnetic materials, usually soft iron.

If, then, we assume the magnetic field to be increased due to the 1 ampere of current, say 50 per cent, then how much increase will result if the current is reduced to a feeble radio current of

100 microamperes? Obviously, the magnetic-field increase over the normal amount of the permanent magnet would be very little. If, therefore, the 100-microampere current due to an incoming signal is to produce approximately the same increase in the magnetic field, then the number of turns must be increased. Thus, an increase in the number of turns will, obviously, increase the resistance of the winding, but the loss due to the resistance is more than compensated for by the increase in the magnetic-field density. The formula for determining the relative increase in ampere-turns is expressed as follows:

$$\text{ampere-turns} = \text{current} \times \text{turns}$$

Ques. 174. How may the sensitivity of the vacuum-tube detector or amplifier be increased?

Ans. The sensitivity of vacuum tubes cannot be increased beyond a certain point. Vacuum tubes depend for their proper operation in the circuit on correct values of filament, plate, and C voltage. The operator must be sure, therefore, that these values are correct. The filament current to the detector and amplifier tubes may be adjusted while signals are being received, and the rheostats left at the points of maximum signal. It frequently happens that the batteries supplying these A, B, and C voltages drop in voltage very quickly after reaching a certain point of discharge. Careful attention must be paid to the condition of these batteries.

The sensitivity of a vacuum-tube detector may be increased enormously by using a regenerative circuit (see Ques. 153).

Ques. 175. Where may variable condensers be used efficiently in a receiving circuit?

Ans. A variable condenser may be used as a short-wave condenser in series with the antenna circuit and across the secondary of the receiving tuner (see Fig. 46). In this latter position it improves the selectivity of the receiver as a whole. This is due to the necessity for making the inductance in the circuit adjustable in fixed steps. In order to tune closely to a given wave length it is necessary to have a continuously variable oscillatory circuit. In practice it is found necessary to increase the capacity of the secondary condenser as the coupling is loosened; when the coupling is tight, as in a stand-by circuit, but little of the capacity of this condenser is used.

A condenser is sometimes shunted across the primary for long wave reception.

Ques. 176. What are some of the faults encountered in vacuum-tube receivers?

Ans. Headphone noises:

1. Loose connections in the circuit or phone-cord tips.
2. Defective grid leak.
3. Corroded or loose contacts of the tube prongs or sockets.
4. Broken-down grid condenser.
5. Defective tube.
6. Abnormal filament current (especially in gas-detector tubes).
7. Power-line induction.
8. Defective or run-down B or A batteries.
9. Loose antenna or ground connections.
10. Poorly soldered connections.
11. Excessive plate voltage on detector plate.

No signals:

1. Open grid circuit in the detector or amplifier circuits.
2. Tuning condenser short-circuited.
3. Poor contacts on inductance switch.
4. Open tuning coils.
5. Improper value of grid-leak resistance.
6. Open plate circuit.
7. Improper filament brilliancy (weak A battery).
8. Deactivated filament.
9. Broken antenna or ground connections.
10. Defective head phones.
11. Tickler connections reversed (No continuous-wave signals can be received).
12. B batteries run down.
13. Broken connections (general).
14. Poor telephone plug and jack contacts.
15. Grounded antenna.
16. High-resistance connection due to a poorly soldered joint.
17. B battery potential reversed.
18. Short-circuited bypass condenser across the primary of the audio transformer winding.

Weak signals:

1. Poorly soldered connections.
2. Deactivated filament.

3. Open in transformer winding.
4. Open by-pass condenser across first audio transformer.
5. Filament polarity reversed.
6. Improper plate-supply voltage.
7. Run-down B battery.
8. Run-down A battery.
9. Poor ground connections.
10. Tickler reversed.
11. Poor contact between tube prongs and socket.
12. Antenna circuit open.
13. Poor antenna insulation.

Ques. 177. Show a regular receiver and explain how you would control oscillation.

Ans. Refer to the diagram in Fig. 46. If the tickler coil L_3 is very closely coupled to L_2, the tube will be set into oscillation. If it is desired to control the oscillations without moving the tickler, then a high resistance (0 to 10,000 or 0 to 100,000) may be connected directly across L_3 and oscillation controlled in that manner. In radio-frequency amplifying circuits, oscillation may also be controlled by inserting a resistance in series with the plate-supply lead or a 400-ohm potentiometer connected across the filament battery and the variable arm to the grid-return lead of the first radio-frequency transformer. Another efficient method is to connect a 500 Ω resistance in series with the radio-frequency grid leads.

Ques. 178. Explain how CW signals are made audible.

Ans. See Ques. 132 and 140.

Ques. 179. If your tubes burned out, how would you use a crystal detector?

Ans. See Fig. 42.

Ques. 180. Explain the causes of an audio-frequency squeal or howl in your receiver.

Ans. Some of the howls or squeals in the amplifier circuit may be due to one of the following causes: open grid connection either at the tube socket or at the *G* terminal at the audio transformer, burned-out secondary in one of the audio transformers, interaction between wires, coupling between transformer cores, defective tube, high-resistance connection due to a poorly soldered joint, improper grid bias, microphonic tube, audio feedback between transformers and telephones due to the close proximity of the telephones and transformers.

Ques. 181. What is the effect of a too low B-battery voltage?

Ans. Weak signals, scratching noise, and distortion or receiver completely inoperative.

Ques. 182. Explain how to reactivate 201*a*-type tubes?

✓ *Ans.* This is the well-known thoriated filament tube, which, when subjected to excessive filament voltage or plate potential, loses its electronic emission to a degree where signals are practically inaudible. These tubes may be rejuvenated by connecting them in the circuit as usual but with the B battery disconnected and allowing them to burn in this condition for from 12 to 24 hours. They may be more rapidly rejuvenated by connecting the filaments across a higher voltage than the tube is rated for up to about 16 volts. Under the latter conditions, the filaments must not be lighted for too long a period, because they will burn out. The usual rejuvenating voltage and time is 8 to 10 volts for a period of about 2 minutes.

Ques. 183. How would you test for burn-out in audio-frequency transformers?

✓ *Ans.* The primary and secondary circuits of an audio transformer may be tested by a pair of telephones and a 22½-volt B battery. The telephones and the battery are connected in series and then shunted across the winding to be tested. If the primary circuit is tested, no click will be heard if the winding is open (unless a by-pass condenser is connected across it). If the secondary winding is to be tested, no click will be heard if the winding is open. It is very important when testing the secondary to note carefully the intensity of the click, because due to the comparatively high resistance of the secondary winding the click will be much feebler. High-resistance phones should be used in these tests.

Ques. 184. Can modulated waves be received on a crystal?

✓ *Ans.* Yes.

Ques. 185. Draw a diagram of a standard wavemeter fitted with a current indicating device, crystal detector, telephones, buzzer, and a battery.

Ans. See Fig. 70. In drawing the diagram for this question, leave out the circuit L_1 and the condenser C_f. H represents the current-indicating device, C_v the variable tuning condenser, L the wavemeter inductance, D the crystal detector, T the telephone, and B the buzzer.

Ques. 186. What is the effect of poor connections in a receiving system? How would you locate and remedy this trouble?

Ans. Poor connections in a receiving system will produce very feeble or no signals. Sometimes a poor connection causes fading of signals or a static effect similar to atmospherical disturbances. It is, therefore, extremely important to have all connections well soldered and all switch contacts free from corrosion or dirt. The remedy is, of course, obvious. The operator may locate the trouble, first, by disconnecting the antenna and ground from the receiver to see if the scratching noise is still present. Then the switch arms and contacts might be inspected for loose or dirty connections. Similarly, the tube prongs and sockets. If the antenna and ground are again connected and the scratching or fading of signals is still noticed, inspect very carefully the antenna connections for corrosive or loose joints. This operation should also be carried out with the ground system. A very common fault in receiving sets which produces considerable scratching and rattling in the telephones is a loose connection on the storage-battery terminals, especially at the positive pole where sulphation may have corroded the copper wire.

Ques. 187. How would you test (*a*) a defective variable condenser; (*b*) a defective grid leak; (*c*) a burnt-out telephone?

Give remedy in each case.

Ans. A defective variable condenser may be tested with a pair of head phones and a battery. If a click is heard when the condenser is in series with the battery and telephones, the condenser is short circuited.

The grid leak may be tested in the same manner, but a higher battery voltage should be used due to its high resistance. If a click is heard, the leak is in good condition. Burned-out telephones may be tested in the same manner.

The remedy for a defective variable condenser is to rotate the plates very slowly and note carefully at which point they touch the stationary plates. Then try if possible to bend the rotary plate which is touching so that it will revolve freely. If all the plates are touching, it will be necessary to adjust the lock screw and shift the plates to the exact center again, making sure that they do not touch the stator plates. Burned-out telephones may be temporarily repaired by unwinding the wire from the bobbins very carefully until the burnt-out section is reached. It may then be carefully soldered and rewound. This is, however, very seldom necessary, because an extra set of headphones is usually available.

Ques. 188. How could you receive CW signals with a crystal detector?

Ans. See Ques. 131 and 132, and Fig. 34*B*.

Ques. 189. If your antenna is blown down in a storm, what precautions will you take?

Ans. The wire must be stretched between riggings and carefully insulated. If the insulators have been broken, a piece of rope soaked in oil may be used as insulators. Care must be taken that the temporary antenna and lead-in wire does not touch any metal parts and must also be tightly fastened to prevent swinging.

Ques. 190. What are the various values of condensers used in a receiver?

Ans. Antenna-series condensers usually range from nearly zero to 0.001 or 0.0025 microfarad. Secondary condensers are usually in the vicinity of 0.001 microfarad. Grid condensers usually have a value of 0.00025 microfarad. Telephone by-pass condensers, 0.0005 or 0.001. Audio-frequency by-pass condensers, between 0.5 and 2 microfarad.

Ques. 191. What precautions should be observed with telephone receivers?

Ans. Telephones should be handled very carefully and should not be dropped, as to drop them may cause a considerable loss of magnetism and, consequently, a decrease in sensitivity. It will sometimes be noticed that if the telephone is connected in the last stage of the audio amplifier, a reversal of the telephone tips will give increased signal strength. It is always advisable to try interchanging until the loudest signal response is obtained. A small 0.006 fixed condenser is sometimes found to give a smoother tone when using the last stage of the amplifier.

Ques. 192. If a blue glow is present in a detector tube, what is the trouble?

Ans. This might be a defective tube or a gas-type detector tube having excessive plate voltage on it. In any event a blue glow will give very unstable operation.

Ques. 193. If a receiver is tuned to 7,000 meters, how would you increase it to 18,000 meters?

Ans. The primary, secondary, and tickler circuits must be loaded by inserting a honeycomb or duo-lateral coil in each of the above circuits. In modern commercial receivers, a high-wave attachment is usually provided for this purpose.

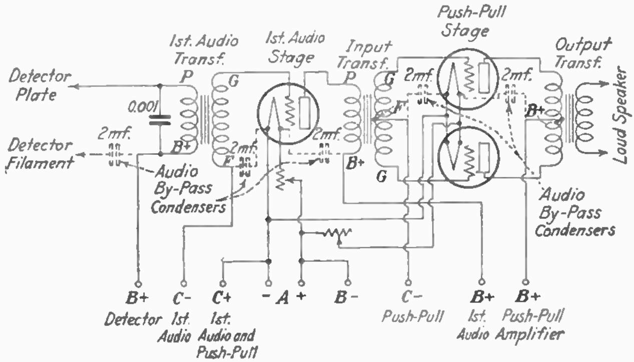


FIG. 51A.

Ques. 194. How would you determine causes of noises in a receiver?

Ans. This trouble may best be determined by a process of elimination. First, disconnect the antenna and ground leads and then check carefully all contacts, switch arms, tube sockets, tube prongs, telephone plugs and jacks, transformers, condensers, grid leak and condenser, storage battery and B battery connections, and their respective voltages. Second, look for a defective tube. Reconnect the antenna and ground and note whether or not the noises are increased. If so, look over antenna and ground connections and look for loose or poorly soldered joints or a possible scraping of the antenna wires against metallic objects. If this does not remedy the trouble, it is probably a local interference due to the ship's generators or atmospherical disturbance.

Ques. 195. Draw a diagram of a one-stage audio amplifier feeding into a push-pull amplifier.

Ans. Figure 51*A* illustrates a typical push-pull amplifier arrangement.

RADIOCOMPASS

Ques. 196. Draw an elementary diagram of a direction finder and explain the principles on which it operates.

Ans. An elementary diagram of a direction finder is shown in Fig. 52.

The principles of operation of the radio direction finder are based primarily on the directional properties of a loop coupled

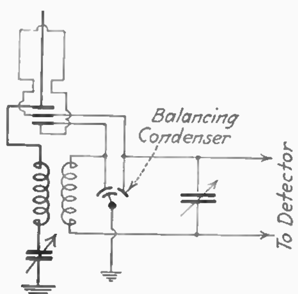


FIG. 52.—Elementary wiring diagram of direction finder.

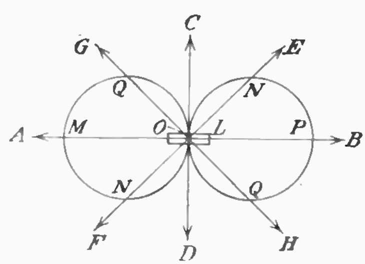


FIG. 53.—Bilateral characteristics.

to a short vertical antenna (10 to 15 feet long). The loop alone has bilateral characteristics as shown in Fig. 53.

Maximum signal intensity *OP* or *OM* is obtained when the plane of the coil *L* lies in the direction of the source of transmission *A* or *B*. If the source is in the direction of *C* or *D* or exactly at right angles to the plane of the coil *L*, then the signal intensity is zero. In all other directions the intensity varies in accordance with the figure-of-eight characteristic in Fig. 53. For example, in directions *OE* or *OF*, *OG* or *OH*, the distances *ON* or *OQ*, respectively, represent the relative signal intensities as compared with the maximum *OM* or *OP*.

The vertical antenna has no directional effect and has a circular characteristic as shown in Fig. 54. If the signal strength is taken as the radius of the circle, it is easily seen that the signal value does not vary with the line of direction from which it is received.

The loop circuit is shown by the light lines in Fig. 52; the heavy lines indicate the antenna circuit.

When the antenna circuit is coupled to the loop circuit, a unilateral characteristic is produced as shown in Fig. 55, heavy lines.

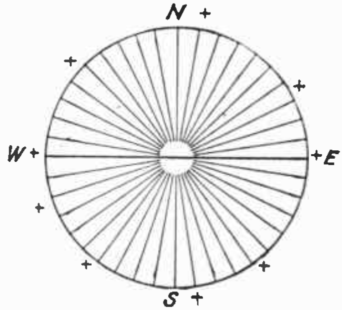


FIG. 54.—Single-wire vertical antenna characteristics.

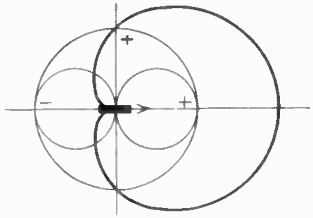


FIG. 55.—Unilateral characteristic.

The results obtained with the loop alone, the vertical antenna alone, and the combination of the two, as shown in Figs. 53, 54, and 55, are separately and collectively the principles underlying the operation of the radio direction finder.

For information on the practical operation of the radio direction finder (radiocompass), see Ques. 199.

Ques. 197. Why is a loop directional in operation?

Ans. If the loop is regarded as an inductance coil cut by a varying magnetic field of a radio wave, it is seen that an e.m.f. is thereby set up in the loop. This is the situation when the wave is traveling in the plane of the loop (see position *A*, Fig. 56).

If the loop is turned so that the plane of the coil is at right angles to the direction in which the wave is traveling, no lines of force cut the coil and no e.m.f. is induced in the coil (see position *B*, Fig. 56).

The direction of the plane of the loop with respect to the oncoming wave effects the amount of e.m.f. induced in the loop, and the loop is said to be directional in operation.

That a loop is directional in operation may also be accounted for as follows: Consider, for the moment, only the two vertical sides of the loop. In this theory, the horizontal wires of the loop have no effect on the induced e.m.f. in the coil. Let us call the wires on one side of the loop *A* and those of the other side *B*. By the fundamental theory of current generation, which says that when a conductor is cut by lines of force an e.m.f. is induced therein, it is understood that a radio wave cutting the wires *A* and *B* will induce an e.m.f. in the wires. If the wave is coming from a direction at right angles to the plane of the coil, the crest of the wave will reach wires *A* and *B* at the same instant and the e.m.fs. induced in both sides of the loop will be in phase. If the wave approaches from any other direction, the induced e.m.fs. will be out of phase, and for a given frequency or wave length the difference will be greatest for a wave approaching in the direction of the plane of the loop.

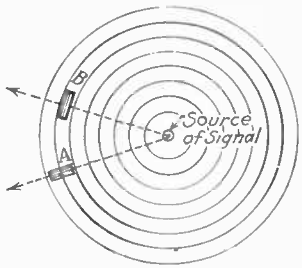


Fig. 56.—Sketch showing loop in two positions relative to oncoming radio wave.

When the e.m.fs. in *A* and *B* are in phase, they neutralize each other and there is no current flow. As these e.m.fs. go out of phase current begins to flow in the loop. This current increases as the loop is turned, due to the difference in phase being increased. When the difference in phase is at a maximum, the e.m.fs. induced in *A* and *B* assist each other most and a maximum current is induced in the loop.

The relation of the phase of the induced e.m.fs. in sides *A* and *B* to the resultant current flow in the loop causes the loop to show directional characteristics.

Ques. 198. What is the *antenna effect* of a loop and what relation has it to the operation of a radiocompass?

Ans. The *antenna effect* of a loop is its tendency to act like a simple antenna. This is due to the loop-to-earth capacity. The result is that it is impossible to get a zero signal with a simple radiocompass circuit, regardless of the position of the loop, unless this effect is eliminated.

It is obvious, therefore, that the accuracy of the radiocompass reading would be affected by the difficulty of finding the *null point* (point of minimum or zero signal) with the *antenna effect* present.

To improve the operation of the radiocompass, therefore, the *antenna effect* must be compensated for. This is done by connecting a balancing condenser across the loop and ground as shown in Fig. 52. This condenser may be adjusted to a point where the *antenna effect* is neutralized and a sharp *null point* obtained.

Ques. 199. How would you proceed to get a bearing on shipboard with a radiocompass from a radiobeacon; from another ship while at sea?

Ans. In order to get a radiocompass bearing from a radiobeacon, proceed as follows:

1. Put receiver into operation by connecting head phones and lighting filaments to proper brilliancy.

2. Throw unidirectional switch to *open* position. On R.C.A. radiocompass type A.G. 1382, this is called the *sense-line* switch. Throw this switch to *line*. This disconnects the radiocompass antenna.

3. Tune the receiver to the transmitting station's signal.

4. Rotate the loop until maximum signal is heard. Adjust *volume* knob for desired volume.

5. Rotate loop about 90 degrees and find the point of minimum signal. Readjust volume control or compensating condenser until a sharp minimum is found. If the loop is now rotated 180 degrees, another point of minimum signal will be found. There are, therefore, two *null points* (minima). One of these points is the bearing of the transmitting station (radiobeacon) with relation to the ship. As the general direction of the beacon is usually known, it is easy to know which of the two bearings (*null points*) is the correct one.

To Determine Exact Direction of Transmitting Station

6. It is obvious that the exact direction of the transmitting station is one of the *null points.* If the general direction of the transmitting station is unknown, which might be the case when taking the bearing of another ship at sea, the unilateral or unidirectional characteristics of the radiocompass must be employed. To do this, throw the unidirectional switch to the *on* position. This connects the small radiocompass antenna to the circuit. On the R.C.A. type A.G. 1382, throw *sense-line* switch to *sense.*

7. Turn the loop to the position of maximum signal, at which point the plane of the loop lies in the direction of the signalling station and points toward it as indicated by an index pointer which has been provided for that purpose.

Ques. 200. How would you get your position from a radiocompass station?

Ans. The general instructions and rules of procedure for obtaining radiocompass bearings are given in Ques. 269, Part VIII.

The actual operating procedure for getting a bearing is as follows:

Example.—A ship (call letters KDWK) desires to get bearings from the New York entrance group (call letters NJY).

The ship operator calls: NJY NJY NJY de KDWK KDWK KDWK QTE?

The radiocompass station answers: KDWK (one to three times) de NJY K.

The ship operator replies: NJY de KDWK MO KDWK MO KDWK MO (call letters KDWK and the special signal, which in this instance is MO, intermingled for about 45 seconds) then KDWK · — · — · K.

The radiocompass station replies: KDWK de NJY QTE Fire Island 156 Manasquan 90 Sandy Hook 30 at 0130 · — · — ·K.

The ship operator repeats the numbers for verification, and mistakes, if any, in reception or transmission may be detected and corrected.

Danger from Reciprocal Bearings.—Attention is invited to the fact that when a single bearing is furnished there is a possibility of an error of approximately 180 degrees, as the operator at the compass station cannot always determine on which side of the station the vessel lies (this is true only of certain stations and should never be true of stations fitted with the unidirectional type of radiocompass). Certain radiocompass stations, particularly those on islands or extended capes, are equipped to furnish two corrected true bearings for any observation. Such bearings when furnished vessels may differ by approximately 180 degrees, and whichever bearing is suitable should be used.

Ques. 201. What two methods of indicating maximum and minimum signal are used in radiocompass installations? Describe the principles on which each operates?

Ans. The two methods are head phones and glow lamp. Head phones indicate through a maximum or minimum sound. The glow lamp is a special type of lamp containing an inert gas. If the current induced into the loop is large enough it may actually be made to ionize the gas medium in the lamp, which will result in a glow. Then, as the loop is rotated to a point where the minimum signal is induced into it, the lamp will not glow. Thus, it will be seen that the lamp will cease to glow between two readings of the sight wires, the mean of which will be the true bearing.

Ques. 202. How are radio compasses protected from possible injury from the ship's transmitter?

Ans. In modern radio compass installations the radio compass equipment is not in use during the period of transmission. When the navigating officer desires to obtain a bearing he notifies the radio operator to disconnect the antenna switch. A switching arrangement is provided with green and red lights. These lights are placed into operation the moment the operator disconnects the antenna. For example in one of the Kolster radio compass installations the green light is on the panel of the compass receiver and the red light in the operators room. Hence, if the green light is not lit on the panel the navigating officer will inform the radio operator to disconnect the antenna switch which immediately lights both the red and green lights. The radio operator must, therefore, cease transmission during the period that his red light is lit.

Ques. 203. Give two distinct types of radio compasses and explain the theory of operation.

Ans. See Ques. 196, 197, 198, and 199.

Two types of compasses in commercial use are the Radio Corporation of America compass Type AG1382 and the Federal Radio compass Type AM4490. The principals of operation of both these types are practically the same with the exception of the receiving systems and indicating methods used.

The R.C.A. compass uses a superhetrodyne receiver and employs the audibility method (telephones) of determining maxima and minima. The Kolster radio compass uses a very sensitive tuned radio-frequency receiver.

The method of determining tho minima and maxima with the Kolsten compass is both audible or visible. In the audible method, the telephones are used as stated before. In the visible method, a glow lamp is so connected that when a maximum signal is being received the lamp glows. Then, as the loop is turned to the minima-signal energy, the glow lamp goes out. Thus, by careful observation, the minima point over the sight wires would be manifested as soon as the light goes out. This method can be satisfactorily used within a radius of 75 miles.

Brief Bibliography

Nilson and Hornung: "Practical Radio Telegraphy," McGraw-Hill Book Company, Inc.

"Principles Underlying Radio Communication"—U. S. Signal Corps, Supt. of Documents, Govt. Printing Office, Washington, D. C.

Morecroft: "Principles of Radio Communication," John Wiley & Sons, Inc.

Keen, R.: "Wireless Direction Finding and Directional Reception," Illiffe & Sons, Ltd., London.

PLATE III.—Weatherproof housing for emergency storage battery installation on shipboard.

PART VI

STORAGE BATTERIES

LEAD-ACID CELL

Ques. 204. What are the active materials and electrolyte of a lead cell?

Ans. Positive plate, peroxide of lead Pbo_2
Negative plate, sponge lead Pb
Electrolyte, dilute solution of sulphuric acid H_2SO_4.

Ques. 205. What two methods are used to determine the voltage of a lead-acid cell?

Ans. Voltmeter and hydrometer. The hydrometer determines the state of charge before and after charging and, therefore, may be used as an indirect-voltage test.

Ques. 206. How would you mix acid with water? At what temperature should batteries be operated? What is meant by a floating charge?

Ans. The acid should always be poured into the water, **never** pour water into the acid.

The proper temperature for charging is at about 70° F. and should never exceed 110° F.

A floating or trickle charge is a slow rate of charge which keeps the battery from sulphating when not in use and thus keeps it in a fairly good condition at all times.

Ques. 207. Describe a hydrometer.

Ans. Figure 57 illustrates a hydrometer used for determining the specific gravity of storage cells.

The hydrometer outfit consists of a glass tube with a rubber tube on one end to insert into the electrolyte and a rubber bulb on the other end with which the acid may be drawn up into the tube. The glass tube contains a small glass float, which is graduated to read the various densities of storage-battery electrolytes. At the bottom of this float a small lead weight or buckshot is placed to make the float read properly. The electrolyte density is indicated on a graduated scale on the tube as shown.

A fully charged cell should bring the scale reading between 1.250 and 1.300.

A discharged cell may read 1.150 or lower.

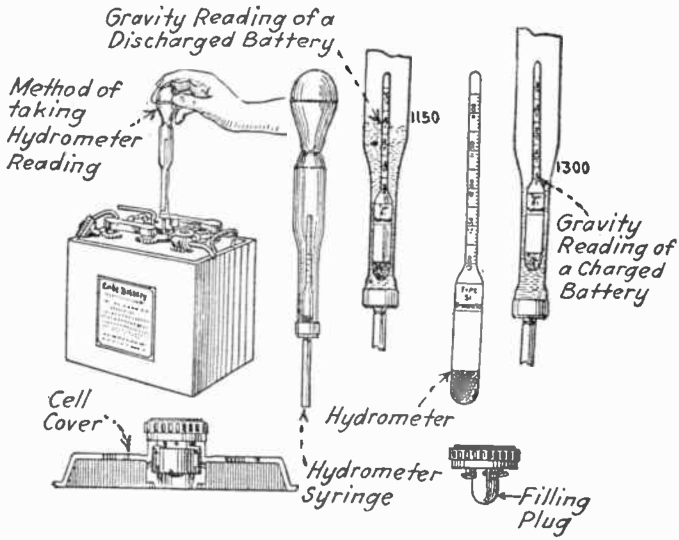


Fig. 57.—Hydrometer.

Ques. 208. What kind of water should be used with storage batteries?

Ans. Chemically pure water free from minerals and acids Water from the city mains may be used if it meets these specifications; otherwise, distilled water *must* be used.

Ques. 209. Without the use of an indicating instrument, how may the operator tell when the batteries are fully charged?

Ans. A set of batteries or a battery is usually fully charged after it has been gassing for from 2 to 4 hours.

Ques. 210. Why is chemically pure water used to replace evaporation?

Ans. Chemically pure water is free from mineral deposits. Impure or mineral waters will prove injurious to the cell, due to the generation of internal "local currents" independent of the regular chemical action of the cell.

Ques. 211. What causes sulphation in a lead cell?

Ans. The chemical action on the plates due to the breaking up of sulphuric-acid molecules (H_2SO_4) which combine with the active materials Pbo_2 and Pb and form $PbSO_4$ or lead sulphate.

This breaking up and forming effect is greatly increased when the battery is discharging and may continue until both plates are totally sulphated and the cell completely discharged.

Some causes of sulphation are as follows:

1. Discharging a cell at a too high rate.
2. Cell leakage due to moist top covers.
3. Allowing the cell to remain idle for a too long period of time.
4. Failure to keep cell on trickle charge when not in use.
5. Extremely rapid sulphation will occur if cells are charged with reversed polarity or alternating current.

Ques. 212. What is the difference between a primary and a secondary cell?

Ans. Primary cells produce electrical energy by chemical action through dissipation of one of the active materials (zinc). When the material is dissolved, the e.m.f. of the cell is decreased and a new element must be inserted. The most common type of primary cell is the well-known dry cell. Secondary or storage cells also produce electrical energy by chemical action but not through dissipation of active materials. In the lead-acid storage cell, an e.m.f. is produced by a combining of the acid with the active materials of the plates during discharge. This forms a layer of lead sulphate over both plates and results in a reduction of both the acid and the active materials and discharge of the cell. If, however, the chemical action is reversed by applying an external e.m.f. in the proper direction, then the sulphation will be driven off both plates and the cell will again be restored to its original condition of charge.

The secondary cell, therefore, differs from the primary cell in that it may be charged by applying an external e.m.f. whenever the cell is discharged.

Ques. 213. Of what advantage is a trickle charge?

Ans. It maintains the specific gravity and voltage fairly constant by preventing current leakage due to moist battery tops. This minimizes sulphation when the battery is not in use. The trickle charge also compensates for internal action in the cells which would in time cause sulphation.

Ques. 213*a*. What is meant by the internal resistance of a cell?

Ans. Internal resistance of a cell is the resistance that a cell offers to a current in the electrolyte or equivalent material which produces a drop in the output voltage. This resistance varies with the following:

1. The area of the plates exposed to the electrolyte.
2. The distance between the plates.
3. Temperature.
4. Strength or density of the electrolyte.
5. Polarization.

The *internal resistance* may, therefore, be defined as the resistance of the volume of the material or electrolyte through which a current must flow in passing from one plate to another inside the cell.

The effect that the internal resistance may have upon the voltage output and, consequently, the current flow can be readily seen if we consider the fact that when a current is flowing through the internal resistance there will be a certain amount of loss or dissipation which will result in a drop of the voltage. This is known as the *internal-resistance drop*, and it is always present when a current is passing through a resistance.

The most common cause for a voltage drop in a cell is the effect of polarization due to the chemical reactions within the cell.

Polarization represents a collection of hydrogen gas on the copper or carbon electrode which tends to offer a large amount of resistance to the flow of current between the plates. It is actually a counter e.m.f. generated by the contact of hydrogen and copper or carbon.

The amount of voltage drop due to the internal resistance can be readily measured by taking voltmeter readings of the cell when under load and then immediately after the circuit is opened. Hence, the amount of internal resistance can also be determined by taking the no-load and the load voltages and current readings and applying Ohm's law as follows:

$$R = \frac{E_1 - E_2}{I} \text{ where } \begin{array}{l} E_1 = \text{the no-load voltage reading} \\ E_2 = \text{the full-load voltage reading} \end{array}$$

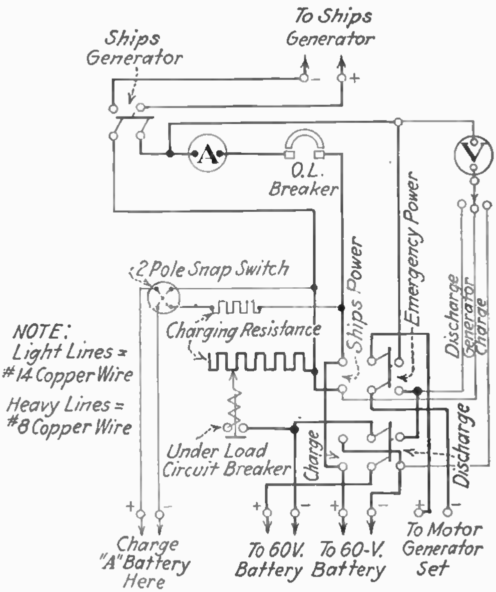


Fig. 58.—Wiring diagram of a modern charging panel, marine type.

Ques. 214. Draw a diagram of a modern radio-battery charging panel such as is designed for shipboard use and which charges the emergency radio-power batteries and the A battery of the receiver.

Ans. Figure 58 is the charging-panel wiring diagram, a photograph of which is shown in Fig. 59.

Ques. 215. What is local action?

Ans. It is the internal chemical action in a cell due to impurities embedded in the active materials or in the electrolyte. These

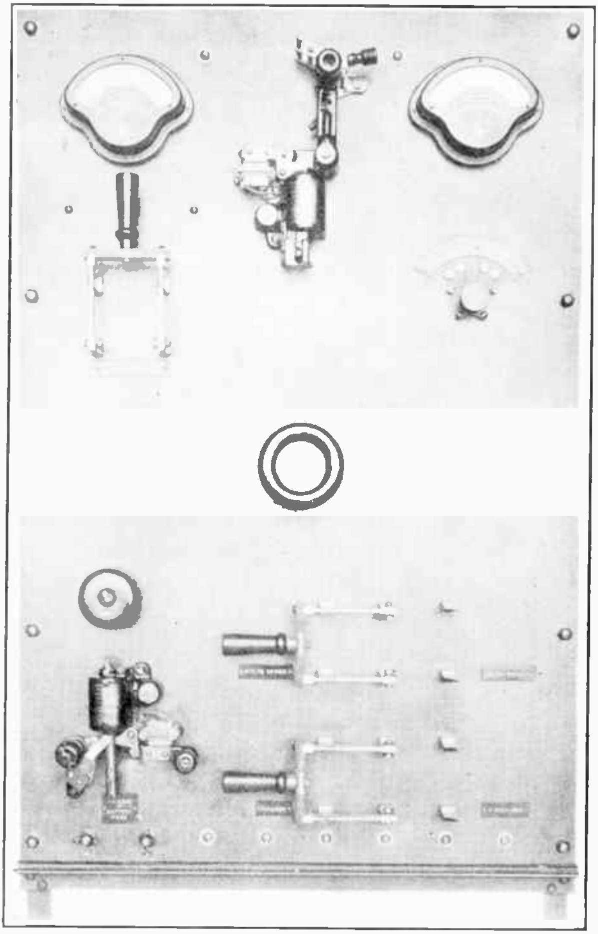


Fig. 59.—Modern charging panel (Ward Leonard) marine type.

impurities generate a local current independent of the normal chemical action of the cell, which will seriously impair the life of the cell if allowed to continue.

Ques. 216. Can alternating current be used for charging storage cells?

Ans. No. Alternating current can be used only if it is rectified by a tube, dry, or chemical rectifier.

Ques. 217. What determines the capacity of a storage cell? What is the unit of capacity of a cell?

Ans. The capacity of a storage cell is determined by the area of the active materials exposed to the electrolyte and the number of plates connected in parallel. The unit of capacity is the ampere-hour. A battery is rated as having so many ampere-hours capacity.

Ques. 218. What may happen if the wrong polarity is secured on the charging line?

Ans. It is obvious that the battery would then be in series with the charging generator instead of being in parallel to it. The net result is that the generator voltage and the battery voltage added together flow in the line and through the battery and the generator. The result might be a reversal of the polarity of the charging generator or, more likely, a ruination of the battery through buckling plates and shedding of active material. The fuses should blow or the circuit breaker open, or both, thus preventing damage in this way. Any resistances or lamps in the circuit might burn out. The meters on the panel would not read properly.

Ques. 219. What is meant by the (*a*) normal charging rate of a storage cell; (*b*) normal discharge rate?

Ans. (*a*) The normal charging rate, as specified by the manufacturer, is the safe amount of current that can flow through a battery when charging without producing too much heat and flooding.

(*b*) The normal discharge rate is the amount of current that can be drawn from a battery without producing too much internal heat and thus preventing damage to the plates.

Ques. 220. What is an underload circuit breaker?

Ans. It consists of a solenoid switch which is connected in series to the lines to be protected. Its position is shown in Fig. 1.

An underload circuit breaker is used on storage-battery charging panels to open the circuit should the voltage of the generator fall below the voltage of the battery being charged. This prevents the battery from discharging back into the generator, thus preventing possible damage to the generator as well as to the battery itself.

Ques. 221. How do you treat a lead-acid storage cell which shows signs of sulphation?

Ans. The entire bank containing the sulphated cell should be subjected to a long, heavy charge. If the sulphation is not serious, this treatment will restore the afflicted cell to normal condition. It is best, if one or more individual cells appear sulphated while the rest of the battery is in good condition, to remove such cells and treat them separately by giving them a charge at a high rate. If the specific gravity of the electrolyte of a cell under treatment for sulphation rises above the normal level, remove some of the electrolyte and replace by pure water until the proper density is secured. Sulphated plates should be handled as little as possible.

Ques. 222. At what temperature does a storage battery work best?

Ans. 70° F., air temperature. The temperature should never exceed 110° F.

Ques. 223. Tell the care necessary to place a lead-acid battery out of service for an indefinite period.

✓ *Ans.* If the battery is to be put out of service for less than a year it should be put into what is called *wet storage.*

This is the method usually applied to radio batteries, provided, of course, they do not require repairs that will necessitate dismantling. To determine this, a careful examination of a specimen cell in the battery is necessary. To place a battery in wet storage it is given an equalizing charge and stored away where it will be free from dust. The level of the electrolyte during the period the battery is in storage must be constantly maintained to about ½ inch above the tops of the plates by the addition of distilled water. During the storage period the battery should be given a charge every 4 months until the cells gas for at least 3 hours. Any cells not gassing should be examined and remedied.

To place a battery in dry storage it is necessary to give the battery a full charge thereby bringing it up to normal condition. Then pour out the electrolyte into a glass container and refill the battery with chemically pure water.

NOTE.—Those interested may obtain a pamphlet from the Electric Storage Battery Company of Philadelphia giving full directions for placing storage cells in storage.

Ques. 224. What precaution should be taken in connection with combining sulphuric acid and water?

Ans. Always pour the acid slowly into the water. Never pour the water into the acid, as to do so occasions a violent chemical action which causes the mixture to boil with injurious violence.

Ques. 225. State fully the care to be given a 60-cell Exide battery equipment such as is used on shipboard.

Ans. A battery equipment, regardless of type, should have careful attention. The electrolyte should be kept about ½ inch above the top of the plates by replacing loss due to evaporation with distilled water. The electrolyte level should never be maintained by replacing acid unless the electrolyte is in some way spilled out. The acid does not evaporate, it being the water in the electrolyte that is so reduced. It is important that the battery be kept fully charged, not only so that it may be ready for immediate use, but also because it is best for the internal condition of the individual cells. The condition of charge of a lead-cell battery may be checked up by taking combined hydrometer and voltmeter readings of the individual cells. If the cells as a whole show comparatively low hydrometer readings, they should be charged. A low-voltage reading indicates the same condition. Radio batteries should be given a check up about once a month. If a cell shows an unnatural condition such as low specific gravity reading and low voltage reading it may indicate sulphation or plate buckling, and it should be cut out of the circuit by disconnecting the lead-strap connectors and jumping the bad cell. As soon as possible the bad cell should be taken out and repaired. The battery should be promptly recharged when the voltage of the individual cell reaches 1.7 volts, therefore the voltage of the entire bank would read 1.7 × number of cells. A battery should not be charged more frequently than once a week unless the service requires it. The few simple rules listed below apply to all cells.

a. Keep open flames away from the battery at all times.
b. Replace spilled electrolyte before charging.
c. When water in cell evaporates add distilled or pure water.
d. Never allow cells to remain in discharged condition.
e. Mix electrolyte in clean earthen or glass jars.
f. Allow solution to cool before putting into cell.
g. Never pour water into sulphuric acid.
h. Never allow salt to get into cell.
i. Use only absolutely pure chemicals and water.
j. Always provide plenty of ventilation.
k. If burned by sulphuric acid apply ammonium hydroxide or baking soda.
l. Don't charge at a too high rate.
m. Don't discharge at a too high rate.
n. When not in use, keep on trickle charge.
o. Take frequent voltage readings.
p. Take occasional hydrometer readings.
q. Keep the level of the electrolyte about ½ inch above the plates by adding chemically pure water.
r. Give an overcharge about once a month.
s. Keep the tops of each battery dry to prevent current leakage.
t. Keep all electrical connections free from corrosion by applying a very thin layer of vaseline after the connection has been made.
u. Do not add acid unless some has been lost due to spilling or flooding, and not even then unless the specific gravity reading does not come up to normal after charging.

Oversulphation may be caused by

1. Wrong specific gravity of electrolyte.
2. Overdischarge.
3. Allowing cell to remain too long in a discharged condition.

Ques. 226. What is the usual voltage and ampere-hour capacity of a commercial (ship) battery installation?

Ans.

	Voltage	Capacity, ampere-hours
Edison cell.....	150	250
Lead cell.......	120	140 to 240

Ques. 227. How would you adjust a charging current giving a too high charging rate to a lower charging rate?

Ans. By inserting an additional resistance in series with the main charging resistance. In commercial installations, the additional resistance is usually provided and is connected in the circuit by opening the short-circuiting switch. This is known as a *trickle-charge resistance.*

Ques. 228. If a charging resistance has burned out, what device may be substituted?

Ans. A bank of lamps connected in parallel and then placed in series with the charging line. Thus, by cutting in or out lamps, the proper amount of charging current may be caused to flow in the circuit.

Ques. 229. If a voltmeter is not at hand, how may the polarity of the charging line be determined?

Ans. If a suitable instrument is not at hand, the positive and negative sides of the line may be determined on circuits of 110 volts or less, by dipping the ends of the two wires in a glass of water in which a very small amount of common table salt, potash, or acid electrolyte has been dissolved. Keep the wires about 1 inch apart. When there is current flowing, gas bubbles will form on both wires, but the wire where the greatest amount of gas bubbles are being formed will be the negative side of the circuit.

Another method to determine the polarity of the line is to place the two wires about 1/4 inch apart on a wet piece of blue litmus paper. Where the positive wire touches the wet paper, a red mark will appear if current is flowing.

Ques. 230. How may the state of charge of a lead cell be determined?

Ans. There are three methods of testing a lead cell for state of charge or discharge, namely, by observing the reading of the ampere-hour meter, by a hydrometer test, or by a voltmeter test under load. The first two tests are the most desirable, although the last one will tell much to the experienced operator.

Ques. 231. Why must a 120-volt bank of storage batteries be connected into two 60-volt sections in parallel for charging?

Ans. Because the charging voltage of the ship's generator would not be sufficient to overcome the resistance of all the cells in series.

The charging voltage necessary per cell is always higher than the discharge voltage per cell. For example, the full charge voltage of a lead cell is 2.1 volts; the voltage necessary to reverse the chemical action in the cell when it is put on charge is 2.5 volts. For an Edison cell the full charge voltage is 1.2 volts; the charging voltage 1.85.

On the standard shipboard installation of emergency batteries, there are usually enough cells to give a discharge voltage of 120 volts (approximately 60 cells). If the discharge voltage of the batteries is 120 volts, the charging voltage would need to be more, at least 150 volts. No ships have a lighting circuit supplying 150 volts. It is necessary, therefore, to divide the 120-volt bank of batteries into two units, usually labelled *A* and *B*, each of which will have 60 volts discharge. These units *A* and *B* may be connected in parallel for charging or in series for discharging by a four-pole double-throw switch as shown in the diagram (Fig. 1). When connected in parallel, the voltage of banks thus connected will be 60 volts, no-load reading. To charge these banks connected as they are, in parallel, will require only about 75 volts. The ship's lighting circuit is usually kept to about 100 volts, and, therefore, charging resistances must be introduced to reduce the voltage fed to the battery banks. Variable as well as fixed resistances are sometimes provided so that the actual charging voltage may be regulated and the charge tapered off as it nears completion.

Furthermore, if the battery voltage should become higher than the charging voltage, due to a possible drop in line voltage, the batteries would discharge through the line and completely discharge and possibly ruin themselves. This is obviated by connecting the batteries in parallel as here described.

In studying this question, reference should be made to the charging panel in Fig. 1.

Ques. 232. Name, describe, and give the function of an ampere-hour meter.

Ans. A common type of ampere-hour meter used with storage-battery equipments is the Sangamo ampere-hour meter. Its function is to indicate the state of charge and discharge of the batteries. It is mounted in a square case and has a circular dial face on which the ampere-hour units are marked. The dial moves clockwise during discharge and counterclockwise during charge. A special contact is provided so that when the batteries are fully charged a contact trips the circuit breaker and opens the charging circuit.

The mechanism of the meter consists of a mercury-type motor consisting of a copper disc floating in mercury and a small field-coil winding which is stationary. By connecting a revolution counter to this motor, a means is provided for recording the total quantity of energy that has passed.

Ques. 233. How should a lead-storage battery be charged? Assume the capacity to be 100 ampere-hours. Discuss care of storage battery.

Ans. A lead-storage battery must be charged with a pure direct current or a rectified alternating current with the proper polarity (positive) connected to the positive terminal of the battery. In addition to this, there must be inserted a resistance in series with the charging line of the proper value to allow the specified number of amperes to flow (usually specified by the maker) and which is dependent upon the ampere-hour capacity of the battery.

A 100-ampere-hour storage battery should charge at approximately 5 amperes at the full charging rate and approximately 1 ampere at the trickle or floating-charge rate.

If the charging voltage is 110 volts and the battery voltage 6 volts, then to charge the battery at the 5-ampere rate the value of the charging resistance to produce this rate can be determined by the formula

$$R = \frac{E - e}{I}$$

where

E = the line voltage (110 volts)
e = the countervoltage of the cell (6 volts)
I = the proper charging rate (5 amperes)

Thus, if the charging voltage is 110 volts and the battery countervoltage is 6 volts, the effective voltage will be 104 volts. Then, by dividing the desired current 5 into the effective voltage 104, the proper resistance value will be found to be 20.8 ohms.

This resistance may be either a fixed unit specially designed for carrying 5 amperes or a bank of lamps sufficient in number to pass 5 amperes, connected in parallel and the bank then connected in series with one side of the charging line.

An additional resistance may be connected in series with the 20.8-ohm unit until the desired trickle or floating-charge rate is obtained. If this rate is to be 1 ampere, the additional resistance should be approximately 80 ohms. At the 5-ampere rate, the battery should remain on charge until approximately 100 amperes have passed through it, which is about 20 hours. Of course, this depends upon the condition of the battery when put on charge.

When fully charged, the voltage of each cell should read 2.1 volts, and the hydrometer specific gravity between 1.250 and 1.275.

Some of the more important rules for keeping a storage battery in good condition are given under Ques. 225.

Ques. 234. What are the charged, charging, and discharged voltages of a lead cell; of an Edison cell?

Ans.

SUMMARY OF DATA ON LEAD AND EDISON CELLS

		Edison cell	Lead cell
Voltage	Charged	1.20	2.10
	Discharged	0.9	1.75
Specific gravity	Charged	1.200	1.270
	Discharged	1.160	1.150
Charging voltage per cell	....	1.85	2.5

EDISON CELL

Ques. 235. What effect will charging an Edison cell have on the electrolyte?

Ans. No effect, beyond losing by electrolysis some water which is replaced by distilled or chemically pure water. It is not necessary to take specific-gravity readings during charge or at any time to determine the extent of charge or discharge, as the electrolyte does not change appreciably with the state of charge or discharge of the battery.

Ques. 236. Of what material are the positive and negative plates of the Edison cell made?

Ans. The material in the positive plate consists of alternate layers of nickel hydroxide and exceedingly thin flakes of pure nickel.

The negative-plate material is powdered iron oxide and metallic iron with a small percentage of mercury added to increase conductivity.

Ques. 237. Of what is the electrolyte of the Edison cell composed?

Ans. The electrolyte consists of a 21 per cent solution of potassium hydrate in distilled water with a small percentage of lithium hydrate having a specific gravity averaging 1.200. The electrolyte does not vary in density during charge and discharge. The Edison electrolyte preserves the steel plates.

Unlike the lead-acid battery, the active materials are not attacked or eaten away by the electrolyte.

Ques. 238. What would be the effect of charging an Edison cell in the wrong direction? What would be the effect on a lead cell?

Ans. There would be no damage done to the Edison cell if the temperature did not rise above 115° F. The only effect would be that the cell would act as an electrolytic gas generator accumulating only a very slight charge in the reverse direction.

If a lead cell were to be charged in the reverse direction, a severe buckling of the plates, loosening of active material, and complete disruption of internal cell parts occur. The meters on the board would indicate trouble by reading backward. In all modern battery equipments, a circuit breaker, or fuses in small installations, is connected in the circuit which protects against such things as charging in the reverse direction.

Ques. 239. Explain construction of an Edison cell.

Ans. The following brief explanation of the Edison cell may be better understood by referring to Fig. 60:

Positive Plate.—The positive plate consists of heavily nickel-plated perforated steel tubes arranged in rows and filled with narrow layers of nickel hydroxide and exceedingly thin flakes of pure nickel.

Negative Plate.—The negative plate consists of a grid of nickel-plated cold-rolled steel holding a number of rectangular perforated pockets filled with powdered iron oxide and metallic iron.

Assembly.—The plates are separated by narrow pins of specially treated hard rubber which is not injured by electrolyte. The end insulator is provided with grooves that take the edge of the plates, spacing and insulating them from the steel container.

Electrolyte.—The composition of the electrolyte is explained under Ques. 237.

Ques. 240. Can the state of charge of an Edison cell be determined by means of a hydrometer?

Ans. No.

Ques. 241. What instrument should be used to determine the amount of charge of an Edison cell? Why?

Ans. The voltmeter. Because the voltage of the Edison cell is the only measurable difference between the condition of the cell when it is fully charged and when it is discharged. A hydrometer should never be used because the specific gravity of the electrolyte does not vary with the degree of charge.

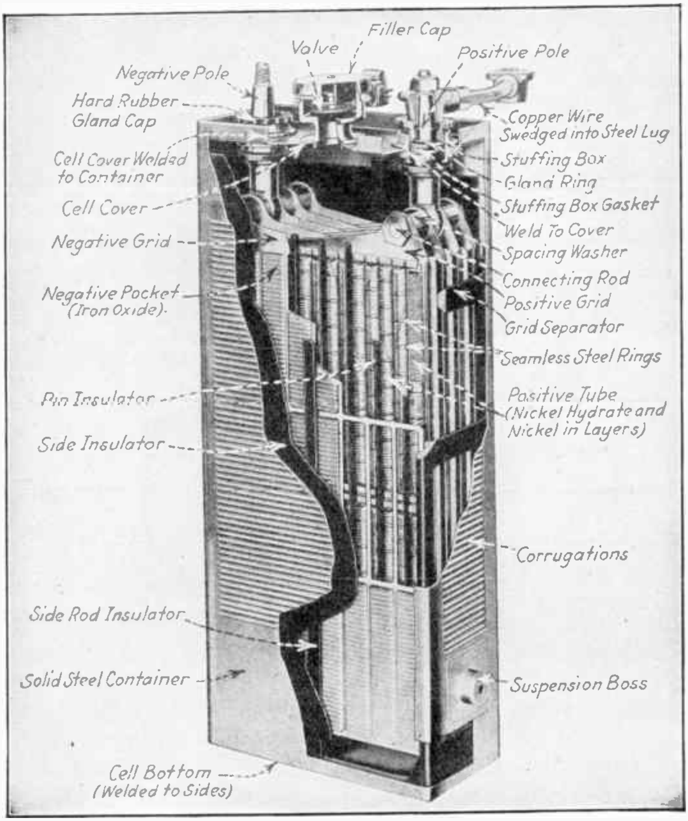


FIG. 60.—Cross-sectional view of the Edison cell.

Ques. 242. How may the proper length of charge of an Edison cell be determined?

Ans. The proper length of charge may be determined by the amount of the previous discharge, preferably by the use of an ampere-hour meter set for between 15 and 25 per cent excess charge, depending on service conditions, or by simply charging until a maximum cell or battery voltage has been reached and maintained for at least 15 minutes. This maximum-voltage value will vary between about 1.80 and 1.90 volts per cell, depending on the temperature, etc., but this is of no consequence because the idea is to reach and reasonably maintain any maximum voltage.

Ques. 243. Is there any action in the electrolyte of an Edison cell?

Ans. There is a chemical action during charge and discharge which does not change the specific gravity of the electrolyte. A hydrometer reading is, therefore, of no value. A complicated chemical reaction resulting in the oxidization and deoxidization, during charge and discharge, of the active materials takes place. (See Ques. 244.) Throughout the total useful life of the cell (which may number many years), the electrolyte gradually weakens and may need renewal from one to two times, depending on the severity of the service. In cases where maintenance and operation have been poor, or where impure water has been used, a third renewal may be necessary.

The low-limit specific gravity beyond which it is inadvisable to run an electrolyte is 1.160. The normal specific gravity is 1.200. The readings indicated above are at 60° F.

Ques. 244. Explain the essential difference between an Edison and a lead-plate storage cell.

Ans. The essential difference between the Edison and lead-plate storage cells is in their chemical and mechanical structure.

The **lead-plate cell** consists of perforated plates of lead antimony into which is compressed the active material ingredients in the form of a paste. The positive plate when formed is reddish-brown in color and is chemically known as peroxide of lead (PbO_2).

The negative plate is grey in color, and the active material is chemically known as sponge lead (Pb). These plates are put into a 16 per cent dilute solution of sulphuric acid (H_2SO_4) and chemically pure water (H_2O). The specific gravity of the acid when diluted should be in the vicinity of 1.300.

The full-charge voltage of the lead cell is 2.1 volts. The discharge voltage is 1.75.

During the period of discharge, the active materials of both positive and negative plates in the cell combine chemically with the acid due to a disintegration of the atomic structure resulting in the formation of lead sulphate ($PbSO_4$). As the rate of sulphation increases, the discharge voltage decreases to an ineffective value (1.75). The cell must then be charged by passing a current through it to reverse the chemical action of the cell, *i.e.*, to drive off the sulphation from the positive and negative plates—chemically, to break up the $PbSO_4$ into its original state before discharge PbO_2, Pb, and H_2SO_4.

The **Edison cell** consists of steel grids into which are placed the active materials.

The positive plate consists of nickel-plated, cold-rolled-steel perforated tubes into which is placed the active material of alternate layers of flaked nickel and nickel hydrate.

The negative plate consists of nickel-plated pockets or squares into which is placed the active material of iron oxide and metallic iron.

The electrolyte is an alkaline 21 per cent solution of potassium hydroxide (caustic potash) with a very small percentage of lithium hydrate and chemically pure water. The density of the electrolyte is 1.200 (this specific-gravity reading remains practically constant during charge or discharge).

The full-charge voltage of the Edison cell is 1.8 volts. This drops to 1.2 volts as soon as discharge under load commences.

The discharge voltage is 0.9 volts per cell. During the period of charge in this type of cell, the negative plate of iron oxide is reduced to a lower state of oxide and the positive plate of nickel hydrate and flaked nickel is brought up to a high state of oxide.

During discharge, the high oxide on the nickel plate is decreased, and the low state of oxide on the negative plate is increased. The chemical action of this cell is, therefore, merely an oxidization and deoxidization of the positive plate during charge and discharge.

Ques. 245. How would you prepare the electrolyte of a dried lead cell?

Ans. The proper method of preparing an electrolyte for a lead storage cell is to mix the acid and the water in a porcelain or glass dish until the specific gravity reading is 1.300. Chemically pure sulphuric acid and distilled water must be used.

Ques. 246. In the event that the case of a storage battery developed a leak, what would you do in order to obtain service from the remaining batteries?

Ans. It would be advisable in this case to disconnect the leaky battery from the circuit. If at all possible, a temporary repair might be effected by greasing the leaky section with paraffin or vaseline.

Ques. 247. What chemical neutralizes the effects of sulphuric acid?

Ans. Ammonia or sodium bicarbonate.

Brief Bibliography

NILSON and HORNUNG: "Practical Radio Telegraphy," McGraw-Hill Book Company, Inc.

VINAL, G. W.: "Storage Batteries," John Wiley & Sons, Inc.

Pamphlets published by the Electric Storage Battery Company, Philadelphia, Pa.

Pamphlets published by the Edison Storage Battery Company, Orange, N. J.

JANSKY and WOOD: "Elements of Storage Batteries," McGraw-Hill Book Company, Inc.

PART VII

MOTORS AND GENERATORS

Ques. 248. What is the no-field release magnet; the no-voltage release magnet; where are they placed?

Ans. The NO-FIELD RELEASE MAGNET is found on the 3-point starting box and it is connected as shown in Fig. 61*a*. It is a small electromagnet and is placed in such a position that when, under normal conditions, the arm of the starter is in full-running position, it is held in that position by the magnetic attraction of the no-field release magnet. The winding of the no-field release magnet is connected in series with the field of the motor. If, therefore, the motor field becomes weak, ceases to exist, or becomes open circuited, the starting-box arm flies back to the *off* position. This action safeguards the machine because if the field weakened, or ceased to exist, excessive sparking would take place at the commutator and the armature would draw a heavier current, both of which are detrimental to the motor. If the field circuit were opened and the arm remained in full-running position, and the circuit was suddenly closed again, after the motor had stopped, the sudden inrush of current to the armature would burn it out because there would be no counter e.m.f. generated to buck the incoming current and hold it to safe limits. The same action would result if the line switch or circuit breaker were opened, fuses blown, or the line otherwise opened.

It is readily seen, therefore, that the no-field release magnet operates also as a no-voltage release magnet and it is sometimes referred to as such.

The NO-VOLTAGE RELEASE MAGNET is found on 4-point starting boxes and is connected as shown in Fig. 61*b*. This magnet is connected directly across the line and consequently has a resistance unit in series with it as shown in the diagram.

The no-voltage or no-field release magnet serves to hold over the starting arm when everything is in perfect working order. Should the line voltage, however, be reduced 90 per cent or cut off entirely, the no-voltage release magnet releases its hold on the starting arm and all current is cut off from the motor.

Most 3-point starting boxes found in commercial practice are manufactured by the Cutler-Hammer Mfg. Co., while most 4-point boxes are made by the General Electric Co.

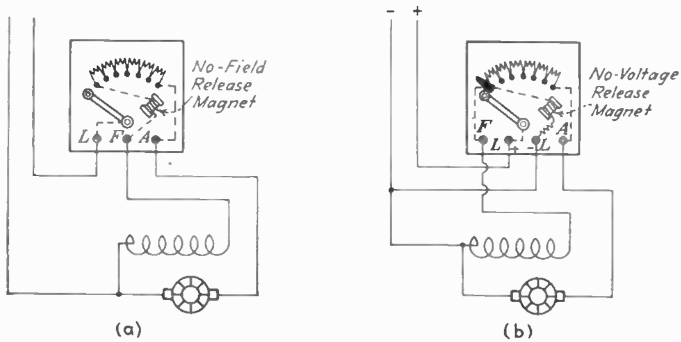


FIG. 61.

Cutler-Hammer starting box equipped with a no-field release magnet.

General Electric starting box equipped with a no-voltage release magnet.

Ques. 249. What will cause a motor and also a generator to overheat?

Ans. Overheating of a motor or generator is usually due to overloading the machine. The remedy is to reduce the load. Overheating is sometimes due to a hot bearing (see Ques. 257).

Ques. 250. Why are series motors not used in radio installations for driving the generator?

Ans. Series motors are used only in installations where a quick-starting torque is necessary and a minimum of load. When a heavy load is applied to a series-wound motor, the motor speed decreases and, consequently, reduces the counter e.m.f., thus preventing the motor from running at a normal speed. Series motors are, therefore, not used, because they do not maintain a constant speed when under a varying load such as is produced when the key is pressed and released in a transmitter.

Ques. 251. Of what use are the resistances in a motor starter, and do they function permanently or temporarily?

Ans. Motor-starter resistances are necessary with machines above ½ horsepower to allow the current to flow into the armature gradually so that the counter e.m.f. may build up and thus prevent a short circuit of the direct-current line. The resistances function temporarily.

Ques. 252. Has an increase of voltage an effect on alternating-current frequency?

Ans. If the voltage is increased by decreasing the generator-field resistance, no frequency change will result. If, however, the voltage is increased by an increase of the generator speed (increasing the motor-field resistance), then the frequency will increase. If the frequency is to be maintained steadily, then no adjustments should be made on the motor-field rheostat. (Also see Ques. 117.)

Ques. 253. How can the speed of a motor be increased or decreased?

Ans. The speed of a motor can be increased by increasing the resistance in the field circuit by increasing the resistance of the motor-field rheostat. The speed may be decreased, likewise, by decreasing the motor-field resistance. If it is desirable to decrease the speed below normal, all of the motor-field resistance must be taken out and an additional resistance inserted in series with the direct-current feed line.

Ques. 254. Is emery paper a good material with which to clean a commutator? Why? What would you use?

Ans. No. Emery paper contains small metallic dust which would short-circuit the commutator segments. Use very fine sandpaper.

Ques. 255. How are the fields of a generator generally excited?

Ans. In radio practice, the fields of the alternating-current generator or alternator are usually separately excited, as shown in Fig. 62, by connecting the field directly in parallel to an external source of direct current.

Ques. 256. Draw a circuit diagram of an automatic starter such as is used on modern radio installations.

Ans. See Fig. 1.

Ques. 257. How should a hot bearing of a motor generator be treated?

Ans. A hot bearing always appears when the machine is running, and, therefore, quick action is necessary to prevent damage to the bearings. In the case of a very hot bearing, **do not stop the machine** but slow it down to its slowest speed. If the machine is stopped, the sudden cooling of the bearings will cause them to contract, and they may "freeze" together; that is, the armature shaft or movable bearing may by its expansion fit so tightly into the bell or frame bearings that it cannot be revolved nor the units separated without considerable difficulty and the danger of permanently injuring the bearings.

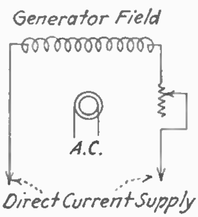


FIG. 62.—Separately excited generator field.

A satisfactory method of treating a hot bearing is immediately to slow down the machine and liberally apply graphite and machine oil to the hot bearings. Everything possible should be done to cool the machine. A towel soaked in ice water, wrung out, and applied to the bearing has been effectively used. A blower or fan may be directed against the hot bearing to cool the surrounding air. Doors or vents leading to the open air should be opened to help cool the machine.

When the bearing is cool again, it may be treated by removing the oil and graphite and flushing with kerosene. The machine is, of course, kept running slowly. After the bearing has been flushed, a good grade of lubricating oil should be poured into the bearing for operation. The hot bearing has then been effectively treated, and the machine may be either stopped or again put into operation.

If the hot bearing again occurs, the machine should be dismantled and the bearings carefully inspected for the trouble. It might be necessary to turn the shaft down slightly in a lathe.

It is only the motor generators having Babbitt-metal bearings which are likely to get hot. Machines equipped with ball bearings rarely give trouble in this way, provided they are regularly greased.

Ques. 258. How is the voltage of a generator increased?

√ *Ans.* The voltage of a generator may be increased by increasing the field excitation. This may be done by decreasing the resistance of the field rheostat which controls the current flowing into the generator field. A.-C. voltage may also be increased by increasing the speed of the generator, but as this will increase the generator frequency, it is not desirable. If desirable, D.-C. voltage may be increased by increasing the speed of the generator.

Ques. 259. Explain fully no-load and full-load voltage.

Ans. **No-load voltage** is the pressure generated when the machine has no external load. In radio transmitters, this is the condition when the key is not closed. This value is the one given as the rated voltage of the machine; for example, a 110-volt generator gives 110 volts on no load.

Full-load voltage is the resultant pressure when the machine is connected to an external load. When a load is placed on the machine, the voltage drops to a lower figure, depending upon the load value. This is illustrated when the key to a transmitting set is closed and the voltage of the generator immediately drops to a lower value depending upon the power being used.

Ques. 260. An alternator has 24 poles and a speed of 3,600 r.p.m. What is the frequency?

Ans. The frequency of the generator may be found by multiplying the number of pairs of poles by the revolutions per second. In this case, if there are 24 poles, there are 12 pairs of poles. If the speed is 3,600 r.p.m., the speed per second would be one sixtieth of that or 60 r.p.s. The frequency, therefore, is pairs of poles multiplied by speed which may be expressed $p \times s = 12 \times 60 = 720$ or Ans.: 720 cycles.

Ques. 261. What is the difference between an alternating-current generator and a direct-current motor?

√ *Ans.* A motor is a machine for converting electrical energy into mechanical energy.

A generator is a device for converting mechanical energy into electrical energy.

An alternating-current generator may be provided with slip rings for the collection of alternating current generated in its armature, and a direct-current motor must always have a commutator for maintaining the armature polarity constant with respect to the motor field.

Ques. 262. If a generator field burned out, what would be the effect?

Ans. Practically no e.m.f. would be generated. A slight amount might, however, still be available due to the residual magnetism in the iron core of the field coils.

Ques. 263. Suppose that your circuit breaker tripped and fuses blew on starting, where would you look for the trouble? Why?

Ans. If the armature does not begin to turn over, the trouble may probably be found in the motor-field rheostat or motor-field winding in the form of an "open." This would cause the circuit breaker to trip, due to the lack of counter e.m.f. when the motor is not in motion. Another possibility, in automatic starting devices, such as a rapidly rising plunger bar would cut out the starting resistances too rapidly and, therefore, prevent the counter e.m.f. from building up, resulting in an abnormal rush of current through the motor armature. If a hand starter is used, pulling the handle over too quickly may cause the breaker to trip and the fuses to blow.

Ques. 264. For what purposes are circuit breakers and fuses used?

Ans. Circuit breakers and fuses are used for the protection of transmitting equipment against heavy overloads due to excessive current flow. This type of protective device is known as an *overload* circuit breaker and is usually inserted in the motor-armature and generator circuits.

Another type of circuit breaker is used in battery-charging circuits for protection against the accidental discharge of the batteries through the ship's generator should the charging voltage drop below that of the batteries. This type of breaker is known as an *underload* circuit breaker.

Ques. 265. What is counter e.m.f. in a motor?

Ans. When a motor armature is set into motion by the distorting effect of the magnetic fields in the armature and field coils as the current is forced through the windings by the applied e.m.f., the armature coils, cutting through the magnetic field, generate a reverse e.m.f. counter to that which set the motor in motion. This back pressure is called the *counter e.m.f.* due to self-induction and directly governs the speed of the motor. For example, if the counter e.m.f. is decreased by weakening the motor field (by inserting a variable resistance in the motor-field circuit), the speed of the motor will increase up to a certain point at which the armature current will draw excessive current and burn out.

Ques. 266. Draw a wiring diagram of a shunt motor using a starting box. Indicate a speed-regulating device in the circuit.

Ans. The diagram (Fig. 64) illustrates a shunt-wound motor with a field rheostat for regulating the speed. Increasing the resistance in the motor-field circuit increases the speed of the motor; decreasing the resistance decreases the speed.

Ques. 267. How could a motor revolving in a counterclockwise direction be made to revolve clockwise?

Ans. By reversing either the armature or field leads, not both. Reversing D.-C. polarity does not reverse direction of rotation.

Ques. 268. How would you decrease the speed of a motor below normal?

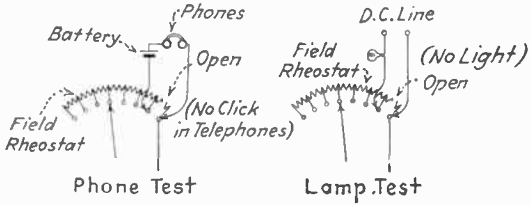
Ans. By inserting a resistance in series with the feed line.

Ques. 269. How would you locate an open in a field rheostat?

Ans. A pair of telephones connected in series with a battery can be connected across the various resistance contacts. If no click is heard, it will indicate an open (Fig. 63*a*).

Another method is illustrated in Fig. 63*b*.

If the lamp does not light, the resistance is open.



(*a*) (*b*)

FIG. 63.—Methods of testing a field rheostat.

Ques. 270. Name three types of motor windings. Explain advantage and disadvantage of each. Draw a diagram of each.

Ans. See Fig. 64.

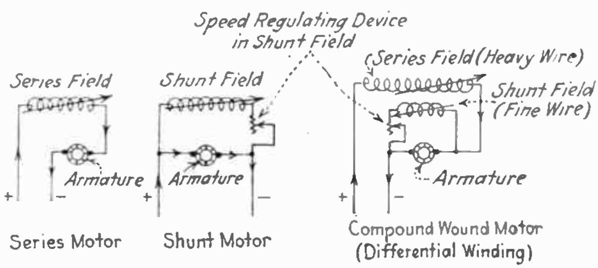


FIG. 64.—Wiring diagrams of series-, shunt-, and compound-wound motors.

Winding	Advantage	Disadvantage
Series	High speed and quick starting	Does not maintain a constant speed when under load
Shunt	Fairly constant speed under load	Slow starting under load
Compound	Self-regulating fields when under load, therefore, very steady speed when overloaded or when subject to varying loads	None (May cost more than others)

Ques. 271. Give the function of the commutator of the direct-current motor.

Ans. The function of the commutator of the direct-current motor is to maintain proper direction of armature current under each field pole. As the various armature conductors pass from one pole to the next, the direction of current flow is thus automatically changed, resulting in a constant turning effort (torque) in one direction.

On a generator the commutator rectifies the induced e.m.f. in the armature conductors and conveys the e.m.f. to outside conductors in one direction only.

Ques. 272. What is the effect of starting a motor too suddenly or too slowly?

Ans. Starting a motor too quickly will cause the breakers to trip or the fuses to blow. This is due to the low resistance of the armature circuit and lack of counter e.m.f. before it comes up to speed. If there were no fuses or breakers in the line the armature winding would burn out.

Starting a motor too slowly may burn out the resistance units in the starting box, as they are made for temporary duty only and cannot stand a heavy current flow for more than a very short period.

Ques. 273. Why are collector rings used on an alternator?

Ans. The function of the collector rings is to conduct the alternating e.m.f. induced in the armature coils to outside conductors.

Ques. 274. Suppose that, on starting your motor, the fuses blow and after replacing the fuses, when the handle is moved to the first contact, a severe flash occurs on the resistance contact when the handle is moved to off position, what is the trouble?

Ans. An open in the motor-field circuit. This is usually found in the motor-field rheostat.

Ques. 275. What causes sparking at the motor commutator?

Ans. 1. Brushes out of position of neutral field.
2. Dirty commutator.
3. Grooved commutator.
4. Open armature coil.
5. Running the motor at a too high speed.
6. Raised insulating wedge.
7. Improperly fitting brushes.
8. Short-circuited armature coil.

Ques. 276. Why are motor generators used in radiotelegraphy?

Ans. Motor generators are used to generate an alternating current for the operation of high-potential transformers. Motor-generator systems, furthermore, are capable of producing variable frequencies and when applied to the transformer and oscillatory system will produce group frequencies of 500 to 1,000 cycles or more. These spark or modulated frequencies are easier to read through atmospherical and other low-frequency disturbances.

On shipboard, direct current only is available from the ship's generator. A motor generator is provided, therefore, to supply alternating current for the operation of the radio transmitter.

Ques. 277. What is a water rheostat?

Ans. A water rheostat consists of a container, made of insulating material such as wood or fiber, filled with salt water

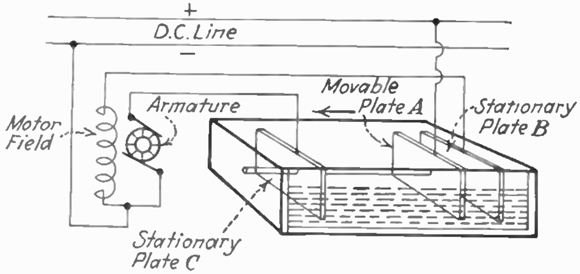


Fig. 65.—Water rheostat.

into which are placed three plates. This arrangement is placed in the circuit as shown in Fig. 65, and the resistance varied by making the distance between the plates greater or smaller, respectively, for high or low resistance. As an example, if such a rheostat is used in place of the starting box in a shunt-motor circuit, the plates are first put in such a position that the plate *A* is nearest plate *B*. In this position the resistance in the field circuit is at a minimum and allows a strong current to flow in the field while the conditions in the armature circuit are the reverse.

Plate *A* is at a maximum distance from plate *C*, and a maximum-resistance value is in the armature circuit allowing only a small current to flow which is desirable when starting a motor. The movable plate *A* is then moved in the direction of the arrow toward *C* and the resistance in the field circuit is increased, decreasing the field current, while the resistance in the armature circuit is decreased, increasing the armature current as the plate *A* approaches plate *C* and as the motor gains speed.

A water rheostat may be used in an emergency when other rheostats are burned out or are out of order. This type of rheostat is also used in electrical laboratories.

Ques. 278. Give a diagram and explain the operation of a generator.

Ans. Figures 66 *a* and *b* illustrate elementary diagrams of alternating-current generators with field regulating device.

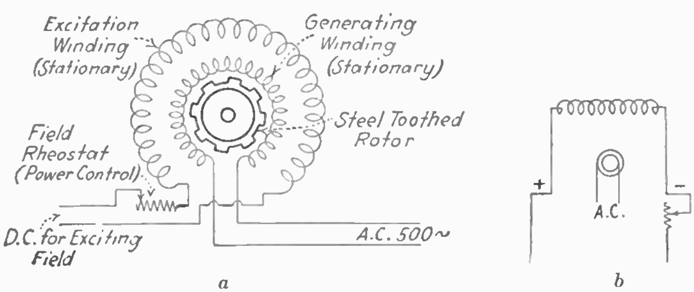


FIG. 66.—Elementary wiring diagram of alternating-current generators. *A*. Inductor type. *B*. Slip ring type.

There are three types of alternating-current generators, rotating field, rotating armature, and inductor. The latter type is the most extensively used and will, therefore, be explained. This type of alternator (marked *A*) consists of a steel-toothed rotor, generator winding, and exciter winding. When the steel rotor is revolving in the excited field, the magnetic path through the rotor is constantly varied due to the steel-toothed projections with respect to the field poles. If, therefore, the magnetic field is constantly varying and an additional winding is placed in the magnetic path, an e.m.f. will be induced due to the cutting effect of the moving fields upon the conductor. In accordance with the law of induction, the direction of an e.m.f. induced is dependent upon the direction of cutting. For example, if the magnetic field is expanding and a conductor is placed into it, then an e.m.f. will be induced in a certain direction. If, now, the magnetic field is contracting, then the induced e.m.f. will be in the opposite direction. Thus, if the field is constantly expanding and contracting, an alternating e.m.f. will be induced into the conductor. The value of the e.m.f. induced will depend upon the strength of the exciter field and upon the rate of cutting. The stronger the field and the greater the rate of cutting (speed of rotor or armature) the greater will be the induced or generated e.m.f. The frequency in cycles per second will be dependent upon the speed of the rotor and the number of field poles in the generator winding.

Ques. 279. Give the main difference between an alternating-current and a direct-current generator.

Ans. The direct-current generator can always be distinguished by the commutator on the generator unit. The commutator in a direct-current generator functions as a rectifier, thereby preventing current reversals in the armature and field and resulting in an evenly varying output current in one direction only and not of changing polarity.

The alternating-current generator produces an alternating current or one that changes its polarity periodically. There are two important types of alternating-current generators, the collector or slip-ring type and the inductor type (see Fig. 66).

Ques. 280. If on commencing to start a motor the armature refused to turn over and a heavy flash occurred at the starter contact, what might the trouble be?

Ans. The trouble is probably due to an open field circuit or to trouble with the bearings. No attempt should be made to hold over the starter under these conditions, as the resistance coils in the starter might burn out if the fuses or circuit breaker do not open the circuit.

Ques. 281. What would happen if the field of a shunt motor were opened while in operation? Why?

Ans. If the field of a motor were opened while the motor was in operation, the fuses would blow or the circuit breaker trip. If neither of these protective devices were provided, an abnormal amount of current would rush through the armature and might possibly burn out one or more of the armature coils. This would be due to the lack of a counter e.m.f. when the field circuit is open. The armature, which is of a comparatively low resistance, would be connected directly across the line if the field opened and, consequently, an abnormal amount of current would flow through it.

The counter e.m.f. generated in a motor armature is due to the heavy self-inductance of the field winding when the motor armature is revolving in it and is always in an opposite direction to the impressed e.m.f. It is for this reason that when a motor is running at the normally designed speed, the current flow through the armature is at a minimum and that as soon as the field is weakened, the counter e.m.f. decreases and the current flow through the armature increases.

Ques. 282. Describe a differential compound-wound motor. Where is the rheostat controlling the speed regulation connected in a compound motor?

Ans. A differential compound motor has two field windings, *i.e.*, shunt and series field. The shunt field consists of many turns of fine wire, and the series field of comparatively fewer turns of heavy wire. This type of motor operates normally as a shunt motor until a heavy load is applied. Then, due to the current in both windings being in opposite directions, there is a tendency for the speed of the motor to increase to compensate for the tendency to decrease in speed due to the load, and, therefore, the result is the maintainance of a fairly constant speed when under heavy load.

The theoretical explanation for this action is as follows: When the motor is operating under normal conditions, the current flow through the armature is limited, due to the powerful shunt field producing a high counter e.m.f. If the current in these windings is circulating in opposite directions, a differential field is produced of a certain density which depends upon the amount of current being drawn by the armature. When the machine is not under a heavy load, the counter e.m.f. produced by the shunt field limits the current flow through the armature and the series field, and, therefore, the magnetic field around the series field will have little or no effect upon the shunt field. As soon, however, as a heavy load is applied, the armature will slow

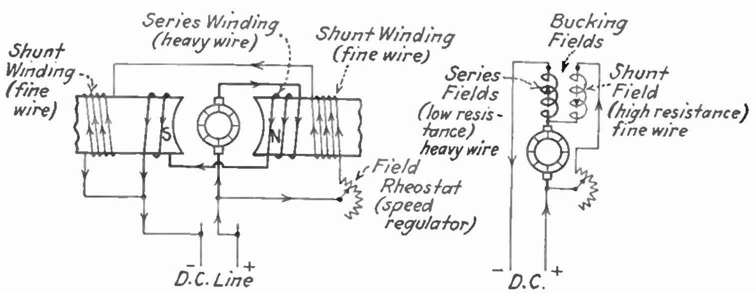


FIG. 67.—Wiring diagrams of a differentially compound-wound motor.

down, and, consequently, the rate of cutting of the lines of force will decrease, which, in turn, will cut down the counter e.m.f. and will allow more current to flow through the armature and series-field windings. This will immediately strengthen the series-magnetic field and, due to the fact that the shunt and series windings are wound in opposition, their magnetic fields will tend to "buck" or neutralize each other which will result in a further decrease in the counter e.m.f. (weakening the field) which will produce a further increase in armature current of a value again to restore the motor to normal speed. It can be readily seen that the automatic weakening of the shunt field with the external load acts as a self-regulating-speed device.

To increase the speed of a differentially compounded motor above normal, a rheostat must be connected in the controlling field, *i.e.*, the shunt field. Figure 67 illustrates wiring diagrams of a differential compound motor with speed-regulating rheostat.

Ques. 283. Suppose that on starting the motor generator there was severe sparking at the commutator and the machine turned over very slowly, what might the trouble be?

Ans. A sparking commutator in this situation usually indicates an open circuit in the armature.

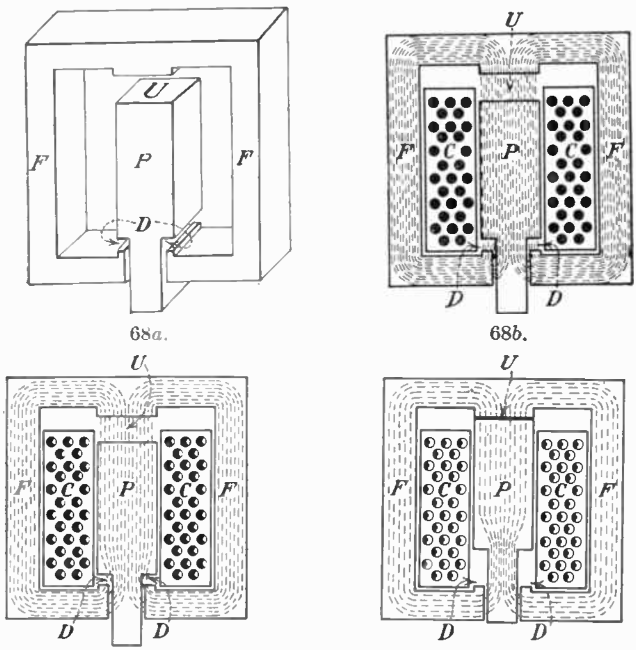
Ques. 284. Describe the principle of operation and construction of the magnetic-saturation automatic starter.

Ans. The type-A series contactor, manufactured by The Electric Controller and Manufacturing Company and widely used on shipboard radio installations, is magnetically operated, but it behaves quite differently from most electromagnets. For instance, it is well known that, with an ordinary solenoid, the more the current flowing through its coil the harder any plunger in it will be pulled up. In the type-A series contactor, however, the plunger does not move when the current in the coil is larger than a certain amount, but it does lift when the current is less than this amount. As it is important to know what causes this peculiar action, the following explanation is given:

Figure 68*a* represents a rectangular iron frame *FF* and plunger *P*. The plunger *P* is narrower at the bottom than at the top, and the narrow part of it fits loosely in an opening at the bottom of the frame *FF*. There are two air gaps *DD* between the plunger *P* and the bottom of the frame *FF*, and one air gap *U* between plunger *P* and the top of the frame *FF*.

Next, assume that a coil is placed around the plunger *P*, as shown in Fig. 68*b*, where the black circles represent the cross-sections of the wires of the coil *CC*. The frame and the plunger are supposed to be the same in Figs. 68*a* and 68*b*. If a heavy current flows through the coil, magnetic lines will stream through the plunger *P* across the air gap *U* back through the frame *FF* and through the narrow part of the plunger *P* and also across the air gaps *DD*. The reason some of the lines go through the air gap *DD* is that the narrow part of the plunger *P* is *saturated*, or, in other words, it cannot carry any more magnetic lines. These lines, therefore, are forced through the air gaps *DD* when a large current flows through the coil. The magnetic lines in the air gap *U* cause an upward pull on the plunger, but the weight of the plunger and the downward pull of the magnetic lines in the air gaps *DD* hold the plunger down.

In Fig. 68*c*, everything is the same as in the previous Fig. 68*b*, except that less current flows through the coil *CC* with the result that there are not so many magnetic lines flowing through



68*a*. 68*b*. 68*c*. 68*d*.

FIG. 68.—Automatic-starter diagrams.

the plunger *P*, the air gap *U*, and the frame *FF*. Most of these lines can now pass through the narrow part of the plunger, but there are still a few in the air gaps *DD*. The downward pull on account of the lines passing through the air gap *DD*, is now less than it was before, but this pull and the weight of the plunger are still enough to hold the plunger down.

In Fig. 68*d*, the current in the coil is still less, and, of course, the magnetic lines are less than they were in Fig. 68*c*. Practically all of them can pass through the narrow part of the plunger *P* so that there is now very little downward pull at the air gaps *DD*. There is, however, still a heavy upward pull at the air gap *U* which is enough to lift the plunger to its new position, shown in Fig. 68*d*.

This is exactly what happens in the operation of this starter.

Figure 69*a* is a cross-section of the type-A series contactor with a coil *CC*; a magnetic frame, or case, *F*; and a plunger *P*. The bottom of the plunger is smaller than the top, like the plunger in Figs. 68*a*, *b*, *c*, *d*, but it is round instead of square. The magnetic lines through the air gap *U* try to lift the plunger. When the current in the coil is larger than a certain amount, the magnetic lines in the air gap *DD* hold the plunger down. Note that the air gap *DD* of Fig. 69*a* is nearer the top of the plunger than the air gaps *DD* of Figs. 68*a*, *b*, *c*, *d* but that its action is the same in each case. When the current becomes less than a certain amount, practically all of the magnetic lines pass through the small part of the plunger, and there is practically no downward pull at the air gap *DD*. The pull at the air gap *U*, however, is enough to lift the plunger, which forces the contact plate *CP* into contact with the two laminated brushes *B*. When the contact plate touches the brushes it short-circuits a part of the starting resistor.

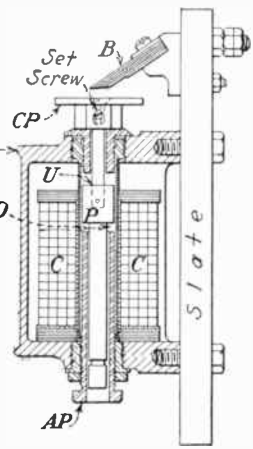


Fig. 69*a*.—Cross-section of series contactor.

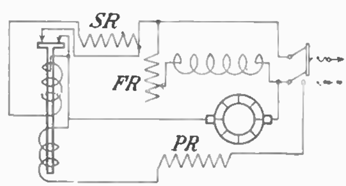


Fig. 69*b*.—Main-coil arrangement of automatic starter.

To adjust the starter, there is a hollow plug *AP* which screws into the bottom of the case *FF*. This is called an *adjusting plug* because by screwing it in or out, the length of the air gap *DD* can be varied, thereby changing the value of the current at which the contactor operates. If the air gap *DD* is very short, the plunger *P* is held down and will not rise until the current through the coil has dropped to a quite small amount. On the other hand, if the adjusting plug is screwed down, the air gap *DD* is greater, and the plunger will lift when a larger current flows through the coil. It is plain, therefore, that the current at which the plunger lifts can be adjusted by screwing the adjusting plug in or out.

The main-coil arrangement of the starter is shown in Fig. 69*b*. In actual operation, the action of the starter is as follows: As soon as the main line or motor switch is closed, a heavy starting current flows through the operating coils of the relay,

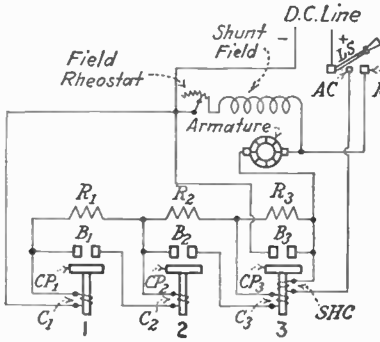


FIG. 69*c*.—Automatic starter showing steps of resistance used.

magnetizing the stem of the plunger to saturation and producing a field across the lower gap *DD*. This field, plus the weight of the plunger, holds the plunger down against the upward pull of the field at the upper gap *U*. As the motor gains speed, it produces a counter e.m.f. in its armature which reduces the current taken from the line and, therefore, the current through the coils of the relay. This weakens the field in the relay, producing a slight weakening of the pull exerted at the upper gap *U* and quite materially reducing the pull exerted at the lower gap *DD*. Finally, the field across the lower gap is so weak that it can no longer hold the plunger down against the pull of the field at the upper gap, and the field at *U* pulls the plunger up.

The non-magnetic rod extending through the top of the frame carries a contact plate which contacts two brushes, short-circuiting the starting resistance and connecting the motor to the line directly.

If the operating coil were left in the circuit, a heavy current resulting from heavy load on the motor might produce such a strong field that the plunger might be pulled down again by the effect of the lower gap *DD*; consequently, the circuit is arranged to short-circuit the operating coil at the same time that the starting resistance is shorted, a separate coil connected directly across the line being provided to hold the plunger up. A protective resistance is arranged in the circuit of this latter coil.

Opening the switch disconnects the motor from the line but leaves the holding coil connected to the motor until after the line circuit is broken; thus, when the starter drops, no current is interrupted at the starter contact. The device makes a circuit when it trips in but does not interrupt a current when it drops; thus, it never becomes pitted or burned rough. As installed on commercial radio sets, however, this type is frequently modified as required in connection with the particular control device used on the set.

To cause the relay to trip in sooner, turn the tube to the left, withdrawing it from the shell. To trip in later, turn the tube to the right, screwing it farther into the shell.

Figure 69*c* illustrates how the device may be used in any number of steps.

The iron parts of the relay are copper plated so that they will not rust. Lubrication is not necessary and, as it makes the device gummy, is not desired. Keep the exposed bright parts polished, and keep dust and dirt out of the moving parts. See that the brushes make contact at the same time and fit the contact plate squarely. Unless the tube becomes loose and loses its adjustment, the above is the only care necessary.

In case it is necessary to adjust the tube, the various steps should be adjusted so that the motor is kept accelerating steadily without jerking or jumping. It is best to screw the tubes in some distance (a couple of revolutions), start the motor, and then withdraw the tubes in order until the various steps trip in at the right times.

It will be noticed that when the last step comes in, all others drop out; thus, in stopping, when the last step is released, all are in a position to come in, in the correct order. Neither one of the plungers can come in ahead of the other as it is not connected in the circuit until the next previous has tripped in. Each one shorts its unit of the starting resistance through the operating coil of the next step.

Ques. 285. Why and where are protective condensers used in motor and generator systems?

Ans. Protective condensers are used to protect the power equipment from high-frequency kick-backs. They are usually connected across the motor armature, motor field, generator field, and generator output. If one of these condensers becomes defective, it is very probable that the fuses may blow or the circuit breaker may trip. This can readily be seen by referring to the main diagram. It will be noted that if either of the condensers is blown, there will be a possibility of a current flow direct to ground, which is practically the equivalent of a short circuit. A defective condenser may be found by connecting a pair of headphones and battery in series with it, and if a click is heard when first closing the circuit and then upon opening the circuit and closing it again another click is heard, the condenser is defective. If, on the other hand, a click is heard at the first time only, then the condenser is in good condition.

Ques. 286. Why is a motor generator necessary for a spark transmitter?

Ans. A motor generator is necessary because the ship's power is always direct current, and, therefore, in order to generate an alternating current for operation of the power transformer, a motor generator must be used.

Ques. 287. Sketch a motor-generator diagram for a tube transmitter?

Ans. See Fig. 1. Draw the circuits, starting with the power switch and ending with the tank inductance.

Brief Bibliography

Nilson and Hornung: "Practical Radio Telegraphy," McGraw-Hill Book Company, Inc.

Timbie: "Essentials of Electricity," John Wiley & Sons, Inc.

Croft: "Practical Electricity," McGraw-Hill Book Company, Inc.

"Naval Electricians' Textbook," vols. I and II, U. S. Naval Institute.

Raymond: "Motor Troubles," McGraw-Hill Book Company, Inc.

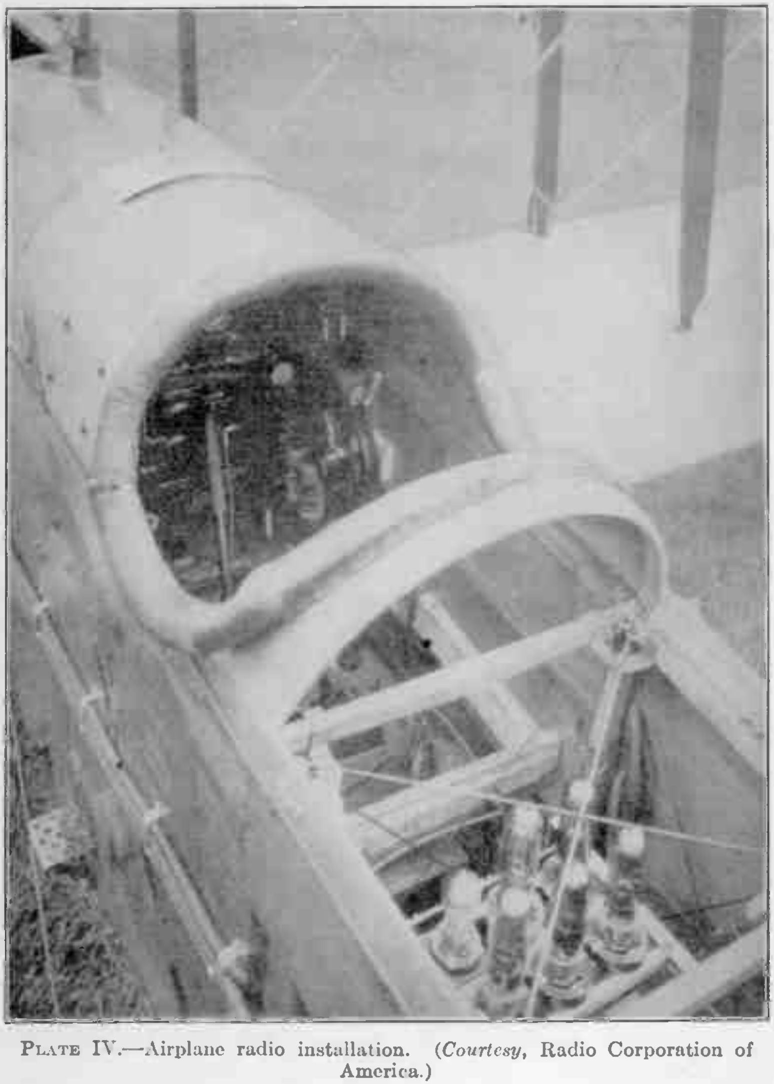


PLATE IV.—Airplane radio installation. (*Courtesy*, Radio Corporation of America.)

PART VIII

RADIO LAWS AND TRAFFIC REGULATIONS

Ques. 288. Under what laws is radio communication in the United States governed?

Ans. The Radio Act of 1927 and the Regulations of the Washington International Radiotelegraphic Convention of 1927.[1]

Ques. 289. What does the law state in regard to the supervision and use of radio apparatus by unlicensed persons?

Ans. The actual operation of all transmitting apparatus in any radio station for which a station license is required by the Radio Act of 1927 shall be carried on only by a person holding an operator's license issued hereunder. No person shall operate any such apparatus in such station except under and in accordance with an operator's license issued to him by the Secretary of Commerce.

Ques. 290. What is the United States distance requirement for signals of distress?

Ans. Every radio station on shipboard shall be equipped to transmit radio communications or signals of distress on the frequency or wave length specified by the licensing authority, with apparatus capable of transmitting and receiving messages over a distance of at least 100 miles by day or night.

Ques. 291. How may the transmitter be adjusted when sending signals of distress?

Ans. When sending radio communications or signals of distress and radio communications relating thereto, the trans-

[1] The reader is advised that an English translation of the new International Radiotelegraph Convention may be secured for 25 cents per copy (stamps not accepted) from the Superintendent of Documents, Government Printing Office, Washington, D. C.

mitting set may be adjusted in such a manner as to produce a maximum of radiation irrespective of the amount of interference that may thus be caused.

Ques. 292. What does the law state regarding priority for signals relating to ships in distress?

Ans. All radio stations, including government stations and stations on board foreign vessels when within the territorial waters of the United States, shall give absolute priority to radio communications or signals relating to ships in distress; shall cease all sending on frequencies or wave lengths that will interfere with hearing a radio communication or signal of distress; and, except when engaged in answering or aiding the ship in distress, shall refrain from sending any radio communication or signals until there is assurance that no interference will be caused with the radio communications or signals relating thereto and shall assist the vessel in distress, as far as possible, by complying with its instructions.

Ques. 293. What does the law state regarding intercommunication between shore stations and ships at sea?

Ans. Every shore station open to general public service between the coast and vessels at sea shall be bound to exchange radio communications or signals with any ship station without distinction as to radio systems or instruments adopted by such stations, respectively, and each station on shipboard shall be bound to exchange radio communications or signals with any other station on shipboard without distinction as to radio systems or instruments adopted by each station.

Ques. 294. What does the law state regarding a silent period near a government station?

Ans. At all places where government and private or commercial radio stations on land operate in such close proximity that interference with the work of government stations can not be avoided when they are operating simultaneously such private or commercial stations as do interfere with the transmission or reception of radio communications or signals by the government stations concerned shall not use their transmitters during the first fifteen minutes of each hour, local standard time.

The government stations for which the above-mentioned division of time is established shall transmit radio communications or signals only during the first fifteen minutes of each hour, local standard time, except in case of signals or radio communications relating to vessels in distress and vessel requests for information as to course, location, or compass direction.

Ques. 295. What does the law state regarding the use of unnecessary power?

Ans. In all circumstances, except in case of radio communications or signals relating to vessels in distress, all radio stations, including those owned and operated by the United States, shall use the minimum amount of power necessary to carry out the communication desired.

Ques. 296. What is the law on secrecy of messages?

Ans. No person receiving or assisting in receiving any radio communication shall divulge or publish the contents, substance, purport, effect, or meaning thereof except through authorized channels of transmission or reception to any person other than the addressee, his agent, or attorney, or to a telephone, telegraph, cable, or radio station employed or authorized to forward such radio communication to its destination, or to proper accounting or distributing officers of the various communicating centers over which the radio communication may be passed, or to the master of a ship under whom he is serving, or in response to a subpœna issued by a court of competent jurisdiction, or on demand of other lawful authority; and no person not being authorized by the sender shall intercept any message and divulge or publish the contents, substance, purport, effect, or meaning of such intercepted message to any person; and no person not being entitled thereto shall receive or assist in receiving any radio communication and use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto; and no person having received such intercepted radio communication or having become acquainted with the contents, substance, purport, effect, or meaning of the same or any part thereof, knowing that such information was so obtained, shall divulge or publish the contents, substance, purport, effect, or meaning of the same or any part thereof, or use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto: *Provided,* That this section shall not apply to the receiving, divulging, publishing, or utilizing the contents of any radio communication broadcasted or transmitted by amateurs or others for the use of the general public or relating to ships in distress.

Ques. 297. What does the law state regarding the transmission of false or fraudulent distress signals; about rebroadcasting?

Ans. No person, firm, company, or corporation within the jurisdiction of the United States shall knowingly utter or transmit, or cause to be uttered or transmitted, any false or fraudulent signal of distress, or communication relating thereto, nor shall any broadcasting station rebroadcast the program or any part thereof of another broadcasting station without the express authority of the originating station.

Ques. 298. What does the United States law state regarding obscene, indecent, or profane language by means of radio?

Ans. No person within the jurisdiction of the United States shall utter any obscene, indecent, or profane language by means of radio communication.

Ques. 299. What is the penalty for violating any United States or international radio law?

Ans. Any person, firm, company, or corporation failing or refusing to observe or violating any rule, regulation, restriction, or condition made or imposed by the licensing authority under the Radio Act of 1927 or of any international radio convention or treaty ratified or adhered to by the United States, in addition to any other penalties provided by law, upon conviction thereof by a court of competent jurisdiction, shall be punished by a fine of not more than $500 for each and every such offense.

Ques. 300. What is the penalty for making a false oath or confirmation in any affidavit required or authorized by the Radio Act of 1927?

Ans. Any person, firm, company, or corporation who shall violate any provision of this Act, or shall knowingly make any false oath or affirmation in any affidavit required or authorized by this Act, or shall knowingly swear falsely to a material matter in any hearing authorized by this Act, upon conviction thereof in any court of competent jurisdiction shall be punished by a fine of not more than $5,000 or by imprisonment for a term of not more than five years or both for each and every such offense.

Ques. 301. Who has supreme authority over the radio service of a mobile station?

Ans. The radio service of a mobile station shall be placed under the supreme authority of the master or of the person responsible for the vessel, aircraft, or other mobile station.

Ques. 301*a*. How many times may a station be called and how much time must elapse between calls, if no acknowledgment is received, according to the International Regulations?

Ans. When a station called does not answer to a call sent three times at intervals of two minutes, the call must cease, and it may be resumed only after an interval of fifteen minutes. The calling station, before resuming the call, must make certain that the station called is not at that moment in communication with another station.

The call may be repeated at shorter intervals if it is not likely to interfere with communications in progress.

Ques. 302. Give the procedure for calling a station.

Ans. In mobile service radiotelegraph correspondence the following procedure shall be used for calling a station:

The calling station shall make the call by transmitting not more than three times the call signal of the station called and the word DE, followed not more than three times by its own call signal.

In making this call the calling station shall use the wave on which the station called keeps watch.

AUTHOR'S NOTE.—The attention signal — · — · — is no longer used.

Ques. 303. What precautions must the operator take before calling a station to avoid interference?

In the mobile service, the following detailed procedure shall be obligatory, except in the case of distress calls or of distress correspondence.

1. Before proceeding with a transmission, the sending station must make sure that no excessive interference will be caused to other communications in progress within its range on the frequency to be used; if there is probability of such interference occurring, it shall await the first break in the transmission with which it might interfere.

2. If, in spite of this precaution, a radio transmission in progress is interrupted by the call, the latter must cease at the first request of a land station open to the international service of public correspondence or by any aeronautical station whatsoever. The station requesting this cessation must indicate the approximate duration of the suspension imposed upon the station whose call has been stopped.

Ques. 304. What is the procedure for answering a call?

Ans. The station called shall reply by transmitting not more than three times the call signal of the calling station, the word DE, its own call signal, and, if it is ready to receive traffic, the letter K (invitation to transmit), followed, if deemed useful, by the appropriate abbreviation and by a number indicating the strength of the signals received.

If the station called is unable to receive, it shall replace in the reply formula the letter K by the signal · — · · · (wait), followed by a number indicating in minutes the probable duration of the wait. If it is probable that this delay will exceed ten minutes, the delay must be explained.

Ques. 305. How is the transmission of a radiotelegram or series of messages terminated? How is acknowledgment of receipt made? What signal indicates conclusion of correspondence between two stations?

Ans. The transmission of a radiotelegram shall be terminated by the signal · — · — · (end of transmission) followed by the call signal of the sending station and the letter K.

In case of transmission in series, the call signal of the sending station and the letter K shall be sent only at the end of the series.

Acknowledgment of receipt of a radiotelegram shall be sent by means of the letter R followed by the number of the radiotelegram; this acknowledgment of receipt shall be preceded by the following formula: call signal of the sending station, word DE, call signal of the receiving station.

Acknowledgment of receipt of a series of radiotelegrams shall be sent by means of the letter R followed by the number of radiotelegrams received as well as by the numbers of the first and of the last telegram composing the series. This acknowledgment of receipt shall be preceded by the formula given above.

The conclusion of work between two stations shall be indicated by each of them, by means of the signal · · · — · — (end of work) followed by its own call signal.

Ques. 306. On the wave of 600 meters what is the maximum period of continuous work between two stations before a pause must be made?

Ans. On the wave of 500 kc/s (600 m.) (or on an authorized wave, in the case of communications with an aircraft station), the periods of continuous work between two stations must not exceed approximately ten minutes; after each of these periods a pause must be observed in order to permit, if necessary, another station to send a priority call or to transmit a priority message.

Ques. 307. What does the International Convention Regulation say about the types of receivers permissible?

Ans. Receiving apparatus used in the mobile service must be such that the current which it produces in the antenna shall be as small as possible and shall not disturb neighboring stations.

Ques. 308. What are the regulations regarding test signals?

Ans. When it is necessary to make test signals in order to adjust the apparatus before proceeding with a call or a transmission, the signals must not be made for more than about 10 seconds and they must be composed of a series of V's followed by the call signal of the sending station.

If a station sends test signals at the request of another station to permit the latter to adjust its receiving apparatus, these signals must likewise be composed of a series of V's in which the call signal of the transmitting station shall appear several times.

Tests and adjustments in any station must be conducted so as not to interfere with the service of other stations engaged in authorized correspondence. The test and adjustment signals must be chosen so that no confusion can be produced with a signal, abbreviation, etc., of special meaning defined by the Regulations.

Any station transmitting for tests, adjustments, or experiments must, during the course of these transmissions, send its call signals at frequent intervals.

Ques. 309. How may a mobile station or stations the names of which are not known be called?

Ans. Stations desiring to enter into communication with mobile stations, without, however, knowing the names of the mobile stations which are within their range of action, may use the signal of inquiry CQ, in place of the call signal of the station called in the calling formula, this formula being followed by the letter K (general call for all mobile stations with request for reply).

In regions where traffic is heavy, the use of the call CQ followed by the letter K shall be forbidden except in combination with urgent signals.

The call CQ not followed by the letter K (general call for all mobile stations without request for reply) shall be employed for radiotelegrams of general information, time signals, regular meteorological information, general safety notices, and information of all kinds intended to be read by anyone who can receive them.

Ques. 310. What is the law regarding the exchange of unnecessary signals?

Ans. The exchange of unnecessary signals shall be forbidden to mobile stations. Tests and experiments shall be allowed in these stations only to the extent that they do not disturb the service of other stations.

Ques. 311. What is the general calling and distress wave for ship and coast stations?

Ans. The general calling wave, which must be used by all ships compulsorily equipped and by coast stations, shall be 500 kc/s (600 m.) (spark, CW or ICW).

Besides the wave 500 kc/s (600 m.) the use of waves of all types between 485 and 515 kc/s (620–580 m.) shall be forbidden.

The wave of 500 kc/s (600 m.) shall be the international calling and distress wave. It may be used, but with discretion, for other purposes, if it does not interfere with distress, urgent, safety, or call signals.

Ques. 312. What is the regulation for standing watch on the distress wave in the maritime service?

Ans. In order to increase safety of life at sea (ships) and over the sea (aircraft), all stations in the mobile *maritime* service must, during their hours of service, take the necessary measures to assure the watch on the distress wave (500 kc/s–600 m.) for three minutes twice per hour, beginning at the 15th minute and at the 45th minute after each hour Greenwich Mean Time.

Ques. 313. What is the distress signal, and what does it indicate?

Ans. The distress signal shall consist of the group · · ·— — —· · · which indicates that the ship, aircraft, or other mobile station sending it is threatened by grave and imminent danger and requests immediate assistance.

Ques. 314. Give the procedure for sending a distress call.

Ans. The distress call shall consist of the distress signal sent three times, followed by the word DE and the call signal of the mobile station in distress, sent three times. This call has absolute priority over all other transmissions. All mobile or land stations hearing it must immediately cease all transmissions capable of interfering with the distress calls or messages and must listen on the wave used for the distress call. This call must not be addressed to a particular station.

Ques. 315. The distress message, what shall it include; on whose authority may it be sent; on what wave length shall it be sent? If no answer is received, what is the procedure? What is the regulation governing the transmission of the distress message for another mobile station? What must a station do on receipt of a distress call?

Ans. The distress message shall include the distress call followed by the name of the ship, aircraft, or other mobile station in distress and information concerning its position, the nature of the distress and the kind of assistance desired.

The distress call and message shall be sent only by the authority of the master or person responsible for the ship, aircraft, or other mobile station.

A ship in distress shall transmit the distress call on the wave of 500 kc/s (600 m.), preferably on ICW or spark. This call must be followed as soon as possible by the distress message.

The distress call and message must be repeated at intervals until an answer has been received, especially during the periods of silence. The intervals must, however, be long enough for stations preparing to reply to the call to have time to start their sending apparatus. In the case where the ship in distress receives no answer to a distress call or message sent on the 500 kc/s (600 m.) wave, the call and the message may be repeated on any other available wave on which attention might be attracted.

Furthermore, a mobile station which is aware that another mobile station is in distress may transmit the distress message on condition that:

a. The station in distress is not itself in a position to transmit it.

b. The master (or his relief) of the vessel, aircraft, or other mobile station believes that further help is necessary.

Stations which receive a distress message from a mobile station which unquestionably is in their immediate vicinity must at once acknowledge receipt thereof, taking care not to interfere with the transmission of the acknowledgments of receipt of the said message sent by other stations.

Stations which receive a distress message from a mobile station which unquestionably is not in their immediate vicinity must listen for a short period before acknowledging receipt thereof in order to permit the stations nearer to the mobile station in distress to answer and acknowledge receipt without interference.

Ques. 316. What shall distress traffic include? What signal must precede the time of filing in the preamble of a distress message? What station shall control distress communications? What is the regulation regarding interference with distress communications? When distress communications are ended, what shall the station which controlled these communications do?

Ans. Distress traffic shall include all messages relative to immediate relief of the mobile station in distress.

All distress traffic must include the distress signal, sent before the time of filing.

The control of distress communications devolves upon the mobile station in distress or upon the mobile station which, by application of the provisions of subparagraph *a*, in preceding answer, sent the distress call. These stations may delegate the control of the distress communications to another station.

All stations which are within the range of the distress communications but which do not take part in them must refrain from using the distress wave until the distress communications are finished. As soon as these communications are established on the distress wave, mobile stations using CW not taking part in them may continue their normal service on other authorized waves if by so doing they are still able effectively to receive the distress traffic.

When distress communications are ended and silence is no longer necessary, the station which has controlled these communications shall send a message on the distress wave addressed to CQ, indicating that the distress communications are ended. This message shall take the following form:

Call CQ (three times), word DE, call signal of the station transmitting the message, distress signal, time of filing the message, name and call signal of the mobile station which was in distress, words "distress traffic ended."

This message shall be repeated, where necessary, on the other waves on which the distress traffic has been sent.

Ques. 317. Give the procedure for acknowledging a distress message. Give other regulations regarding the acknowledgment of receipt of a distress message.

Ans. Acknowledgment of receipt of a distress message shall be made in the following form:

Call signal of the mobile station in distress (three times), word DE, call signal of the station acknowledging receipt (three times), group RRR, distress signal.

Every mobile station which acknowledges receipt of a distress message must make its name and position known as soon as possible, taking care not to interfere with other stations more favorably situated to render immediate relief to the station in distress.

If a mobile station employing continuous waves not included in the band 485 to 515 kc/s (620–580 m.) hears a distress message sent on the wave of 500 kc/s (600 m.), during other than the obligatory silence periods on the wave of 500 kc/s (600 m.), and if the ship, aircraft, or other mobile station is not in a position to render assistance, the said station must take all possible steps to attract the attention of other mobile stations in the vicinity, which are working on waves not included in the band mentioned above.

Repetition of the distress call or message, by mobile stations other than the one in distress, shall be permitted only on authorization from the master (or his relief) of said stations, taking care not to cause interference by useless repetition.

A station repeating a distress call or message shall add to the end thereof the word DE followed by its own call signal transmitted three times.

In a case where a station receives a distress call or message but is not in a position to render assistance and has reason to believe that there has been no acknowledgment of receipt of the distress message, it must repeat the message on full power on the distress wave and take all the necessary steps to advise the authorities who are capable of useful intervention.

Ques. 318. What is the "urgent signal," and what does it indicate? Over what shall it have priority? When may it be employed? How shall it affect other stations that hear it? On whose authority may this signal be sent?

Ans. The urgent signal shall consist of several repetitions of the group XXX, sent by distinctly separating the letters of each group and the successive groups; it shall be sent before a call. This signal shall indicate that the calling station has a very urgent message to transmit concerning the safety of the ship, aircraft, or other vehicle in which it is located; of a ship, aircraft, or other vehicle in sight; or, finally, of the safety of any person on board or in sight therefrom. In the aircraft radio service the indication PAN shall be used as an urgent signal (see next Ques.).

The urgent signal shall have priority over all other communications except those of distress, and all mobile or land stations which hear it must avoid interfering with the transmission of such urgent traffic.

As a general rule, the urgent signal may be employed only if the sending mobile station addresses it to a specific station.

Mobile stations which hear the urgent signal must continue to listen for at least three minutes. At the expiration of this period and if no urgent message has been heard, mobile stations may resume their normal service.

Land and ship stations nevertheless, which are in communication on authorized waves, other than that used for the transmission of the urgent signal and of the call which follows it, may continue their normal work without interruption.

The urgent signal shall be transmitted only with the authorization from the master or the person responsible for the ship, aircraft, or other mobile station.

Ques. 319. If you heard an aircraft station saying P A N by radiotelegraphy or radiotelephony, what would you understand it to mean?

Ans. In the aircraft radio service, the indication P A N shall be used as an urgent signal, by radiotelegraphy or radiotelephony, when an aircraft station wishes to give notice of damage which compels the aircraft to land without requiring immediate assistance. In the case of radiotelegraphy, the three letters must be well separated in order that the signals A N be not transmitted as the signal P.

Ques. 320. What is the distress call for an aircraft station equipped with radio telephone?

Ans. The distress call for an aircraft station using the radio telephone is MAYDAY. This is the English phonetic word for the French *m'aidez*, which means "help me."

Ques. 321. What is the "safety signal," and what does it indicate? On what wave shall it be sent? When shall it be sent?

Ans. The safety signal shall consist of the transmission of the group TTT, with the letters well separated, followed by the word DE and by the call signal of the station sending it. It shall indicate that this station is about to transmit a message concerning the safety of navigation or giving important information relative to meteorological warning messages.

The safety signal and the safety message shall be sent on the wave of 500 kc/s. (600 m.) and, if necessary, on the normal listening wave of ship and aircraft stations.

The safety signal shall be sent once during the first silent period and near the end of that period. All stations hearing it must continue to listen on the normal calling wave (ship stations) or on the authorized wave (aircraft station) until the message preceded by the safety signal shall have ended. The transmission of this message shall begin immediately after the end of the silent period.

Ques. 322. Give the regulations regarding the address of radiotelegrams.

Ans. 1. The address of radiotelegrams destined for mobile stations must be as complete as possible; it must be composed of the following:

a. Name or designation of the addressee, with any additional information, if necessary.

b. Name of the ship or, in the case of an aircraft, the call signal as published in the first column of the nomenclature.

c. Name of the land station charged with the transmission, as it appears in the nomenclature.

The name and call signal provided for under *b*, however, may be replaced at the sender's risk by the designation of the route followed by the mobile station, this route being determined by the names of the ports of departure and of destination, or by any other equivalent information.

When a radiotelegram received from a mobile station is relayed over the general communication system, the land station shall transmit as origin the name of the mobile station whence the radiotelegram emanates as this name appears in the nomenclature, followed by the name of the said land station.

2. Mobile stations authorized to be without the official nomenclature of telegraph offices may follow the name of the telegraph office of destination by the name of the territorial subdivision and, if necessary, by the name of the country of destination, if it is doubted whether, without this addition, the routing will be made without delay.

The name of the telegraph office and the supplementary information shall in this case be counted and charged for only as a single word. The agent of the land station receiving the radiotelegram shall retain or delete this information, or again modify the name of the office of destination as may be necessary or sufficient to route the radiotelegram to its proper destination.

Ques. 323. When it is possible for a mobile station to send its radiotelegrams to more than one land station what shall determine the land station to which it shall send its messages?

✓ *Ans.* 1. In principle, a mobile station using ICW, phone, or spark shall send its radiotelegrams to the nearest land station.

When, however, the mobile station may choose among several land stations, situated at approximately the same distance, it shall give the preference to that located on the territory of the country of destination, or of the normal transit of the radiotelegrams to be sent. When the station chosen is not the nearest, the mobile station must cease work or change the type or frequency of the emission upon the first request made by the land station in the interested service which is actually the nearest, the request being based upon the interference which the work in question causes the latter.

2. A mobile station using continuous waves included in the authorized band may transmit its radiotelegrams to a land station which is not the nearest. It is, however, recommended in this

case that preference be given to the land station established on the territory of the country of destination or of the country which it appears could most reasonably effect the transit of the radiotelegrams to be sent.

Ques. 324. When communications between ship stations interfere with the work of coast stations what is the regulation which governs the situation?

Ans. Except in the case of distress, communications between ship stations must not interfere with the work of coast stations. When this work is thus interfered with, the ship stations causing it must stop sending or change waves, upon the first request of the coast station with which they interfere.

Ques. 325. What must a mobile station which does not have fixed working hours do about notifying the land station with which it is in communication about its periods of service?

Ans. A mobile station which does not have fixed working hours must inform the land station with which it is in communication the time of closing and the time of reopening its service.

Ques. 326. On what waves may the ship station communicate with the coast station? What is their general listening wave?

Ans. 1. In the case where waves other than the normal wave may be used, the ship station shall follow the instructions of the coast station with which it is in communication. In principle, the normal wave of 500 kc/s (600 m.) must not be used for the transmission of long radiotelegrams in regions where the radio work is heavy.

2. During their hours of service, stations using for their work ICW, phone, or spark, and open to the international service of public correspondence, must continue to listen on the wave of 500 kc/s (600 m.), except when they are exchanging traffic on other waves.

Ques. 327. What is the regulation regarding interference with "to all stations" (CQ)[1] transmissions?

[1] QST is no longer used.

Ans. During transmissions "to all stations" of time signals and of meteorological messages intended for stations of the mobile service, all stations in that service the transmissions of which might interfere with the reception of the signals and messages in question must keep silent in order to permit all stations so desiring to receive these signals and messages.

Ques. 328. Give the general instructions and rules of procedure to be followed by mobile stations in obtaining radiocompass bearings.

Ans.

PROCEDURE FOR OBTAINING RADIOCOMPASS BEARINGS

I. GENERAL INSTRUCTION:

A. Before calling one or more radiocompass stations, the mobile station, in order to request its bearing, must refer to the nomenclature for:

1. The call signals of the stations to be called to obtain the radiocompass bearings desired.
2. The wave on which the radiocompass stations listen, and the wave or waves on which they take bearings.
3. The radiocompass stations which, connected by special wires, may be grouped with the radiocompass station to be called.

B. The procedure to be followed by the mobile station depends on varying circumstances. Generally, the following must be taken into account:

1. If the radiocompass stations do not listen on the same wave, whether it be the wave on which bearings are taken or another wave, the bearings must be requested separately from each station or group of stations using a given wave.
2. If all the radiocompass stations concerned listen on the same wave, and if they are able to take bearings on a common wave—which may be a wave other than the listening wave—they should all be called together, in order that the bearings may be taken by all these stations at the same time, on one and the same transmission.
3. If several radiocompass stations are grouped by means of special wires, only one of them must be called even if all are

furnished with transmitting apparatus. In this case, the mobile stations must, however, if it is necessary, specify in the call, by means of the call signals, the radiocompass stations whose bearings they wish to obtain.

II. Rules of Procedure:

A. The mobile station shall call the radiocompass station or stations on the wave indicated in the nomeclature as being their listening wave. It shall transmit the abbreviation QTE which means:

"I wish to know my radiocompass bearing with respect to the radiocompass station which I am calling"

or

"I wish to know my radiocompass bearing with respect to the station or stations whose call signals follow"

or

"I wish to know my radiocompass bearing with respect to the radiocompass stations grouped under your control," the call signal or signals necessary, and shall close by indicating, if necessary, the wave which it is going to use to determine its bearing. It shall then await instructions.

B. The radiocompass station or stations called shall prepare to take the bearing; they shall, if necessary, notify the radiocompass stations with which they are connected. As soon as the radiocompass stations are ready, such as these stations as are provided with sending apparatus shall reply to the mobile station in the alphabetical order of their call signals, by giving their signal followed by the letter *K*.

In the case of radiocompass stations which are grouped, the station called shall notify the other stations of the group and shall inform the mobile station as soon as the stations of the group are ready to take the bearing.

C. After having, if necessary, changed to its new transmitting wave, the mobile station shall reply by sending its call signal combined, when need be, with another signal, during a length of time sufficiently prolonged to permit the bearing to be taken.

D. The radiocompass station or stations which are satisfied with the operation shall transmit the signal QTE ("Your bearing with respect to me was ——— degrees"), preceded by the time of the observation and followed by a group of three figures (000 to 359), showing in degrees the true bearing of the mobile station with respect to the radiocompass station.

If a radiocompass station is not satisfied with the operation, it shall request the mobile station to repeat the transmission indicated under *C*.

E. As soon as the mobile station has received the result of the observation, it shall repeat the message to the radiocompass station, which shall then state that the repetition is exact or, when necessary, shall correct it by repeating the message. When the radiocompass station is certain that the mobile station has correctly received the message, it shall transmit the signal "end of work." This signal shall then be repeated by the mobile station, as an indication that the operation is finished.

F. The data concerning (*a*) the signal to be used to obtain the bearings, (*b*) the duration of the transmission to made by the mobile station, and (*c*) the time used by the radiocompass station in question shall be given in the nomenclature.

Ques. 329. What must a mobile station do which is about to close its radio service on entrance to port?

Ans. Every mobile station whose radio service is about to close by reason of arrival in port must notify the nearest land station.

Ques. 330. Give the order of priority in the establishment of communications in the mobile service.

Ans. The order of priority in the establishment of communications in the mobile service shall be as follows:

1. Distress calls, distress messages, and distress traffic.
2. Communications preceded by an urgent signal.
3. Communications preceded by the safety signal.
4. Communications relative to radiocompass bearings.
5. All other communications.

For the transmission of radiotelegrams covered by No. 5 above, the order of priority shall, in principle, be the following:

1. Government radiotelegrams.
2. Radiotelegrams relating to the navigation, movement, and requirements of ships, the safety and regularity of air services,

and radiotelegrams containing weather observations destined to an official meteorological service.

3. Service radiotelegrams relative to the operation of the radio service or to radiotelegrams previously exchanged.

4. Public correspondence radiotelegrams.

Ques. 331. Give the order of procedure for a mobile station when communication becomes difficult.

Ans. In the mobile service, when communication becomes difficult, the two stations in communication shall make every effort to complete the transmission of the radiotelegram being handled. The receiving station may request not more than two repetitions of a radiotelegram the reception of which is doubtful. If this triple transmission is ineffective the radiotelegram shall be kept on hand awaiting a favorable opportunity for completion of the transmission.

If the mobile station believes it impossible to reestablish communication with the receiving station within 24 hours it shall proceed as follows:

It shall immediately inform the sender of the reason for the non-transmission of his telegram. The sender may then ask:

1. That the radiotelegram be transmitted by the intermediary of another land station; or by the intermediary of other mobile stations.

2. That the radiotelegram be held until it may be transmitted without additional charge.

3. That the radiotelegram be canceled.

Ques. 332. On what wave length or frequency do radio-compass stations operate; radiobeacons?

Ans. 800 meters (375 kilocycles per second); 1,000 meters (300 kilocycles per second).

Ques. 333. Set up a radiotelegram with a 12-word check.

Ans. Rdo Nr 1 SS America W 12 Date — · · · —

To Robert Smith

143 West 73 St

New York — · · · —

Delay unavoidable arriving Saturday

— · · · —

Manning

Ques. 334. What does CQ mean; PRB?

Ans. CQ is the general call "to all stations" (see also Ques. 309). PRB means "I wish to communicate by means of the International Signal Code." If followed by a question mark, it means "Do you wish to communicate by means of the International Signal Code?"

Ques. 335. What is the International Signal for "I am being interfered with; stop sending"?

Ans. QRM; QRT.

Ques. 336. What do the International Regulations say about the type of equipment to be used in radio stations?

Ans. The stations covered by these regulations must, so far as practicable, be established and operated under the best conditions known to the practice of the service and must be maintained abreast of scientific and technical progress.

All stations, whatever their purpose, must, so far as practicable, be established and operated so as not to interfere with the radio communications or services of other contracting governments and of individuals or of private enterprises authorized by these contracting governments to carry on public radio communication service.

Authors' Note.—The above regulations presumably make it unlawful for any commercial or government station to work a spark transmitter the wave of which is of such a character as to cause unnecessary interference (one which has a decrement of more than 0.2, for example).

It also makes it useless for any station to complain about interference unless the complaining station is fitted with a modern receiving equipment.

Ques. 337. Give and explain 15 international abbreviations.

Ans. Refer to the chart in Appendix II. Fifteen commonly used abbreviations follow: QRA, QRK, QRL, QRM, QRN, QRT, QRU, QRV, QRW, QRX, QSU, QTE, QTC, QTF, CQ. The question-and-answer form of each of these signals should be learned. CQ is the general call to all stations and has no other form except when used as explained under Ques. 250.

Ques. 338. Has the master or other person in control of a mobile station a right to censor all messages received or transmitted by the radio station?

Ans. Yes, the master or other person responsible for the vessel, aircraft, or other mobile station, having supreme authority over the radio service, has the right under the law to exercise any censorship of radiotelegrams passing through the station whenever he thinks it necessary.

Ques. 339. Explain fully the cable-count system.

Ans. The cable-count system of counting the check is used for radiograms. This system provides that all words in the address, text, and signature must be counted and charged for. In this system, messages are divided into three classes, *viz:*

1. Plain language.
2. Code language.
3. Cipher language.

Plain-language messages must be written entirely in plain language. Words are counted on the basis of 15 characters to the word. Any fractional part of 15 characters is also counted as 1 word. Numbers up to 5 in a group would be counted as one word, over 5 as two words.

Examples:

Gymnasium	one word	7,583	one word
Intellectualization	two words	37,463	one word
Unconstitutional	two words	987,641	two words
Constantinople	one word		

Code language is made up of pronounceable words of no direct meaning not to exceed 10 characters in length. If a code word exceeds 10 characters in length it is counted at the cipher rate (five letters to the word), and this is noted in the check. Non-pronounceable code words are counted at the cipher rate. Words in which the meaning has been concealed by reversing the order of the letters or syllables will not be accepted as code words.

Examples:

BEYINXJEHI	one word
X-ray	two words
XQNOW	Not accepted—counted as cipher

Cipher language is counted at the rate of 5 letters to the word and may be made up of any combination of letters or figures.

Examples:

QPWNY	one word
QPXNWY	two words
A5C	three words

When a message is written in mixed language, a careful check up under the following rules must be made:

Code and Plain Language.—Maximum length of word chargeable is 10 characters.

Plain Language and Cipher.—The plain language is charged at the rate of one word for every 15 characters or fraction thereof, and the groups in the passages in cipher language at the rate of one word for every 5 characters or fraction thereof.

Plain Language, Code Language, and Cipher Language.—The words in plain language and code language are charged as code language, and the words in cipher are charged as cipher. The word street, road, park, or square is always counted as one word aside from its designator in the address. Hyphenated or compound words are counted as so many separate words depending on the number of parts.

Names of places, such as New York, New London, or Frankfurt am Main, are counted as one word in the address and two words in the text.

If New York is written Newyork or New London is written Newlondon and like examples, they are counted as one word in the text and so charged for. They should be written as two separate words in the address but as the names of all cities count as one word in the address they are charged for as one word.

LAWS, RULES, AND REGULATIONS PERTAINING ESPECIALLY TO AMATEURS

Ques. 340. What does the International Radiotelegraphic Convention say about amateur stations?

Ans. All the general rules and regulations fixed in the convention apply to amateur stations. In particular, the frequency of the waves emitted must be as constant and as free from harmonics as the state of the art permits. In the course of their transmissions, these stations must transmit their call signals at frequent intervals.

The exchange of communications between private experimental stations (amateurs) of different countries shall be forbidden if the administration (government) of one of the interested countries has given notice of its opposition to this exchange.

When this exchange is permitted, the communications must, unless the interested countries have entered into other agreements among themselves, be carried on in plain language and be limited to messages bearing upon the experiments and to remarks of a private nature for which, by reason of their unimportance, recourse to the public telegraph service might not be warranted.

Ques. 341. What do the United States Amateur Regulations say about spark transmitters?

Ans. Spark transmitters will not be authorized for amateur use.

Ques. 342. What kind of coupling must amateurs use on their transmitters according to United States Amateur Regulations?

Ans. Amateur stations must use circuits loosely coupled to the radiating system or devices that will produce equivalent effects to minimize key impacts, harmonics, and plate-supply modulations. Conductive coupling, even though loose, will not be permitted, but this restriction shall not apply against the employment of transmission-line feeder systems to Hertzian antenna.

Ques. 343. What is the United States regulation about communication between amateur and commercial or government stations?

Ans. Amateur stations are not permitted to communicate with commercial or government stations unless authorized to do so by the licensing authority except in an emergency or for testing purposes. This restriction does not apply to communications with small pleasure craft such as yachts and motor boats holding limited commercial-station licenses which may have difficulty in establishing communication with commercial or government stations.

Ques. 344. What is the United States regulation regarding broadcasting by amateur stations?

Ans. Amateur stations are not authorized to broadcast news, music, lectures, sermons, or any form of entertainment or to conduct any form of commercial correspondence.

Ques. 345. What is an amateur station according to United States and international law?

Ans. An amateur station is a station operated by a person interested in radio technic solely with a personal aim and without pecuniary interest. Amateur licenses will not be issued to stations of other classes.

Ques. 346. As an amateur-station operator, what would you do if you heard an SOS call from a vessel under various circumstances?

Ans. Immediately cease all transmission. Copy all signals and messages possible from the ship in distress. If no answer to the distress call is heard, telephone the nearest commercial or naval radio station and give them full particulars. Continue to listen in for any further particulars and report them, if necessary to the commercial or naval station. Remain silent until distress traffic is finished. These regulations may be modified in certain special instances.

Ques. 347. What are the zones of watch?

Ans. The following chart illustrates the various zones, western limits, eastern limits, and duration of hours of service:

Zones	Western limits	Eastern limits	Duration of hours of service, Greenwich Mean Time	
			8 hours	16 hours
A Eastern Atlantic Ocean, Mediterranean, North Sea, Baltic	Meridian 30° W. coast of Greenland	Meridian 30° E. south of the coast of Africa, eastern limits of the Mediterranean, of the Black Sea, and of the Baltic, Meridian 30° E. to the north of Norway	From 8 to 10h From 12 to 14h From 16 to 18h From 20 to 22h	From 0 to 6h From 8 to 14h From 16 to 18h From 20 to 22h
B Indian Ocean, eastern Arctic Ocean	Eastern limit of Zone A	Meridian 80° E. western coast of Ceylon to Adam's Bridge, thence westward around the coast of India	From 4 to 6h From 8 to 10 From 12 to 14h From 16 to 18h	From 0 to 2h From 4 to 10h From 12 to 14h From 16 to 18h From 20 to 24
C China Sea, western Pacific Ocean	Eastern limit of Zone B	Meridian 160° E.	From 0 to 2h From 4 to 6h From 8 to 10h From 12 to 14h	From 0 to 6h From 8 to 10h From 12 to 14h From 16 to 22h
D Central Pacific Ocean	Eastern limit of Zone C	Meridian 140° W.	From 0 to 2h From 4 to 6h From 8 to 10h From 20 to 22h	From 0 to 2h From 4 to 6h From 8 to 10h From 12 to 18h From 20 to 24h
E Eastern Pacific Ocean	Eastern limit of Zone D	Meridian 70° W., south of the coast of America, west coast of America	From 0 to 2h From 4 to 6h From 16 to 18h From 20 to 22h	From 0 to 2h From 4 to 6h From 8 to 14h From 16 to 22h
F Western Atlantic Ocean and Gulf of Mexico	Meridian 70° W. south of the coast of America, east coast of America	Meridian 30° W. coast of Greenland	From 0 to 2h From 12 to 14h From 16 to 18h From 20 to 22	From 0 to 2h From 4 to 10h From 12 to 18h From 20 to 22h

Ques. 348. What is the difference among Eastern Standard Time (EST), Greenwich Meridian Time (GMT), and Pacific Time (PT)?

Ans. The difference among these three time periods in New York City is approximately as follows:

New York City noon (EST), San Francisco 9 A.M. (PT) and London 5 P.M. (GMT). Hence, there is a difference of 3 hours between Eastern Standard Time and Pacific Time and 5 hours between Eastern Standard Time and Greenwich Meridian Time.

Brief Bibliography

"International Radiotelegraph Convention," 25 cents per copy (stamps not accepted); Supt. of Documents, Govt. Printing Office, Washington, D. C.

DAVIS: "The Law of Radio Communication," McGraw-Hill Book Company, Inc.

PART IX

GENERAL AND THEORETICAL QUESTIONS

Ques. 349. What is a sharp wave?

Ans. A sharp wave is one in which the logarithmic decrement per complete oscillation does not exceed two-tenths. This term always refers to damped waves.

Ques. 350. What is a pure wave?

Ans. A pure wave is the radiated wave of a transmitter the character of which is such that it radiates two or more wave lengths, the shorter wave not radiating more than 10 per cent as much energy as is radiated by the desired longer wave. This term always refers to damped waves.

Ques. 351. What is capacitance (capacity)?

Ans. That property possessed by a condenser that enables it to hold a charge of electricity. The charge is in the form of an electrostatic strain between the plates of a condenser.

Ques. 352. What is the effect of placing a condenser in series with the antenna, and under what conditions is it necessary?

Ans. Placing a condenser in series with the antenna decreases the resulting capacitance and, consequently, the wave length (frequency). When the natural wave length of the antenna is higher than that which is desired, the wave length of the circuit may be reduced by connecting a condenser in series. The wave length may be reduced nearly to one-half by this method but not below such a value for reasonable efficiency. Any decrease below the natural wave length tends to decrease efficiency. In addition to decreasing the antenna wave below its fundamental, the series condenser also permits fairly critical resonance adjustment with the secondary circuit, an important factor in the reception of continuous-wave signals.

Ques. 352a. Describe a form of decremeter. Give diagram and operation.

Ans. A circuit diagram of the Kolster decremeter is shown in Fig. 70.

Description.—The decremeter consists of a single-turn coil L_1, which is connected in series with the circuit to be measured. The inductance value of this coil is so low as to be negligible. Coil L is placed in inductive relation to coil L_1 and is

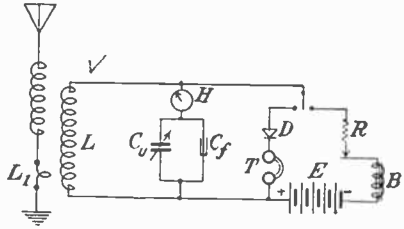


FIG. 70.—Wiring diagram of Kolster decremeter.

the inductance of the decremeter circuit. It is important that the coupling between coils L and L_1 be at a minimum coupling position when the decremeter is in use. C_v is a variable condenser to which is attached the decremeter scale through gears. A small condenser marked C_f is fixed in value after proper adjustment and is placed in parallel with C_v.

An indicating meter is represented by H. The scale of the meter is so marked that the readings are proportional to the square of the current measured.

If it is desired to measure the wave length of distant stations, the crystal detector D and head telephones T may be used to indicate resonance.

The decremeter may be used for calibration purposes by using the buzzer provided and indicated in the circuit as *R.B.*

Operation.—To measure the decrement of an oscillating circuit, connect coil L_1 in series with the circuit to be measured, as indicated in the diagram. Then rotate the condenser to the position of resonance, as indicated by a maximum reading on the current meter. The maximum reading is then reduced to one-half its value by rotating the condenser toward the minimum or maximum ends of its scale. The next operation is to set the decrement scale at zero and clamp it so that when the condenser scale is again rotated it will rotate with it. The condenser is then rotated back until the current-meter reading rises from one-half maximum to maximum and back to one-half maximum. The reading now opposite zero on the decrement scale is the sum of the decrements of the circuit under measurement and the decremeter decrement. By subtracting the latter decrement, which is given on a chart supplied with the decremeter, from the sum of the decrements given on the decremeter scale, the decrement of the circuit under measurement can be readily obtained.

The decremeter is used to measure the character of the wave emitted by the spark transmitter (damped waves). As spark sets are replaced by tube or arc sets which radiate waves of zero (or nearly so) decrement, the decremeter will become a less needed device.

Ques. 352*b*. What are three ways in which resonance may be indicated on a wavemeter? Draw diagrams.

Ans. Resonance may be indicated by:

1. Telephone receiver and detector.
2. Current square meter. (Radio frequency ammeter.)
3. Glow lamp.

See Fig. 71.

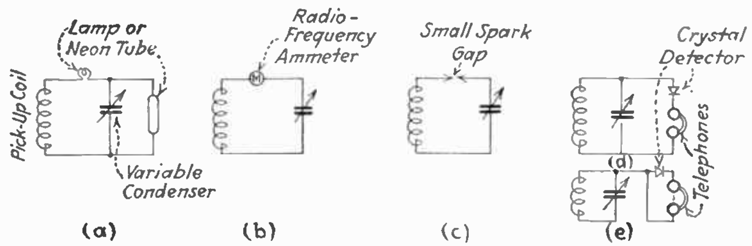


FIG. 71.—Methods of indicating resonance on a wavemeter.

Ques. 353. Draw a wavemeter with head phones and detector connected unilaterally; bilaterally.

Ans. See Fig. 72.

Ques. 354. Has an undamped wave a decrement?

Ans. It has zero decrement.

Ques. 355. What is meant by a broadly tuned circuit?

Ans. A broadly tuned circuit is one that responds (receiver) or transmits (transmitter) over a wide range of wave lengths (frequencies); one in which the logarithmic decrement exceeds two-tenths.

Broad emission may be due either to interaction between coupled circuits when they are tightly coupled or to resistance in the oscillatory circuits. Thus, if the coupling is loosened and the resistance in the secondary oscillatory circuit is maintained at a minimum, the damping will be low and the tuning sharp. On the other hand, if the coupling is too tight or too much resistance is present in the secondary circuit, a higher damping will result and the wave may be of a highly damped or broad character. This usually applies to spark transmitters.

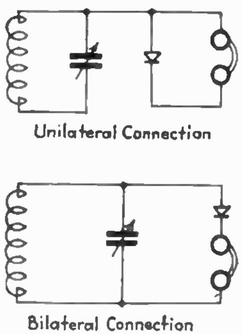


FIG. 72.—Two methods of connecting phones and detector on wavemeter.

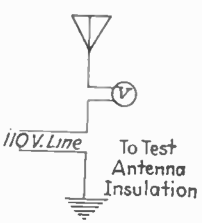


FIG. 73.—Method of testing an antenna for grounds.

Ques. 356. Show by diagram how an antenna may be tested for grounds.

Ans. Ground leaks in antenna insulation may be detected by connecting a voltmeter in series with antenna and applying a 110-volt current as shown in the diagram (Fig. 73). If no deflection is shown by the meter, the insulation is good; if the meter indicates a flow of current (deflects), the insulation is faulty and should be remedied. A practical method used by radio operators and inspectors on shipboard is to transmit on full power and watch closely for arcing in the antenna circuit and antenna proper. The radiation ammeter will not register if the antenna is badly grounded.

Ques. 357. What are the advantages of undamped waves?

Ans. Some of the principal advantages of undamped waves are due to the perfect syntony obtainable. This permits close tuning and reduces interference between stations which are close together. The detector arrangements used for the reception of undamped waves have better mechanical features than the crystal detector sometimes used for damp-wave reception and are not so easily put out of adjustment.

In spark systems there are groups of oscillations separated by comparatively long intervals of inactivity, so that if high-speed transmission is attempted there are not many trains of oscillations per dot or dash, whereas with undamped oscillations these periods of inactivity are absent; hence, high-speed work is possible.

With a given power, much greater distances are covered with undamped waves than with damped waves.

Another feature bearing on the greater efficiency of undamped waves is the fact that longer waves can be employed with this type of apparatus, thus reducing absorption.

Ques. 358. What determines the capacity of a condenser?

Ans. The area and number of plates in parallel; the character and thickness of the dielectric.

Ques. 359. Two condensers of 0.007 and 0.005 microfarads are connected in series. What is the total capacitance?

Ans. The formula for condensers in series when uneven capacities are used is

$$C = \frac{1}{\frac{1}{c_1} + \frac{1}{c_2}}$$

Solution

$$C = \frac{1}{\frac{5+7}{0.035}} = \frac{1}{\frac{12}{0.035}} = \frac{0.035}{12}$$

0.0029183 microfarads or 0.003 microfarads.

Ques. 360. When three condensers of 0.002 microfarads each are connected in series, what is the total effective capacity?

Ans. Capacity of 1 condenser (0.002) divided by 3 or

$$C = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}} =$$

$$C = \frac{1}{\frac{1}{0.002} + \frac{1}{0.002} + \frac{1}{0.002}} = \frac{1}{\frac{3}{0.002}} = \frac{0.002}{3} = 0.0006 + \text{mfd.}$$

Ques. 361. What is the effect if a few condensers are removed from the closed oscillatory circuit and the set retuned to resonance by the aerial tuning inductance?

Ans. If a few condensers are removed in the closed circuit, the oscillatory frequency increases (wave length decreases) and the power decreases. If, however, the antenna circuit is tuned to resonance after the change, then the transmitter can be used for transmission on a lower wave length.

Ques. 362. Describe what happens to a wave train when it strikes the receiving aerial.

Ans. When an advancing wave train strikes an aerial it cuts the wires of which the aerial is composed and induces an e.m.f. therein. This e.m.f. causes oscillations in the aerial circuit as long as the cutting continues. There is connected in the aerial circuit directly or by means of inductive coupling a detector or rectifying instrument which breaks up the antenna oscillations into a series of low-frequency unidirectional pulses which are audible in the telephone receiver.

Figure 48 illustrates in graph form the incoming signal; the rectified signal; and the telephone pulse.

Ques. 363. What is the effect of distributed capacity in a coil at various frequencies?

Ans. The most important objective in coil design is to minimize the distributed capacity and the high-frequency resistance. The former is, perhaps, the most important because of the tremendous amount of energy lost whenever it is present in a coil.

The distributed capacity in a coil is usually due to the close proximity of the turns with respect to one another. If the turns on a coil are very close, the distributed capacity will be very great and, consequently, will produce a considerable loss. It is, therefore, necessary to have each turn separated by a very small air gap to insure a minimum of distributed capacity.

The space winding in coil design has helped considerably in reducing these losses and is at the present time considered the most efficient method for minimizing distributed capacity losses.

The amount of spacing necessary cannot be accurately given because it varies with the frequency at which the coil is to be used and also on the amount of current passing through it.

At extremely high frequencies the distributed capacity of a coil increases considerably, and, in addition, it also increases the inductance of the coil due to the shunt effect of the capacity across the inductance. It is for this reason that coils designed for frequencies above approximately 200,000 cycles (below 1,500 meters) are usually space wound. This does not mean that no distributed capacity is present in coils above the 1,500-meter wave, but the detrimental effect is considerably less. It is even necessary to decrease the distributed capacity in high-wave coils by winding them in "banked" form.

Ques. 364. How are radiofrequency currents converted into audiofrequency currents to render them to audibility?

Ans. By rectification systems such as crystal detectors, vacuum-tube detectors, slipping-contact detectors, and choppers. The last two systems are now obsolete.

Ques. 365. What are the characteristics of the wave train in quenched, rotary, non-synchronous, and synchronous gaps?

Ans. The characteristics of the wave train in a quenched-gap system are slowly damped. This is due to the high quenching or damping properties in the primary circuit which enables the antenna to oscillate with a low degree of damping because of a minimum of energy retransfer to the primary, thus making it possible to obtain a sharp wave of low decrement not exceeding two-tenths.

In synchronous gap equipments the train characteristics are almost identical to each other because of the good quenching in the primary circuit.

In rotary, non-synchronous gaps, the wave trains are not so slowly damped due to the comparatively poor quenching in the primary circuit, and, therefore, this type of gap does not allow sharp wave transmission unless the coupling is considerably loosened.

Ques. 366. What is the difference between alternating current and interrupted direct current? State how each is produced.

Ans. An interrupted direct current or pulsating current is a direct current the flow of which is interrupted regularly (see Fig. 74*A*).

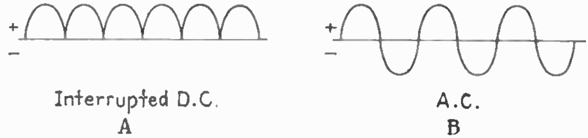


FIG. 74.—Interrupted direct current and alternating current.

An alternating current is an alternating current or one in which the direction of flow (polarity) changes periodically (see Fig. 74*B*).

A direct pulsating current may be produced by a buzzer, an induction coil primary, or a direct-current generator.

An alternating current may be produced by a generator of either the collector-ring or the inductor type, a vacuum-tube oscillator, an oscillating arc, or an induction-coil secondary.

Ques. 367. What is meant by spark or group frequency, generator frequency, wave-train frequency?

Ans. By *spark* or *group frequency* is meant the number of sparks jumping the spark gap each second. It is dependent upon the generator frequency. In modern transmitters properly adjusted, there is one spark per alternation of the alternating-current supply. For example, if the generator delivers 500 cycles per second, the spark frequency is 1,000 per second or, in other words, a spark discharges across the spark gap one thousand times per second.

Generator frequency is the number of cycles per second of e.m.f. delivered by the alternator. Frequency is always expressed in cycles per second.

Wave-train frequency denotes the number of wave trains or groups of wave trains radiated per second by the open radiating or antenna circuit of a radio transmitter.

Ques. 368. What is the usual resistance of phones used in radio reception?

Ans. 2,000 to 3,000 ohms per pair.

Ques. 369. Name three places where condensers can be used to advantage in a receiving set?

Ans. 1. In series with the antenna.

2. In shunt to the antenna or primary inductance.

3. In shunt to the secondary inductance.

Ques. 370. What advantage is obtained by providing variable coupling in a receiving tuner?

Ans. It enables critical adjustments between primary and secondary circuits to provide broad or sharp tuning.

If the coupling is tight, considerable reaction between the primary and secondary circuits results. This is called a *high-damping* or *broad-tuning adjustment* and is ordinarily used by operators for general listening-in purposes.

If the coupling is loosened, the reaction between the primary and secondary is minimized, and low damping or sharp tuning results. This enables the operator to tune sharply to the particular station he desires and thus eliminates interference.

Ques. 371. Give the advantages and disadvantages of stranded and solid conductor for radio purposes.

Ans. Practically, the advantage of a stranded over a solid conductor is its greater tensile strength, especially when used for antenna systems. The solid conductor, however, is much easier to work with, especially in soldering.

Electrically, the stranded conductor is slightly more efficient than the solid conductor at high frequencies. This is due to the tendency of high-frequency currents to concentrate on the surface of the conductor (the skin effect of high-frequency currents). The conductor, therefore, which offers the most surface (skin) to the flow of high-frequency current offers less resistance to its flow. The stranded conductor offers less resistance to the flow of high-frequency currents than a solid conductor.

Resistance is decreased in high-frequency circuits by using conductors made up of many strands of enameled wire twisted together so that each strand is on the outer surface of the cable with respect to every other one. Another method is to use tubular conductor or a conductor made up by arranging strips of copper on a drum of high-insulating material.

Ques. 372. A loud speaker is connected in the plate circuit of an amplifier; will the polarity affect the operation? Why?

Ans. Not necessarily, although in many cases it will. It depends upon the grade, physical dimensions, and character of

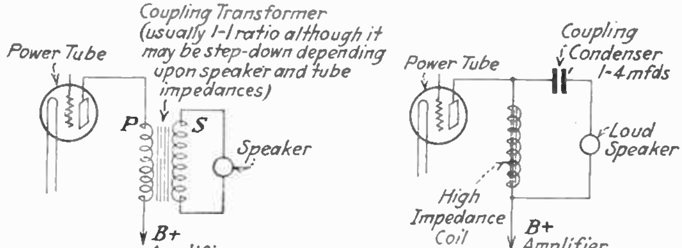


FIG. 75.—Two methods of connecting a loud speaker.

the magnetic material used in the speaker and the method in which the speaker is connected in the circuit.

For example, if the loud speaker is connected in a circuit in which the current flow through it is excessive, the magnet winding may burn out, but if the design is for a heavy current flow through the winding, it will not burn out. If, however, the current flow is heavy and a poor grade of magnetic material is used, then it is very possible that a reversal of polarity will distort the molecules in the magnetic material, resulting in a demagnetization of the speaker.

Two methods for connecting a loud speaker in an amplifier-plate circuit to prevent it from demagnetizing or burning out are illustrated in Fig. 75.

The speaker may, however, be connected directly in the plate circuit if the voltage does not exceed 135, but even then a poor grade of magnetic material in the speaker may be demagnetized upon reversal of polarity.

Ques. 373. A circuit has a fundamental frequency of 700 kilocycles per second. What is the wave length emitted?

Ans.

$$\lambda = \frac{N}{f}$$

Where λ = wave length in meters
N = speed of electromagnetic waves in meters per second
f = frequency in cycles per second

1 kilocycle = 1,000 cycles, 700 kilocycles = 700,000 cycles,

Thus,

$$\lambda = \frac{300,000,000}{700,000} = 428 + \text{meters}$$

Ques. 373*a*. How would you convert 600 meters into kilocycles?

Ans. To convert wave length into kilocycles, divide the wave length into the speed of electromagnetic waves in meters per second.

$$F = \frac{N}{\lambda}$$

Hence,

$$\frac{300,000,000}{600} = 500,000 \text{ cycles or } 500 \text{ kilocycles}$$

Ques. 374. What is capacity, inductance, reluctance, impedance, potential?

Ans. The *capacity* of a condenser is defined as the quantity of electricity (charge) that it contains when the electrical pressure between the two sets of plates is unity or one. In practical systems of units, a condenser is said to have a capacity of 1 farad if it holds a charge of 1 coulomb when a pressure of 1 volt exists between the plates. A condenser is sometimes referred to as a device which stores up energy in a strained or electrostatic form.

Inductance is the property of a circuit by virtue of which a current flowing through it causes a magnetic field to be set up and linked with that circuit and, possibly, also, with one or more neighboring circuits. In cases where the flux produced is linked with the circuit carrying the current, the term *self-inductance* is used, and where a magnetic flux produced by a current in one circuit is linked with a second circuit, *mutual inductance* is said to exist between the two circuits.

Self-induction may be defined as a phenomenon whereby an e.m.f. is induced in a circuit itself when the current in the circuit changes or varies. The e.m.f. induced is always in a direction opposite to the impressed e.m.f. when the current is rising.

Mutual induction may be defined as that phenomenon between two circuits *A* and *B* whereby an e.m.f. is induced from circuit *A* into circuit *B* when the field in the circuit *A* expands and contracts due to a varying current flowing in it.

Reluctance is the opposition offered by a magnetic circuit to the passage of a flux through it. Reluctance is the same to a magnetic circuit as resistance is to an electrical circuit.

Impedance is the total opposition offered by a circuit to the passage of an alternating current and is given by the ratio of voltage to current, being measured in ohms.

Potential and Potential Difference.—In electrostatics, the potential at a point is defined as the work done in bringing a unit positive charge from an infinite distance away to that point, and the potential difference between two points as the work done in moving a unit positive charge from the one point to the other. Thus, potential is that which tends to drive electricity from one point to another and may be looked upon as a sort of electrical "pressure" which tends to drive electricity from a point where the potential is high to a point where it is low.

Similarly, in electrical circuits, the potential difference between two points (such as the ends of a resistance) is the difference of electrical pressure between those points driving or tending to drive current from one point to the other.

Ques. 375. What is meant by skin effect?

Ans. The high-frequency resistance due to the non-uniform distribution of current throughout the cross-section of a linear conductor. It is caused by the variations in the intensity of the magnetic field due to the current in the conductor. It is the tendency of a high-frequency current to travel along the outer surface (skin) of its conductor.

Ques. 376. State Ohm's law in full. How would you find the resistance in a circuit if the voltage and current are known?

Ans. Ohm's law:

The current strength in any direct current circuit is equal to the e.m.f. applied to the circuit, divided by the resistance of the circuit, or

$$I = \frac{E}{R}$$

where I = the current flow in amperes
E = the e.m.f. in volts
R = the resistance in ohms

The amount of e.m.f. required to maintain a certain current strength in which the resistance is known is equal to the product of the current and the resistance, or

$$E = I \times R \text{ expressed } E = IR$$

To find the value of the resistance required to be inserted in any circuit, so that a given current will flow under a known pressure: the resistance is equal to the pressure to be applied, divided by the current strength that is to be maintained, or

$$R = \frac{E}{I}$$

Thus, if it is desired to find the resistance where the voltage and amperage are known, apply the formula above.

Ques. 377. Explain the difference between current strength and quantity.

Ans. *Current strength* in an electrical circuit means the *rate of flow* of an electrical current and is expressed in *amperes.*

The distinction between *rate of flow* and *quantity* (expressed in coulombs) may be readily seen from the following example: Let us assume a stream of water flowing at the *rate* of 1 gallon per second. At this *rate* the amount of water delivered to a tank in 1 hour would be 3,600 gallons. This figure would be expressed as the *quantity* of water flowing. Likewise, electrically, the *rate of flow* (current strength) refers to the number of amperes that flow in a circuit regardless of total time, whether in seconds or hours. If the quantity of electricity in coulombs is to be determined, the length of time of flow and number of amperes flowing must be known. Thus, to find the quantity in coulombs, the current (amperes) must be multiplied by the time of flow in seconds.

$$\text{Coulombs} = I \times t$$

Ques. 378. What three factors determine resistance?

Ans. Character of the material, length, and cross-section.

Ques. 379. How many watts are expended across an arc having a hot resistance of 20 ohms at 300 volts?

Ans. To find wattage, multiply the voltage by the amperage, or

$$W = E \times I \text{ (direct-current circuits)}$$

The current must first be determined by Ohm's law:

$$I = \frac{E}{R} \text{ or } I = \frac{300}{20}$$

$$I = 15 \text{ amperes}$$

Hence,

$$W = 15 \times 300$$

or

$$4{,}500 \text{ watts (4.5 kilowatts)}$$

Ques. 380. Name three kinds of electricity, and give an example of each.

Ans.

Kind of electricity	Produced by
1. Frictional....................	Static machine
2. Chemical....................	Primary and secondary cells
3. Dynamic....................	Alternators and generators

Ques. 381. What are three ways of telling the presence of electricity?

Ans. Indicating devices such as the galvanometer, gold-leaf electroscope, and the glow indicator (ionized tube).

Ques. 382. Draw a diagram using nine dry cells which will give the highest voltage; nine dry cells which will give the highest current; nine dry cells which will give 4.5 volts.

Ans. See Fig. 76.

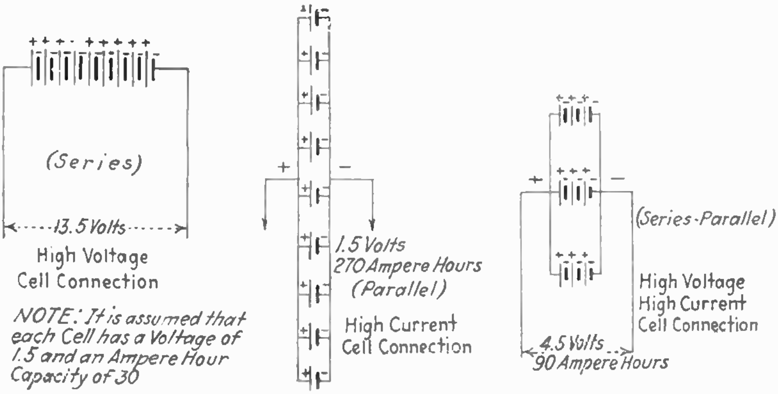


FIG. 76.—Methods of connecting dry cells.

Ques. 383. Draw a diagram of a voltmeter, ammeter, and wattmeter in an alternating-current power circuit.

Ans. See Fig. 77.

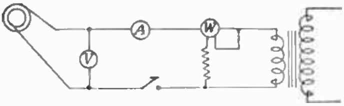


FIG. 77.—Meters in power circuit.

Ques. 384. Draw a circuit showing three resistances:

a. **In series**

b. **In parallel,**

c. **In series-parallel.**

Ans. See Fig. 78.

Ques. 385. Draw a diagram of ten cells in series; in parallel; in series-parallel.

Ans. See Fig. 76; add one additional cell.

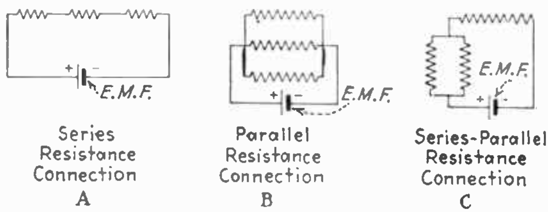


Fig. 78.—Methods of connecting resistances.

Ques. 386. Show a sketch of a wire carrying current, and mark the direction of the lines of force (magnetic lines) around the wire.

Ans. See Fig. 79.

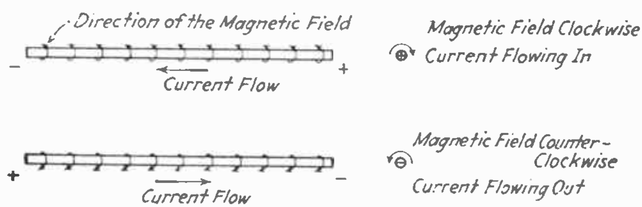


Fig. 79.—Wire carrying current showing lines of force.

Brief Bibliography

Nilson and Hornung: "Practical Radio Telegraphy," McGraw-Hill Book Company, Inc.

"Principles Underlying Radio Communication"—U. S. Signal Corps, Supt. of Documents, Govt. Printing Office, Washington, D. C.

Morecroft: "Principles of Radio Communication," John Wiley & Sons, Inc.

Lauer and Brown: "Principles of Radio Engineering," McGraw-Hill Book Company, Inc.

"Radio Instruments and Measurements," *Bur. Standards Circular* 74, Supt. of Documents, Govt. Printing Office, Washington, D. C.

Lewis, E. H.: "The A. B. C. of Vacuum Tubes," The Norman Henley Publishing Company.

Croft: "Practical Electricity," McGraw-Hill Book Company, Inc.

Swoope: "Lessons in Practical Electricity," D. Van Nostrand.

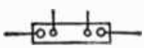
SYMBOLS


Alternator (single phase)


Alternator (two phase)

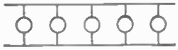

Alternator (three phase)


D.C. Generator


Ammeter Shunt


Circuit Breaker

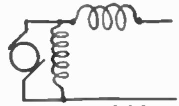
Frequency Meter

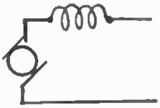

Lamp Bank

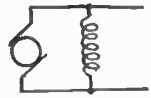

Link Fuse


Enclosed Fuse

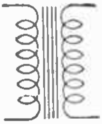

Plug Fuse

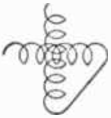

Compound Motor

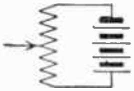

Series Motor


Shunt Motor


Filament Switch (S.P.S.T.)


Audio Frequency Transformer


Variometer


Voltage Divider (potentiometer)

Voltmeter

Wattmeter

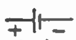
The symbols following are reproduced by permission of The Institute of Radio Engineers

Ammeter

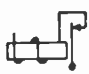

Antenna or Aerial


Arc


Battery

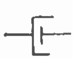


Battery (polarity indicated)


Buzzer


Coil Antenna

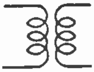

Condenser, Fixed

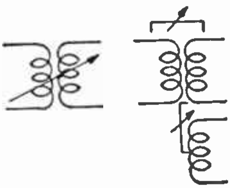

Condenser, Shielded


Condenser, Variable


Condenser, Variable (with moving plate indicated)


Counterpoise


Coupler, Inductive (mutual inductor)


Coupler, Inductive (with variable coupling)


Crystal Detector

Frequency Meter (wavemeter)

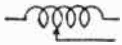
Galvanometer


Ground


Inductor


Inductor, Iron Core


Inductor, Variable


Inductor, Adjustable


Jack


Key


Lightning Arrester


Resistor


Resistor, Variable


Spark Gap, Non-synchronous


Piezoelectric Crystal


Spark Gap, Plain


Spark Gap, Quenched


Spark Gap, Synchronous

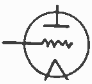

Telephone Receiver


Loud Speaker


Telephone Transmitter (microphone


Thermo-element


Transformer


Vacuum Tube, Triode


Vacuum Tube, Diode

Voltmeter


Wires, Joined


Wires, Crossed not Joined

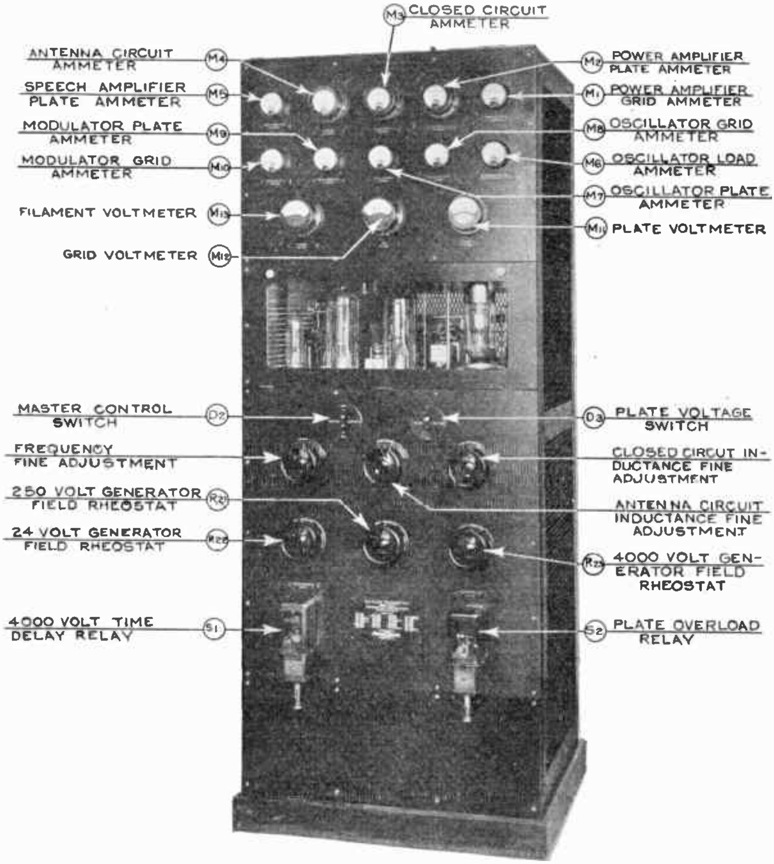


Plate V.—Front view, Western Electric broadcasting transmitter, type 6A, 1 K. W. (*Courtesy*, Western Electric Company.)

PART X

BROADCASTING TRANSMITTERS AND DEFINITIONS

Ques. 387. Draw up a schematic wiring diagram of a complete broadcasting transmitter with the following parts: double-button carbon microphone, single-stage microphone amplifier, two-stage power amplifier, transmitting set using Heising system of modulation. Discuss the function of all parts.

Ans. Figure 81 illustrates a schematic wiring diagram of a complete broadcast transmitter, including a double-button carbon microphone, single-stage microphone amplifier, two-stage power amplifier, and the Heising system of modulation.

Part I

In this circuit, the microphone-diaphragm vibrations produce electrical variations due to the changes in resistance brought about by the compressing and releasing effect of the carbon granules. These variations are very feeble in amplitude and must, therefore, be suitably amplified before they can be passed to the modulator tubes.

The 400 ohms resistance enables the proper adjustment of current flow of 18 to 20 milliamperes through the microphone and transformer primary circuit. The variations are then passed through a transformer to an amplifier properly controlled by the 400-ohms volume resistor.

Part II

This circuit contains the single-stage microphone amplifier necessary for increasing the feeble variations produced by the microphone diaphragm.

Part III

This section is the two-stage amplifier for increasing the slightly increased microphone variations to a higher level so that the proper signal volume will be impressed upon the modulator grids.

PART IV

First, assume the oscillatory circuit of Part V to be properly adjusted to oscillate at a definite frequency (wave length).

Assume, therefore, a steady plate current flowing in both the oscillator and modulator plate circuits when no signal is impressed upon the modulator grids.

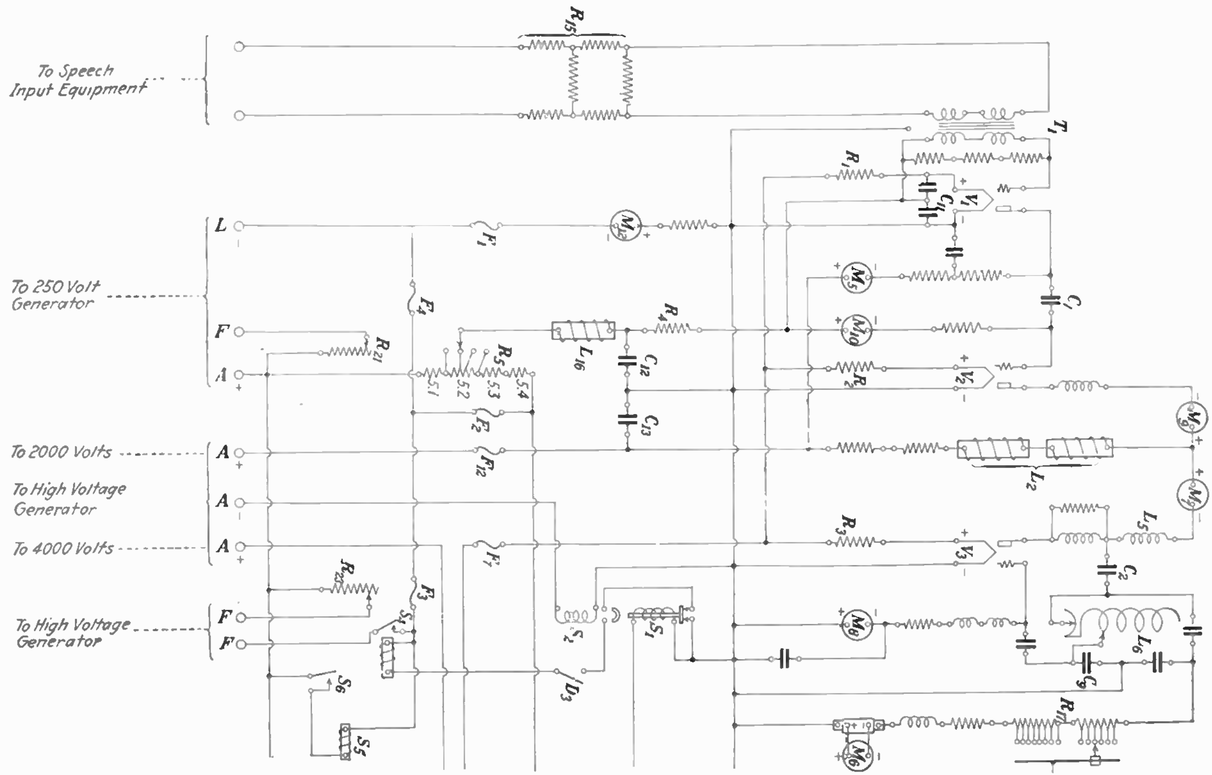
When the microphone is set into vibration due to impressed sound waves, the feeble variations are amplified to the proper level through the single-stage speech amplifier and the two-stage power amplifier and are then impressed upon the modulator grids.

The alternating e.m.f.'s. on the grids of the modulator tubes cause the plate current to vary accordingly. The plate current, however, is maintained very steadily due to the high inductance (choke coil) in the modulator plate circuit. Thus, when the modulator grids receive a positive charge from the signal variations, the choke coil will tend to prevent any change in the plate-circuit current, which causes the modulator tubes to draw away some current from the oscillator tubes, and the oscillator current, consequently, decreases. Then, when the modulator grids become negative, due to the signal variation, the modulator plate current will tend to decrease, and the oscillator plate current will again increase, all of this being due to the choke coil maintaining steadily the current supply to both modulator and oscillator tubes.

It is, therefore, quite obvious that the oscillator plate current is varied at an audio or speech frequency, and, consequently, the radiofrequency antenna current is correspondingly varied.

PART V

This is the high-frequency generating circuit which carries the modulated wave in electromagnetic form to be transferred into the antenna system and radiated.


To Speech Input Equipment
To 250 Volt Generator
To 2000 Volts
To High Voltage Generator
To 4000 Volts
To High Voltage Generator
L
F
A
A
A
A
F
F
R15
T1
R1
C11
V1
M12
F1
F4
M5
C1
R4
M10
L16
R21
R5
5.1
5.2
5.3
5.4
C12
R2
V2
C13
F2
M9
F12
L2
M4
R3
V3
L5
F7
C2
R20
F3
S4
S2
S1
M8
L6
C9
S6
D3
R17
S5
M6

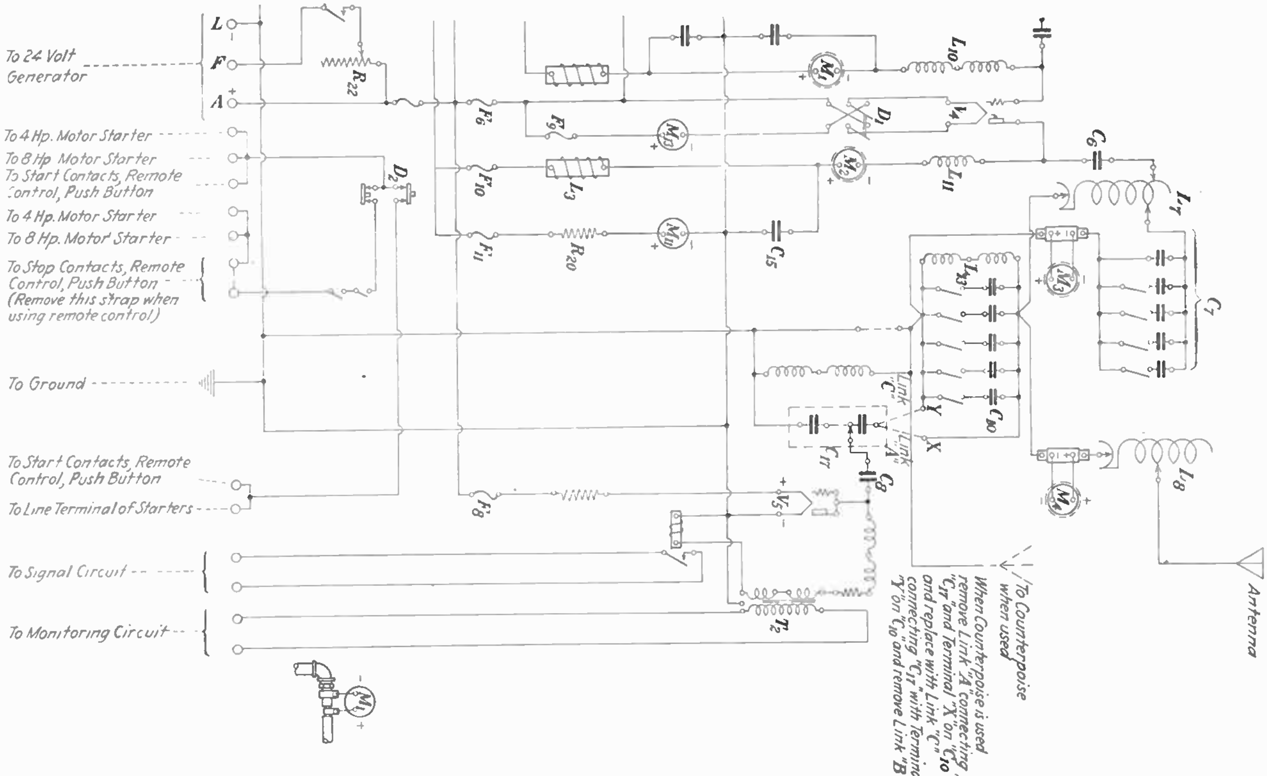


FIG. 80.—Wiring diagram, Western Electric broadcast transmitter 6A.

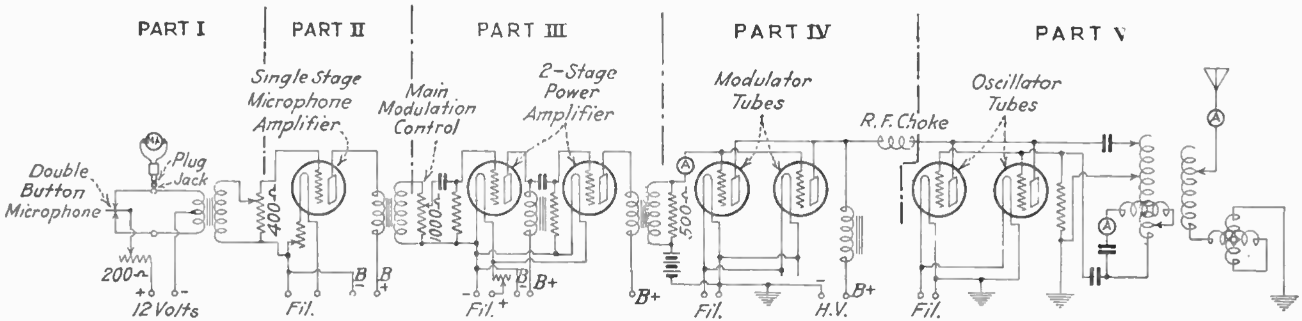


FIG. 81.—Simplified schematic wiring diagram of a broadcast transmitter.

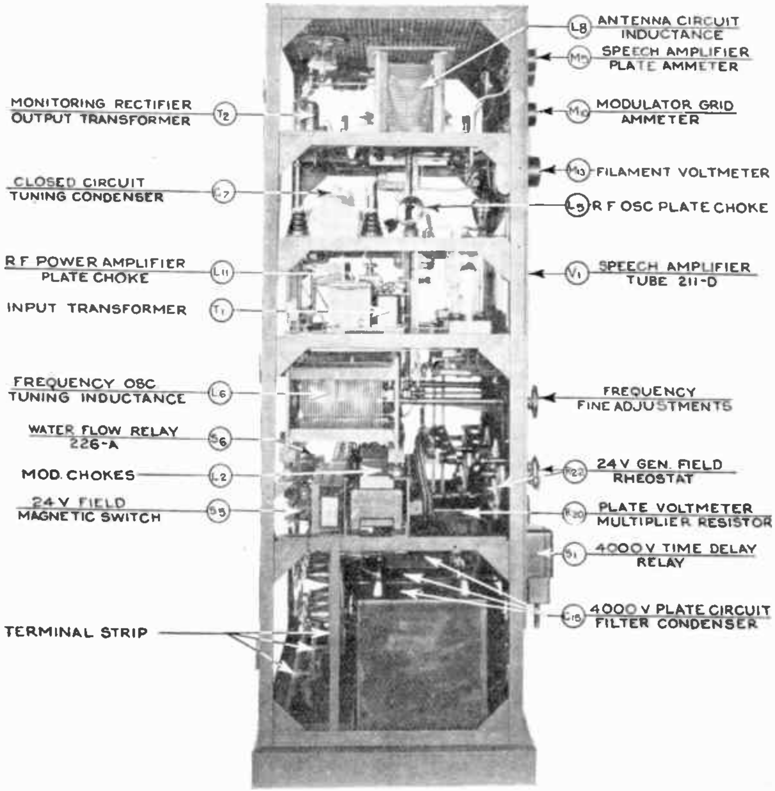


PLATE VI.—Left side view, Western Electric broadcasting transmitter, type 6A, 1 K.W. (*Courtesy*, Western Electric Company.)

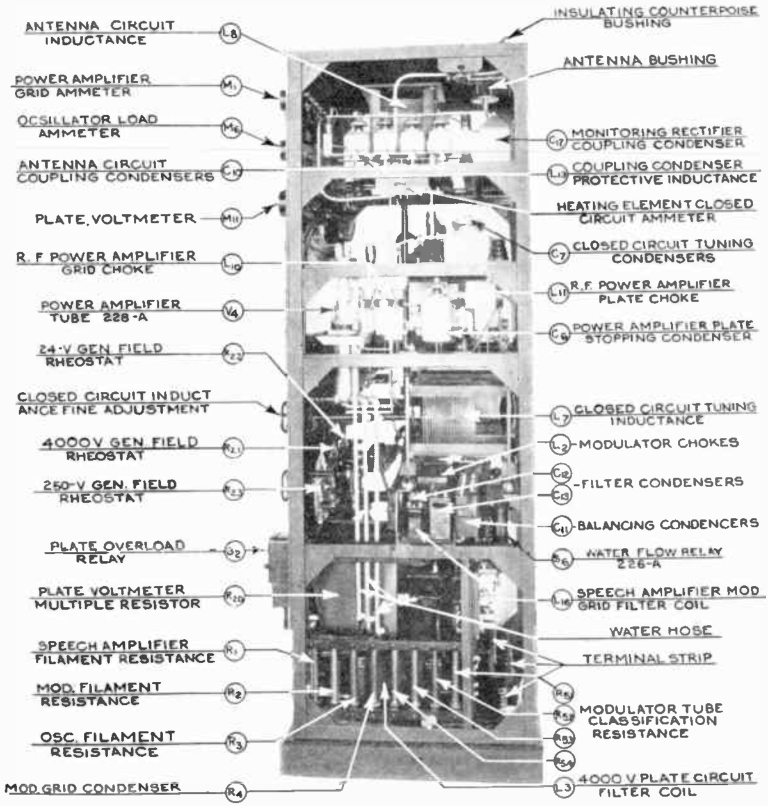


PLATE VII.—Right side view, Western Electric broadcasting transmitter, type 6A, 1 K. W. (*Courtesy*, Western Electric Company.)

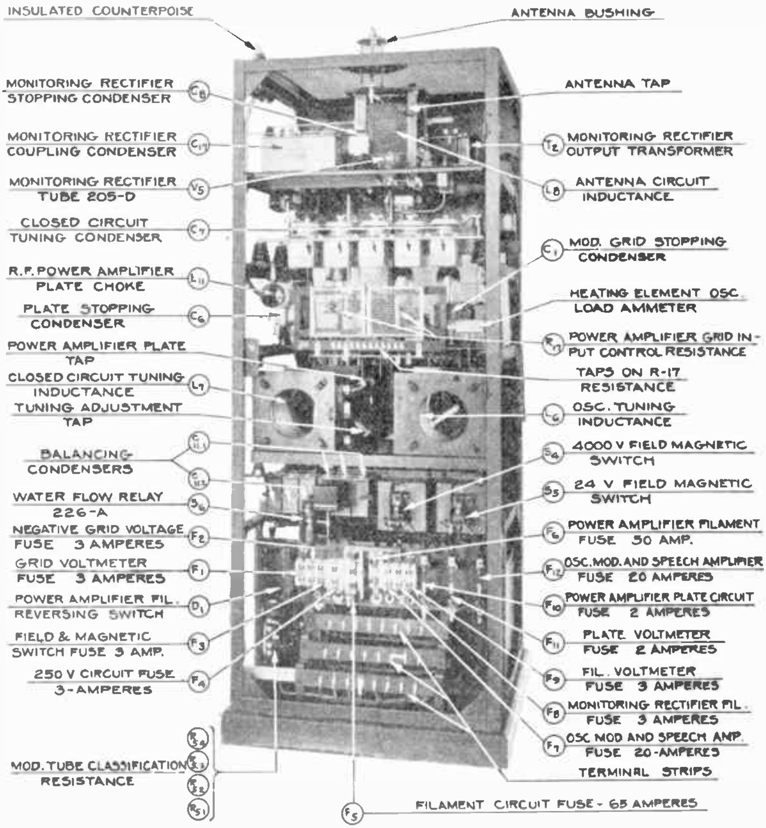


PLATE VIII.—Rear view, Western Electric broadcasting transmitter, type 6A, 1 K. W. (*Courtesy*, Western Electric Company.)

Ques. 388. Describe the construction of a high-quality carbon microphone transmitter. What is the effect of excessive direct current on such a microphone? How would you test for button balance? Define packing; blasting. What is the remedy for each?

Ans. The construction of a high-quality carbon microphone is illustrated in Fig. 82 and Fig 82*A*.

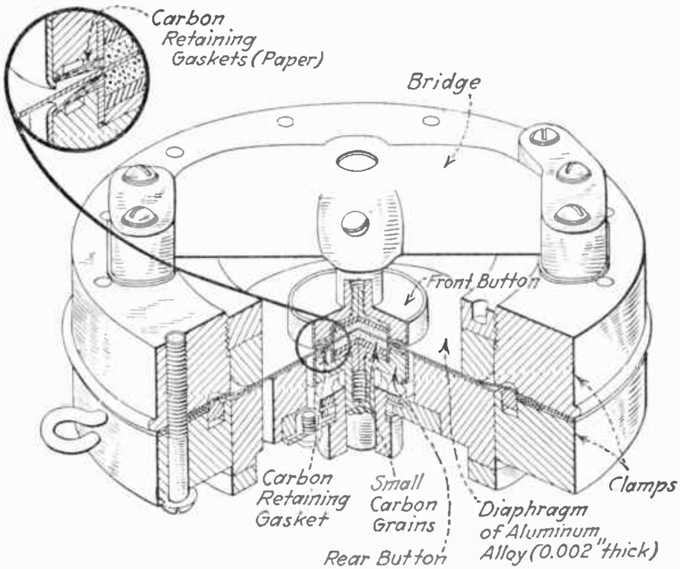


FIG. 82.—Cross-sectional view of carbon microphone.

This unit is mounted in a frame and is supported by springs so that mechanical vibration cannot impair the quality.

If excessive current is passed through the microphone, the carbon granules will become "packed," and any sound wave impressed upon the diaphragm may not produce the proper compressing and releasing action of the carbon granules, and, consequently, no change in resistance results. It is the change in resistance, due to the compressing and releasing effect, which causes the electrical variations in the circuit to which the microphone is connected.

Figure 83 illustrates a telephone-mixing panel using three microphones and shows the variable-resistance units for adjusting

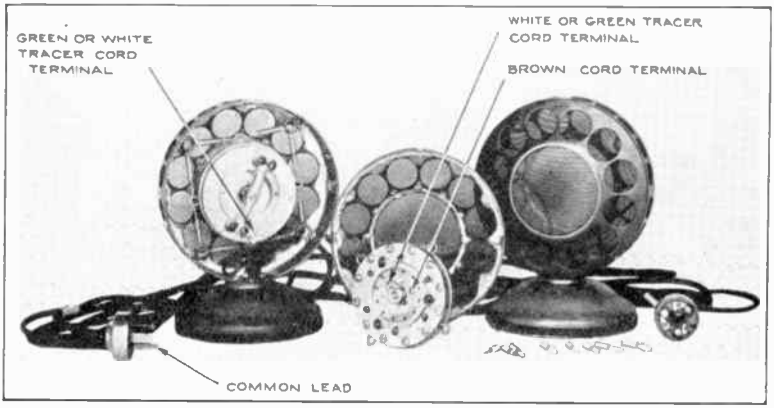


FIG. 82a.—View of parts, Western Electric broadcasting microphone transmitter No. 373-W and No. 387-W with 1-B transmitter mounting, No. 788 cord and plug. (*Courtesy*, Western Electric Company.)

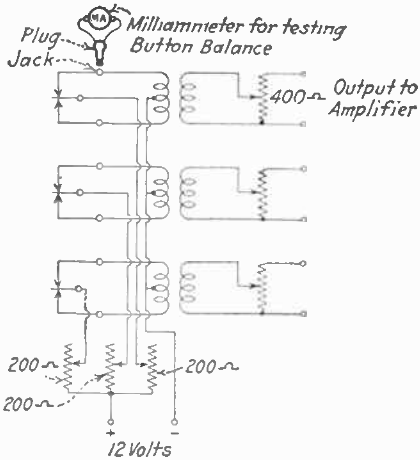


FIG. 83.—Mixing panel.

each microphone to the proper balance. The current must first be disconnected and the microphone shaken to rearrange the carbon granules in the unbalanced side, or, if the current is on, the granules may be rearranged by blowing into the unbalanced side.

Each "button" microphone has a jack, as shown in Fig. 83, into which a milliammeter can be plugged for testing button balance. This should be between 18 and 20 milliamperes. A carbon microphone should never be moved with the current on, as this will ruin the microphone very rapidly.

Packing is the effect previously mentioned where the carbon granules are too heavily compressed due to excessive microphone current.

Blasting is the overloading of the amplifier grids due to excessive microphone pressure. This condition is usually prevalent with powerful soprano vibrations. Blasting is considerably minimized if the microphones are properly placed as in Fig. 87 and the volume decreased.

For example, if No. 3 microphone is used, then No. 1 is omitted, but No. 2 is cut down about one-half at the mixer panel.

Ques. 389. When is negative grid bias used in an amplifier, and what is the effect on quality? What is "plugging" or overloading of tubes in an amplifier? Give two ways by which it may be detected.

Ans. A negative grid bias is used in an amplifier when the plate voltage is in excess of 90 volts to prevent the grid from becoming positive.

When the proper grid bias is applied for a given plate voltage and given tube characteristics, the quality of the amplifier is at its best, provided, of course, that all the other apparatus is properly adjusted and designed.

"Plugging" or "overloading" of tubes refers to an excessive grid variation applied to the amplifiers from the feed circuit, which will result in an increase of the plate-current variations, possibly producing considerable distortion. Overloading of an amplifier tube due to too heavy impressed grid variations may be minimized by increasing the negative grid bias to overcome the excessive grid-current flow. This will, however, alter the efficient operating characteristic of the tube, and, therefore, the overload tendency should be eliminated by decreasing the input to the amplifier grids.

Two methods of detecting an overload in the amplifier are inserting an ammeter in the plate circuit and inserting one in the grid circuit of the amplifier tube.

For example, if the plate ammeter under normal operating conditions reads 100 milliamperes, then as soon as a signal variation is applied to the grid no change in the plate-current reading should result. If the meter pointer fluctuates above and below 100 milliamperes, it is a sure indication that the amplifier tube is overloaded.

Ques. 390. How may the percentage of modulation of a broadcasting transmitter be checked? What is a volume indicator?

Ans. The percentage of modulation may be checked by having a suitable indicating device in the plate circuit of the modulator tube. This device usually consists of an alternating-current voltmeter calibrated in microvolts in conjunction with a specially designed transformer.

A volume indicator indicates the volume level of the program supplied by the amplifier to the radio transmitter. This panel consists of a variable switch and contacts, filament rheostat, potentiometer, and a millimilliampere galvanometer. This panel gives readings in terms of a unit of power used in telephone engineering known as T U (transmission unit). The T U is used in power measurements because of its convenience from a technical standpoint over the older unit, the watt. When power measurements are made in T Us a certain value is selected which is known as *zero level.* This does not mean absolute zero in power but merely a certain set value of power. For example, if the panel is calibrated on the basis that the zero level is 0.005 watt, then any amount of power less than 0.005 watt will be indicated by the negative (−) on the panel contacts, provided, of course, the measurements are made in T Us. Thus, if the amount of power is more than 0.005 watt, it will be indicated on the panel contacts as positive (+); and by observing the number of units above or below the zero level, an actual indication of the loudness of the sound may be obtained by referring to the amount of deflection either plus (+) or minus (−) on the meter.

Figure 84 illustrates the panel arrangement of the switch and meter together with the filament rheostat and grid-bias control.

The bias control should be varied so that the galvanometer needle gives a constant deflection of five divisions when there is no input to the volume-indicator panel.

In addition to the level-measuring switch there is another switch of the D.P.D.T. "cam" type for inserting larger steps should the smaller level switch not give the proper result.

The large steps are from 0 to +16, and +30 T U, and the small ones are each 2 T U and cover a range of 20 T U from −10 to +10 T U.

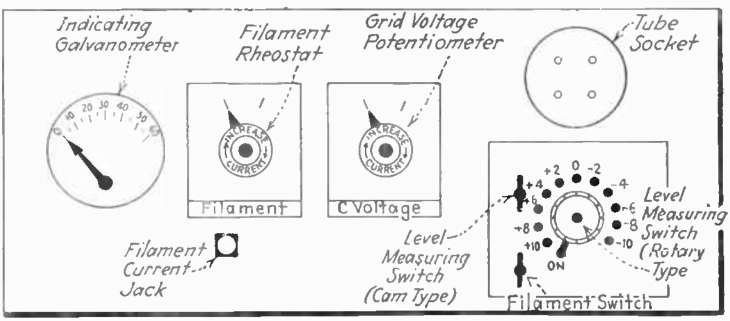


FIG. 84.—Volume indicator.

For example in the 1 K. W. Western Electric 6A transmitter the correct volume level to the transmitter can be determined by taking the algebraic sum of the D.P.D.T.-cam-switch and the rotary-switch settings when the needle on the galvanometer swings to 30 divisions about once in 10 seconds during transmission. On other transmitters this may vary between 5 and 10 seconds.

In other words, the volume level applied to the 6A transmitter can be measured by adjusting both switches until the 30-division deflection is obtained once in every 10 seconds and taking the algebraic sum of the switch settings as the reading. For example, if the setting of the D.P.D.T. cam switch is +30 and the reading of the rotary switch is −8, then the energy of level measured is 30 − 8 or 22 T U.

A table showing the relative power ratios in T Us follows:

T U	Power Ratio
1	1.26
2	1.6
3	2.0
4	2.5
5	3.2
6	4.0
7	5.0
8	6.3
9	8.0
10	10
20	100
30	1000
40	10,000
50	100,000
60	1,000,000
70	10,000,000
80	100,000,000
90	1,000,000,000

Ques. 391. In testing the wave length, or frequency, of a circuit, should the wavemeter (frequency meter) be placed near to, or at some distance from, the circuit in question? Why?

Ans. If the circuit to be tested is a part of the transmitting system, the wavemeter should be placed at a safe distance (depending upon the power being used) to prevent excessive induction and possible damage to the meter.

If the wavemeter is brought too close to the transmitter, the indicating device of the wavemeter may burn out, or, if the transmitter in question is a high-power broadcast transmitter, the wavemeter coil may burn up.

Ques. 392. Approximately what band of audiofrequencies must a broadcasting system transmit in order to deliver natural-sounding speech?

Ans. The approximate band of frequencies to deliver natural-sounding speech is between 60 and 6,000 cycles.

Ques. 393. How are broadcasting studios built to decrease reverberation?

Ans. The studio ceiling and walls are covered by an acoustical treatment consisting of 1-inch-thick, special acoustical hair felt next to the wall, with a layer of muslin stretched over the hair felt and spaced from it by ½ inch of air space. The muslin is painted with a sound-transmitting paint, which allows the hair-felt wall covering to absorb the sound. The muslin is provided only to give a better appearance to the room. This covering of hair felt and muslin extends to a line on the walls about 3 feet above the floor. From this line down, a solid material, such as gypsum wall board, may be used.

Another method is to use a material known as *Celotex*, instead of hair felt. *Celotex* lends itself to an attractive finish, which makes the use of a muslin covering unnecessary.

Heavy curtains or drapes may be used in certain places to control reverberation time.

The floor is covered with thick carpet, and the furniture is heavily cushioned.

A studio room treated in the manner described above will have the relatively short and desirable reverberation time so necessary to good broadcasting.

Ques. 394. Show by diagram how you would place the microphone and instruments in picking up an orchestra consisting of violin, banjo, saxophone, cornet, and piano.

Ans. Figure 85 illustrates the proper placement of a microphone in picking up an orchestra consisting of violin, banjo, saxophone, cornet, and piano.

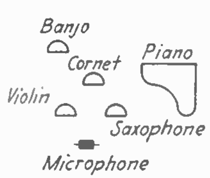


FIG. 85.—Instrument placement before microphone, small orchestra.

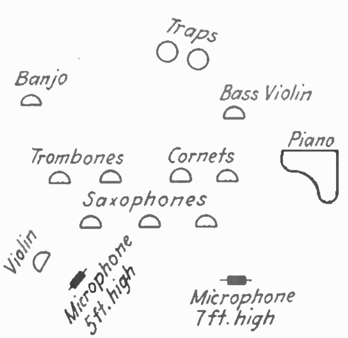


FIG. 86.—Instrument placement before microphone, jazz band.

Figure 86 illustrates one of the most efficient arrangements for a jazz band consisting of trombones, cornets, violin, piano, bass violin, banjo, saxophones, and traps.

Figure 87 illustrates a very efficient arrangement of a large orchestra in a studio.

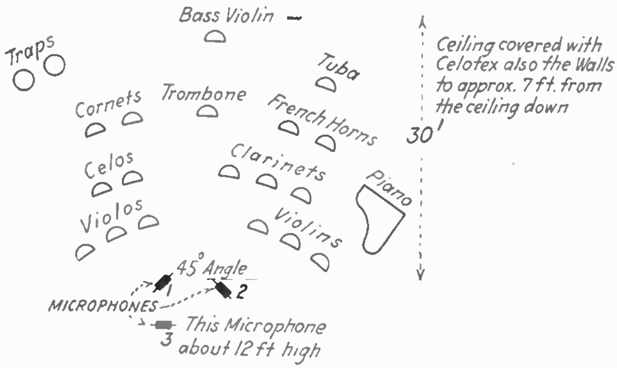


FIG. 87.—Instrument placement before microphone, large orchestra.

DEFINITIONS RELATING TO BROADCASTING

Acoustics in broadcasting has to do with the ability of a studio to produce echoes.

Carrier.—The carrier wave is the high-frequency continuous wave generated by the vacuum-tube oscillators upon which the audiofrequency modulations are superimposed.

Echo.—The repetition of sound caused by the reflection of the sound waves.

Frequency.—The number of vibrations or cycles produced in a second of time.

Fundamental Note.—A basic vibration, free from harmonics. It might, however, be referred to as a generating tone for a series of harmonics.

Modulation.—To form into a certain pitch or key or to a certain proportion. To vary or inflect in a natural or musical manner.

The variation of an audiofrequency of the amplitude of the high-frequency oscillations in a radio-telephone transmitter, in accordance with the wave shape representing the low-frequency or speech vibrations.

Modulation, Over.—The improper forming of sounds to a certain proportion and generally referred to as "crowding."

Modulation, Percentage.—Refers to the degree or amplitude in which the modulated variations are impressed upon the oscillator tubes without producing distortion. In modern broadcasting systems, it has been found that a 40 per cent modulated signal produces very fine quality in the transmitted program. If the signal could be modulated at about 90 per cent, extremely fine quality could be obtained. A transmitter designed for this percentage of modulation, however, would be extremely expensive and for this reason is probably not now in general use.

Musical Tone.—A sound having such regularity of vibration as to impress the ear with its individual characteristic, especially in regard to pitch, and to enter into harmonic relations. A tone is characterized by its pitch (rate of vibration), its force (amplitude of vibration), and its timbre (complexity of vibration). A simple tone is one resulting from a vibration at a fixed rate. Its pitch is definite, therefore, although its force may vary, and it can hardly be said to have timbre. But nearly all musical sounds are complex (composite or compound), that is, composed of two or more tones. These components are called *partial tones*, of which the lowest, which predominates and determines the pitch, is called the *fundamental tone*, or fundamental, and the others, *upper partials* and *overtones*. The peculiar quality or timbre of a tone is due to the number, vibration rates, and intensities of its overtones and varies with the nature of the vibrating body and the method of excitation. Overtones which are in the harmonic series of the fundamental (that is, having vibration numbers equal to two, three, four, five, etc., times that of the fundamental) are called *harmonics*.

Noise is either a sound of a too short duration, or else it is a confused mixture of discordant sounds. In broadcasting, any sounds which originate in the studio and are independent of the program emitted, which are foreign to the program, might be referred to as noise or undesirable sounds.

Overtones.—A partial tone, sounded by a simple vibration which is one of the component vibrations of a complex musical tone. The term is usually applied to any of the upper partial tones as distinguished from the fundamental tone or first harmonic vibration.

The highest and lowest fundamental pitches on a piano in cycles per second are approximately 5,000 to 27 cycles, respectively.

Period is that length of time it takes the first echo to resound after the fundamental note has been sounded. The time between a phase of vibration and its recurrence.

Resonance.—The ability to return the sound or the echo. A prolongation or increase of sound due to the sympathetic vibration of some body capable of moving in the proper period. For example, if a tuning fork is placed near another object of the same pitch or a harmonic of the pitch, the latter will also sound. A body shaped as a sounding board, such as a piano or violin, is capable of vibrating in various ways and in doing so reinforces any of a number of tones. This is due to the excitation of the air particles in the immediate vicinity or in the enclosures of the musical instruments.

Reverberation, as applied to acoustics, refers to the act of causing reflection of sound waves; reechoing sound.

Reverberation time is defined as follows: Assume a sound source to produce a sound intensity (energy) at a given point in a room of one million times the energy, which would be just audible; if this source be stopped, the reverberation time is the time taken for the sound energy at that point to fall to a just audible value. Reverberation time in various studios varies from 0.4 to 0.7 second as compared to approximately 1.1 seconds for an ordinary studio-size room, the walls of which are not covered with reverberation-reducing material.

Side Bands.—The bands of frequencies on either side of the carrier frequency, produced by the process of modulation.

For example, assume a high-frequency continuous oscillation at 600,000 cycles per second (500 meters) having a low frequency of, say, 1,000 cycles superimposed upon it. The result will be a variation in the amplitude of the high-frequency oscillation at 1,000 cycles per second which will produce an unsteady oscillating condition. This unsteady condition is the result of the three high frequencies producing an interaction, just as in the case of beat reception of continuous-wave signals. Thus, in this particular example, the three waves will have frequencies of 599,000, 600,000, and 601,000 cycles per second, respectively, in which the middle frequency is called the *true carrier wave.* The upper and lower frequencies of 599,000 and 601,000 cycles, respectively, are called the "lower" and "upper" side frequencies. Thus, any interaction of either of the side frequencies with the carrier frequency will produce a beat note of 1,000 cycles per second.

In broadcast transmission, several or many audiofrequencies may be superimposed simultaneously upon the carrier wave, and, therefore, there will be a number of "lower" and "upper" side frequencies below and above the carrier frequency, and these bands of frequencies are termed the *lower-side-band* and *upper-side-band* frequencies, respectively.

It is this interaction of all the frequencies in the "side bands" in conjunction with the carrier wave which make the complex wave forms of speech and music.

Speech, drummy, is referred to as a decidedly low-frequency tone characteristic devoid of practically all the high frequencies. This is caused by the amplifier passing the low frequencies only.

Speech, tinny, is referred to as a decidedly high-frequency tone characteristic devoid of practically all the low frequencies. This effect is due to the amplifier passing the high frequencies only.

Brief Bibliography

GOLDSMITH, ALFRED N.: "Radio Telephony," Wireless Press.

Proceedings of The Institute of Radio Engineers as follows:

BAKER, W. R. G.: "Description of W. G. Y., Schenectady," August, 1923.

LITTLE, D. C.: "Description of K. D. K. A., Pittsburgh," June, 1924.

NELSON, E. L.: "Transmitting Equipment for Broadcasting," October, 1924.

WEINBERGER, J.: "R. C. A. Broadcasting Stations," December, 1924.

LITTLE and DAVIS: "K. D. K. A.," August, 1926.

Information regarding the procuring of the above *Proceedings* may be obtained by addressing The Institute of Radio Engineers, 33 West 39th Street, New York, N. Y.

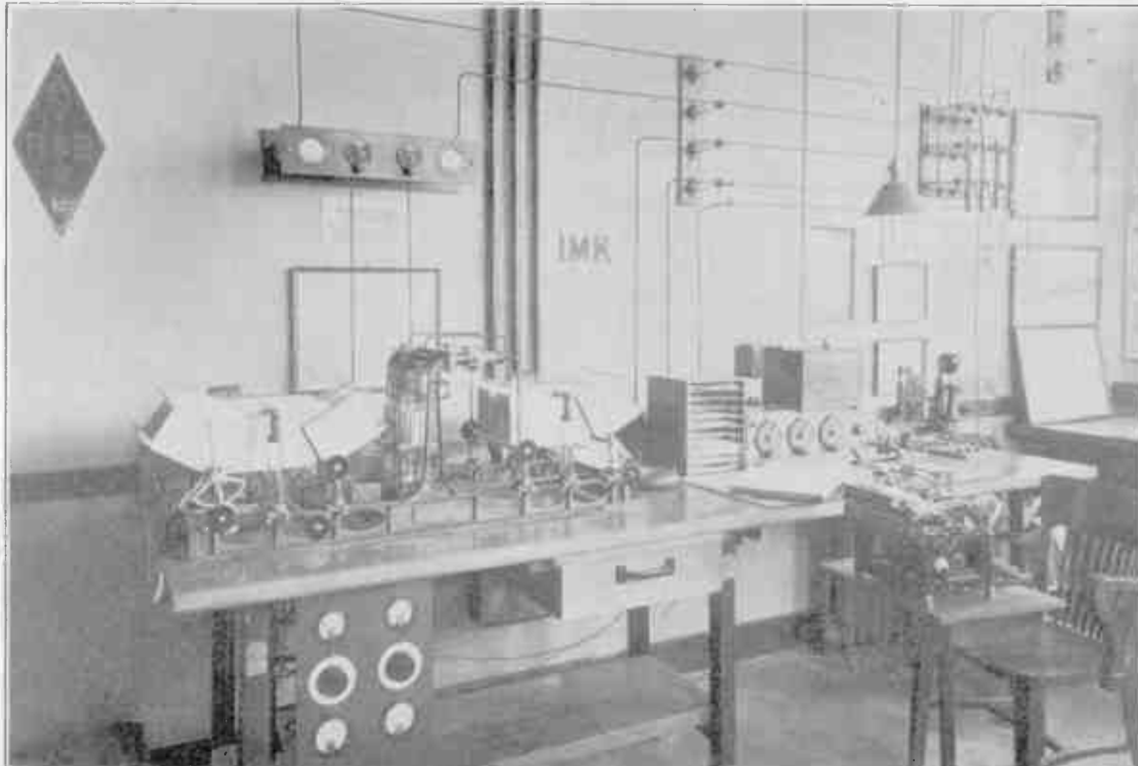


PLATE IXA.—American Radio Relay League (A.R.R.L.) Headquarters station W1MK.

This station has two transmitters. The main one, a 500 watt tuned-plate tuned-grid transmitter with interchangeable coils for the different amateur frequencies is shown on the table. An auxiliary transmitter, shown under the table, is a 250 watt Hartley permanently tuned to a given wave in the forty-meter band. (*Courtesy*, American Radio Relay League.)

PLATE IXB.—Station W1MK power supply.

The power-supply equipment illustrated above is contained in a seperate room and either motor-generator or mercury-arc supply is available by means of switches on the operating table. (*Courtesy*, American Radio Relay League.)

PART XI

AMATEUR STATION OPERATION

Ques. 395. Describe completely the operation of an amateur transmitter. Draw diagram.

Ans. The complete operation of the transmitter illustrated in Figs. 88 and 89 is as follows:

When the filament switch is closed and the plate-supply voltage is connected, a *steady* plate current flows from $B+$ through L_3, MA, P to F and back to $B-$. This conventional plate-current flow is a result of the electronic emission from the filament to the plate when the latter is connected to a positive potential and is indicated at the milliammeter MA. No plate current can flow through the oscillatory circuit due to the blocking action of C_3. As soon, however, as the plate current flows, at the instant when the filament circuit is closed, a displacement current flows in C_3 which excites the oscillatory constants L_2, C_2, and C_4 and, hence, the grid. This grid excitation is due to a voltage drop across the section of the coil L_2 at the points A and B. Continuous oscillations will then be generated at a definite frequency depending upon the inductive and capacitive values of L_2 and C_2.

Assuming the circuit to be oscillating continuously at a frequency of 3,750 kilocycles, or 80 meters, electromagnetic energy is transferred from the oscillating circuit L_2C_2 into the antenna and counterpoise radiating circuit by induction through the medium of the antenna coil L_1 provided the antenna-oscillating system is carefully adjusted to resonance at C_1; the coupling must also be adjusted between L_1 and L_2. The waves may then be broken up into code groups by manipulation of the hand key K.

Ques. 396. Give a complete diagram of an amateur tube transmitter and receiver. Label all the parts.

Ans. A diagram of a low-power amateur transmitter is illustrated in Fig. 88, and the function of each part follows:

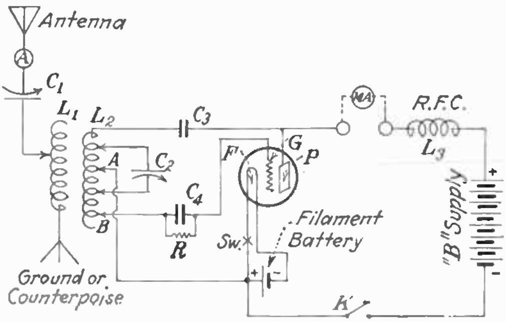


FIG. 88.—Wiring diagram of a simple amateur transmitter.

B: **voltage supply** for the plate circuit of the tube.

Filament battery for heating the filament of the tube to produce an electronic emission.

SW: **filament switch** for closing the filament circuit.

K: **telegraph key** for making and breaking the oscillations into code groups.

MA: **milliammeter** for determining the amount of milliamperes flowing in the plate circuit. The milliammeter will also serve as an oscillation indicator when the load circuit L_2C_2 is adjusted to oscillate at a certain frequency.

R.F.C.: **radiofrequency choke coil** for preventing the high-frequency oscillations generated by the tube and circuits L_2C_2 from passing through the plate-supply circuit, *B*, thereby maintaining a steady oscillating condition.

C_3: **plate blocking radiofrequency-bypass condenser,** for bypassing the radiofrequencies generated in the oscillatory circuits and preventing a short circuit of the power supply *B* through L_2.

C_4: **grid condenser,** for maintaining a periodic negative charge on the grid to insure efficient oscillation. This charge must not be allowed to accumulate because of the blocking action which would result, and, therefore, a dissipating resistance *R* must be connected across C_4.

R: **grid-leak resistance,** for dissipating at the proper intervals, the negative accumulations on the grid, due to the condenser blocking action, so as to maintain a continuous oscillating condition.

L_2C_2: **inductance and capacity constituting the closed or exciting oscillatory circuit,** for adjusting the transmitter to a definite frequency.

C_1: **antenna or counterpoise condenser,** for adjusting the radiating circuit to resonance with the excitation circuit L_2C_2.

L_1: **antenna or secondary inductance,** for adjusting the radiating circuit to resonance with the excitation circuit in conjunction with C_1. Pick-up medium for transferring the oscillations from C_2L_2 into the antenna circuit L_1C_1. It is also the coil which enables the proper coupling adjustment with L_2.

A: **radiofrequency ammeter,** for determining conditions of resonance in circuit C_1L_1 with C_2L_2 at either the fundamental or one of the harmonic frequencies. The radiofrequency ammeter may also be used for determining the distribution of current in the radiating system by placing it in various portions of the circuit.

Ques. 397. How would you adjust your transmitter so that it will comply with the law as to wave length, frequency etc.

Ans. 1. Adjust the wavemeter to the desired wave length or frequency with the aid of the tuning chart, making sure that the desired wave or frequency is in the amateur band.

2. Place the wavemeter (frequency meter) in an inductive relation to the coil L_2 at a distance of approximately 2 feet.

3. Disconnect the aerial and counterpoise leads on the coil L_1.

4. Press the key and tune the closed oscillating circuit and slowly rotate the variable condenser C_2 until a light is obtained on the wavemeter indicating lamp. If the light is too bright, move the wavemeter farther away until the lamp is fairly dim. Then vary the condenser above and below the apparent resonant point to make sure that the energy is concentrated at only one particular wave length (frequency) and that it does not extend over too many divisions above or below resonance. If the energy is not concentrated at one sharply defined point the wavemeter is probably too close to the transmitter. If, on the other hand, no indication is obtained, bring the wavemeter closer and again vary the wavemeter condenser. If, after various distances have

been tried, no indication is obtained (assuming lamp to be in good condition), then the transmitter is probably not oscillating. This might be due to a poor tube, improper grid leak, improper value of R. F. choke coil, open grid condenser, filament not adjusted properly, plate potential too low or poor connections, short-circuited tuning condenser, open coil, or improper adjustments of the clips on L_2. In a simple transmitter of this type, a check up on the above probable faults will usually produce

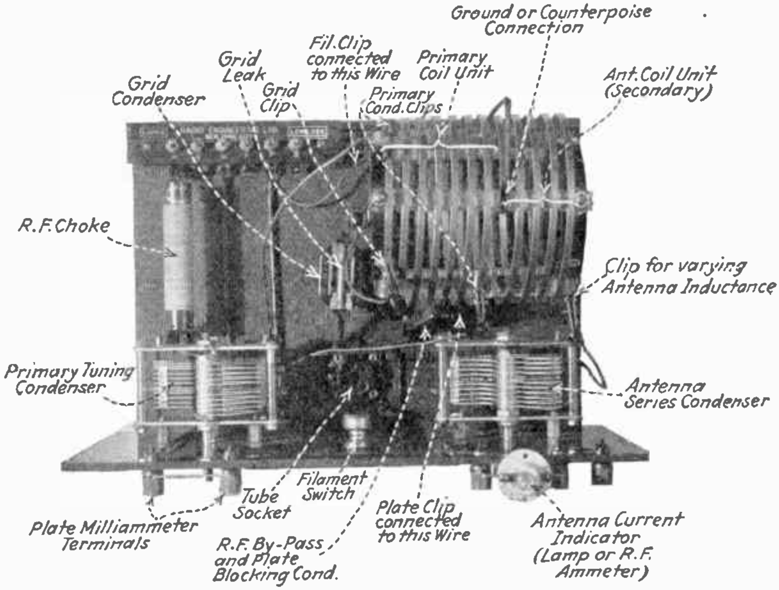


FIG. 89.—Low-power amateur transmitter (*Courtesy*, Radio Engineering Laboratories.)

results. When the transmitter is oscillating steadily and the wavemeter condenser and tuning condenser C_2 are properly adjusted to resonance at the desired wave length (frequency) the tuning of the closed oscillating circuit is completed.

Before taking the next step, however, which is to connect the antenna and counterpoise, observe the reading of the plate milliammeter and the color of the plate. If the plate is red or even slightly reddened, the plate current is too high, as indicated on the meter. To decrease the plate current, shift the center tap clip, one turn at a time, toward the grid clip; to increase the plate current, this clip should be moved toward the plate clip, away from the grid clip. If the plate current is too high and the antenna and counterpoise connected and the key pressed, the tube is very likely to burn out. Special attention, therefore, should be paid to this matter.

5. Connect antenna and counterpoise leads. Press the key. If the antenna is not properly adjusted to the proper wave length (frequency), as it probably will not be, it will now react on the closed circuit and throw it off the resonance point. The wavemeter light will indicate this by a decreased brilliancy or by going out entirely. To bring the antenna circuit in tune

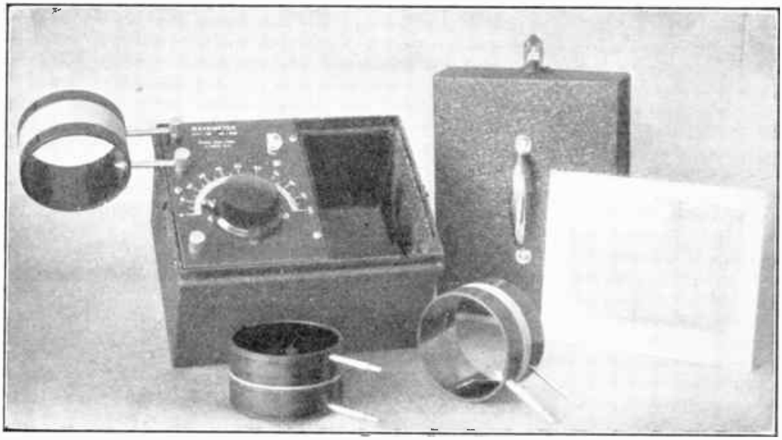


FIG. 90.—Short-wave wavemeter. (See Fig. 71*a* for diagram.) (*Courtesy, General Radio Company.*)

with the closed circuit, adjust the antenna-tuning condenser until the wavemeter again registers resonance. If resonance is not obtained by adjusting the tuning condenser, move the clip on the secondary of the oscillation transformer and also adjust the coupling between the two circuits.

Again adjust the condenser and repeat these three operations until resonance is obtained. If resonance cannot be obtained by these operations, the antenna system is either too long or too short.

For 14,000 and 7,000 kilocycles per second (20.8 and 41 meters), start with a 65-foot antenna and cut it down until best results are obtained.[1] This will be indicated by the largest relative increase in the plate milliammeter reading with and without the antenna and feed lines connected.

As a continual check on the emitted wave, place the wavemeter near the antenna lead-in and observe bulb brilliancy. This brilliancy may thereafter serve as a notice to the operator of the steadiness of the emitted wave during operation. Figure 90 illustrates a short-wave wavemeter a circuit diagram of which appears in Fig. 71*a* (also see Ques. 391).

Ques. 398. What adjustments are necessary on an amateur transmitter in order to comply with the law as to wave length, etc.?

Ans. The various adjustments necessary on a transmitter to comply with the law are as follows:

1. Careful adjustment of all clip connections, condensers, etc., to prevent a possible shifting of the wave to an unlawful-amateur frequency or wave length. This is extremely important because of the very small number of frequency or wave-length allocations in each of the amateur bands.

One of the most accurate systems for maintaining the frequency (wave length) of a transmitter constant is the crystal control method of frequency stabilization.

2. Proper antenna design for efficient operation at either the fundamental frequency of the oscillator or one of the harmonic frequencies of the antenna.

3. Proper filtering of the plate supply to insure a steady oscillating characteristic (not necessary with pure direct current as obtained with batteries).

4. Fairly loose coupling to minimize reactionary tendencies which might result in unstable operation.

5. Accurate tuning of the tube and antenna circuits with a reliable make of wavemeter. This should be done quite frequently to determine any change in the frequency of the emitted wave.

Ques. 399. Describe completely the operation of the receiver.

Ans. The operation of the receiver illustrated in Fig. 91 is as follows: When the filament switch *SW* is closed and the rheostat R_2 is properly adjusted, an electronic emission from both filaments will bombard the plates of the detector and amplifier tubes, resulting in a plate-current flow in both plate circuits. The oscillatory circuit L_2C_1 is now adjusted by varying C_1 to the desired wave length. C_2 is then varied until a "click" or "hiss" is heard in the amplifier telephone circuit. This denotes oscillation at a frequency near the oscillatory period of the circuit L_2C_1. For the reception of continuous waves, the condenser C_2 should be adjusted for each change in the wave length at C_1 by the click or hiss method.

Assume an incoming continuous-wave signal inducing an e.m.f. into the oscillatory circuit ANT, L_1, and GND, resulting in a high-frequency oscillating current flow in the coil L_1. This produces a varying magnetic field about coil L_1 which cuts coil L_2 due to its inductive relation and induces an e.m.f. across

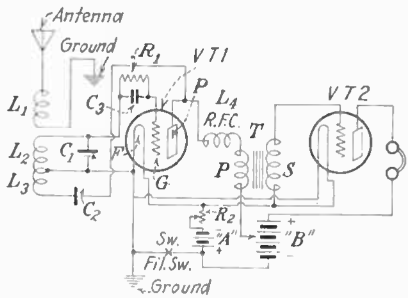


FIG. 91.—Amateur short-wave receiver.

it which results in a high-frequency current flow in the circuit L_2C_1 (provided, of course, that the circuit is tuned to the frequency of the incoming signal). The high-frequency variations across C_1 also apply voltage variations between G and F of the detector tube, resulting in alternate positive and negative charges on the grid G at the incoming-signal frequency.

These charges produce a variation in the detector-plate high-frequency circuit P, C_2, L_3, F, P, at the same frequency but of increased amplitude due to the amplifying action of the tube. These high frequencies cannot pass through the primary circuit of the transformer due to the choking action of the radiofrequency choke coil L_4 and, therefore, pass freely through the plate oscillatory circuit P, C_2, L_3, F, P. It is evident that so far no signal variation will be present in the transformer primary circuit and, hence, that no sound will be heard in the telephone.

Furthermore, if the choke coil were not provided, the high-frequency signal energy in the plate circuit would be practically lost, due to the high impedance of a transformer winding to high frequencies. If, however, the circuit L_3, C_2 is adjusted to a point of self-oscillation, as previously explained, with the click or hiss method, then an audible signal may be heard in the telephone receiver by the self-heterodyne method of "beat" reception. For example, assume the incoming-signal frequency to be in the order of 7,500 kilocycles or 40 meters and the tube oscillating in the vicinity of, say, 7,501 kilocycles, then both of these high-frequency variations will be impressed upon the grid G which, in turn, will again produce similar variations in the plate oscillatory circuit. Whenever two frequencies are closely related as in the above example and are superimposed upon one another, they will tend to neutralize one another at regular intervals and will thus produce a beat or wave corresponding to the difference between the two frequencies 7,500 and 7,501 or 1 kilocycle. This beat note being in the audible range of frequencies will then readily pass through L_4 and the primary winding of the audiotransformer and will produce a varying magnetic field about the primary which will cut the secondary and induce a high-voltage e.m.f. across it which will be applied to the grid of the amplifier tube. This will result in a plate variation in the amplifier plate and telephone circuit of high amplitude, and, consequently, a 1 kilocycle beat note will be heard in the telephones. It can thus be readily seen that the pitch of the received signal can be varied to any desired point by changing the incoming or oscillator frequency by the careful adjustment of either C_1 or C_2.

The function of each part in the above receiver is as follows:

C_1: **secondary shunt condenser,** for tuning the coil L_2 to a definite frequency. This condenser forms a part of the oscillatory circuit L_2C_1 and is the main tuning element in the receiver.

L_2: **secondary inductance,** for picking up the high-frequency field variation about coil L_1 and in conjunction with C_1 forms the other part of the oscillating circuit C_1L_2. The size of both L_2 and C_1 determines the frequency characteristic of the receiver circuit (wave length).

L_1: **antenna or primary inductance,** for inducing the high-frequency oscillations into the secondary circuit L_2C_1.

L_3: **inductive feed-back or tickler coil** for inducing an e.m.f. into the oscillatory circuit L_2C_1 to produce oscillations in the tube itself for the reception of continuous waves by the *beat* method.

C_2: **capacitive feed-back condenser,** for feeding the radio-frequency plate variations to the grid in conjunction with L_3. Here C_2 acts as a radiofrequency controlling medium by varying its capacitive reactance. In other words, the proper degree of oscillation desired can be obtained by the careful adjustment of C_2 for each change in the wave length of circuit L_2C_1.

C_3: **grid condenser,** for maintaining the proper negative bias on the grid to insure good detection (grid rectification).

R_1: **grid-leak resistance,** to allow negative charges on the grid to leak off at the proper intervals; to prevent *choking* due to the blocking condenser C_3.

R_2: **filament rheostat,** for adjusting the detector and amplifier filaments to the proper current flow for maximum efficiency.

L_4: **radio-frequency choke coil,** for preventing the high-frequency variations from flowing through the high impedance of the transformer primary winding, thereby forcing the oscillations through the low-reactance high-frequency circuit L_3C_2, consequently producing greater efficiency at these high frequencies.

T: **audio transformer,** for stepping up the voltage variations of the *beat* signal to a higher volume level.

VT-1: **detector and oscillator tube,** for generating its own oscillations and rectifying the signal into audible *beat* variations.

VT-2: **amplifier tube,** for increasing the amplitude of the beat-signal variations in conjunction with the step-up audio-transformer T.

Filament battery A, for supplying the filament current for both tubes.

B battery, for supplying the plates of both tubes with the proper positive potential.

Brief Bibliography

American Radio Relay League, Hartford, Conn. "Amateurs' Radio Handbook."

Ballantine, Stuart: "Radio Telephony for Amateurs," David McKay.

APPENDIX I

INFORMATION REGARDING COMMERCIAL AND AMATEUR RADIO OPERATOR'S LICENSE EXAMINATIONS

License Law.—International and United States radio law requires that every person operating a commercial or amateur transmitting station be licensed. In the United States, the licensing of radio operators comes under the jurisdiction of the Department of Commerce at Washington, D. C.

Radio Districts.—In order effectively to carry out the requirements of the law, the United States and its possessions have been divided into so-called *radio-inspection districts*, over each of which a Chief Radio Supervisor has charge. The district numbers, territory in the district, and headquarters address are given below:

District 1. Headquarters, Custom House, Boston, Mass. Includes Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut.

District 2. Headquarters, Subtreasury Building, New York, N. Y. Includes New York City, county of New York, Staten Island, Long Island, and counties on the Hudson River, to and including Schenectady, Albany, and Rensselaer and, in New Jersey, counties of Bergen, Passaic, Essex, Union, Middlesex, Monmouth, Hudson, and Ocean.

District 3. Headquarters, Detention Building, Immigration Station, Fort McHenry, Md., Baltimore, Md. Includes New Jersey (all counties not included in the second district), Pennsylvania (counties of Philadelphia, Delaware, all counties south of the Blue Mountains, and Franklin County), Delaware, Maryland, Virginia, District of Columbia.

District 4. Headquarters, Post Office Building, Atlanta, Ga. Includes North Carolina, South Carolina, Georgia, Florida, Tennessee, Alabama, Porto Rico, and Virgin Islands.

District 5. Headquarters, Custom House, New Orleans, La. Includes Mississippi, Louisiana, Texas, Arkansas, Oklahoma, and New Mexico.

District 6. Headquarters, Custom House, San Francisco, Calif. Includes California, Hawaii, Nevada, Utah, and Arizona.

District 7. Headquarters, L. C. Smith Building, Seattle, Wash. Includes Oregon, Washington, Alaska, Idaho, Montana, and Wyoming.

District 8. Headquarters, Commerce Building, Detroit, Mich. Includes New York (all counties not included in the second district), Pennsylvania (all counties not included in the third district), West Virginia, Ohio, and Michigan (lower peninsula).

REGULATIONS GOVERNING THE ISSUANCE OF RADIO OPERATORS' LICENSES

1. Commercial Extra First Class.—To be eligible for examination, an applicant for this class of license must have held a commercial first-class license and must have been actually engaged as an operator at stations open to public correspondence for at least 18 months during the 2 years previous to his application. A speed in transmission and reception of at least 30 words per minute, in code groups, Continental Morse Code, and 25 words per minute, in plain language, American Morse Code, 5 characters to the word, must be attained. The questions in this examination will cover the same subjects required for a commercial second-class license but considerably wider in scope. A total percentage of at least 80 will constitute a passing mark. Holders of licenses of this class are authorized to act as chief operator at any licensed radio station.

2. Commercial First Class.—To be eligible for examination, an applicant for this class of license must have been actually engaged as an operator at stations open to public correspondence for at least 12 months. Aplicants for this class of license must pass code tests in transmission and reception at a speed of at least 20 words per minute in Continental Morse Code, in code groups, and 25 words per minute in Continental Morse Code, in plain language (5 characters to the word). The practical and theoretical examination will cover the same subjects as required for the commercial second-class license. A total percentage of 75 will constitute a passing mark. Holders of this class of license are authorized to act as chief operator at any licensed radio station.

3. Commercial Second Class.—Applicants for this class of license must pass code tests in transmission and reception at a speed of at least 16 words per minute in Continental Morse Code, in code groups, and 20 words per minute in Continental Morse Code, in plain language (5 characters to the word). The practical and theoretical examination shall consist of comprehensive questions under the following headings:

(*a*) Diagram of radio installation: Applicants are required to draw a complete wiring diagram of a modern marine radio installation as used aboard American vessels. The applicant may be required to draw either a spark, arc, or vacuum tube transmitter (with radiotelephone attachment).

(*b*) General principles of electricity, theory, adjustment, operation, and care of modern radiotelegraph and radiotelephone apparatus.

(*c*) Receiving apparatus.

(*d*) Operation and care of storage batteries.

(*e*) Motors and generators.

(*f*) International regulations governing radio communication and the United States Radio Laws and Regulations.

(*g*) Experience: The applicant's answers will be rated on the basis of 100 per cent. In addition to the percentage thus obtained, an allowance for experience will be added as follows: Three months' or more satisfactory service at a station open to public correspondence under a commercial license, 10 per cent; two months' satisfactory service at a station open to public correspondence under a commercial license, 7.5 per cent; one month's satisfactory service at a station open to public correspondence under a commercial license, 5 per cent; service at United States Government stations open to public correspondence, same as above; service at other United States Government stations of three months or more duration, 5 per cent; less than three months, in proportion; graduates of residence radio schools, 5 per cent; amateur operators or graduates of correspondence radio schools, 2 per cent. Applicants must present satisfactory written evidence of their experience in order to obtain due allowance. A total percentage of 65 will constitute a passing mark for this class of license.

This license is valid for the operation of any licensed land or aircraft radio station or on any vessel except as indicated in the following. Holders of this class of license are not authorized to act as chief operator on a vessel in the first class. They will be authorized to act as chief operator on a vessel in the second class upon submission of written evidence at any time during the term of the license indicating six months or more satisfactory service as an operator at a station open to public correspondence.

4. Broadcast Class.—Applications for this class of license must pass code tests in transmission and reception at a speed of at least 20 words per minute in Continental Morse Code, in code groups, and 25 words per minute in Continental Morse Code, in plain language (5 characters to the word). The theoretical examination will cover the same subjects as indicated for the commercial second-class license, except that under subject (*a*) the applicant is required to draw a diagram of a modern broadcast transmitter and under subject (*b*) the questions will relate strictly to broadcast apparatus. An allowance for service as an operator at a broadcast or other station will be made in accordance with the scale indicated under 3.—Commercial second class. Holders of this class of license are authorized to act as operator only as a licensed broadcast station.

5. Radiotelephone Class.—No code test is required for this class of license. The practical and theoretical examination for this class of license shall consist of questions on adjustment and operation of radiotelephone apparatus and knowledge of international regulations governing radio communication and the United States Radio Laws and Regulations. The applicant must demonstrate his ability to transmit and receive clearly conversation by telephone apparatus. Whenever possible, a demonstration of the applicant's ability to operate radiotelephone apparatus will be required. A percentage of 75 will constitute a passing mark. Holders of this class of license are authorized to act as operator only at licensed radiotelephone stations of 300 watts or less input power.

6. Amateur Extra First Class.—To be eligible for examination, an applicant for this class of license must have had at least two years, service as a licensed radio operator and must not have been penalized for violation of the radio laws. The applicant must pass code tests in transmission and reception at a speed of at least 16 words per minute in Continental Morse Code, in code groups, and 20 words per minute in Continental Morse Code, in plain language (5 characters to the word). An applicant must pass a special examination relating to amateur apparatus and international regulations and acts of Congress affecting amateur stations and operators. A percentage of 75 will constitute a passing mark. This license is valid for the operation of licensed amateur radio stations only.

7. Amateur Class.—Applicants for this class of license must pass a code test in transmission and reception at a speed of at least 10 words per minute, in Continental Morse Code (5 characters to the word). An applicant must pass an examination which will develop knowledge of the adjustment and operation of the apparatus which he desires to use and of the international regulations and acts of Congress in so far as they relate to interference with other radio communications and impose duties on all classes of operators. A percentage of 70 will constitute a passing mark. This license is valid for the operation of licensed amateur radio stations only.

8. Temporary Amateur License.—Amateurs who can not present themselves for examination may be issued temporary licenses valid for the operation of a particular station until such time as they can be examined for a regular license but not to exceed a period of one year. The applicant must submit a sworn statement attesting to his ability to transmit and receive at a speed of not less than 10 words per minute in Continental Morse Code.

9. Renewals.—(*a*) Commercial extra first class: These licenses may be renewed without examination provided the record shows 12 months' satisfactory service in a land or ship station open to general public service, at least 6 months of which must have been during the last 12 months of the license period. Holders of these licenses employed as radio inspectors, radio instructors or in similar occupations requiring exceptional qualifications where the duties require the testing, or demonstrating, or otherwise using commercial radio apparatus and the telegraph codes may be issued renewals of their licenses without examination, provided such employment has covered a period of 18 months out of the 2-year license period. Where the applicant has not regularly used the telegraph codes, he will be given the code examination as for an original license, and if he has used only one code, he will be examined in the code not used.

(*b*) Other renewals: Renewal licenses may be issued to operators of other classes without examination, provided the operator has had three months' satisfactory service during the last six months of the license term. One year satisfactory service out of two years of the license term may be accepted for renewal at the discretion of the examining officer.

(*c*) Holders of commercial first-class or commercial second-class radio operator licenses who have not had sufficient service at commercial stations to permit the unconditional renewal of such licenses, but indicate satisfactory service at broadcasting stations for the length of time necessary for renewal, and are unable to pass the required code test or to present themselves for a code test, may be issued restricted renewals of their existing licenses. The licenses so issued should bear across their face, preferably in red, the following restrictions: "This license not valid for the operation of any limited or general public stations."

Applicants holding restricted commercial operators' licenses, broadcast or radio-telephone operators' licenses may be issued renewals of such licenses provided the service records indicate three months' satisfactory service during the last six months of the license term. One year satisfactory service out of the two-year term of the license may be accepted at the discretion of the examining officer. Renewal commercial first class or commercial second class licenses so issued shall bear the indorsement, "This license not valid for the operation of any limited or general public station."

Holders of restricted licenses may have this restriction removed at any time during the term of this license by passing the code test required for the class of license held by them. This restriction will be removed by the supervisor of radio or examining officer by drawing lines through the restriction and adding on the license adjacent thereto the following: "Restriction removed," date and initials of the examining officer. The expiration date of the license will remain the same.

Applicants who have passed the regular commercial examination but who hold renewal commercial licenses indorsed, "This license is not valid for the operation of any limited or general public station," may be issued unconditional renewals of such licenses provided they have the required service as indicated above and pass the code test required by the regulations for the class of license held by them.

(*d*) Renewals or new licenses may be issued a reasonable length of time previous to the expiration of existing licenses but must bear the exact date of issue, which must correspond with the date on Form 756 forwarded to the radio division. Operators who fail to apply for renewal of their licenses on or prior to the date of expiration must be reexamined. If, because of circumstances over which the applicant has no control, an operator is unable to apply for renewal of license on or prior to the date of expiration, an affidavit may be submitted to the radio division through the supervisor of radio or examining officer, attesting to the facts, which will be considered by the radio division, which will advise the supervisor of radio or examining officer in regard to the issue of a renewal of the license without reexamination. Service records must be completed and signed only by masters, employers, or the duly authorized agents of either. Any improper alteration of the service record or the forgery of masters' or employers' signatures constitutes a violation of the regulations, and the operator may suffer suspension of license for a period not exceeding two years, at the discretion of the Secretary of Commerce.

10. Duplicate Licenses.—Operators who have lost a valid operator's license may submit an affidavit to the radio division through the supervisor of radio or examining officer, attesting to the facts, which will be considered by the radio division which will advise the supervisor of radio or examining officer in regard to the issue of a duplicate of the lost license. Duplicate of licenses will bear the same date of issue and will expire on the same date as the original. If the original license is recovered, it must be forwarded to the radio division or one of its officers for cancellation and filing. Duplicates of amateur station licenses or of expired operator licenses will not be issued.

11. Reexamination.—No applicant who fails to qualify will be reexamined within three months from date of the previous examination. However, when an applicant for the commercial first-class license fails in the code examination he will be reexamined the same day for any other one class of license desired. Those who pass the code test successfully but fail to at ain a total percentage of at least 75 but do attain a total percentage of at least 65 will be issued a commercial second-class license, if desired. Those who fail in the code examination for the broadcast-class license will be examined the same day for either the radiotelephone or amateur class license, if desired. An applicant for the broadcast-class license who fails to attain a total percentage of at least 75 but does attain a percentage of at least 65 will be issued a radiotelephone-class license, if desired. All examination papers, except amateur, whether the applicant qualifies or not, will be forwarded to the Department of Commerce, radio division, for filing.

REGULATIONS GOVERNING THE RENEWAL OF COMMERCIAL OPERATORS' LICENSES EXPIRING AFTER JANUARY 1, 1929

Operators now holding commercial extra first-class licenses will be issued renewal licenses of the same class without examination, provided they have the required length of service.

Operators now holding commercial first-class licenses will be issued one of the new commercial first-class licenses without theoretical examination, provided they can show satisfactory service for a period of at least 12 months as an operator at stations open to public correspondence, have knowledge of the operation of radiotelephone apparatus, and can successfully pass code tests as required under the new regulations.

Operators now holding commercial first-class licenses who have had less than 12 months but more than 6 months' satisfactory service as operators at stations open to public correspondence will be issued commercial second-class licenses without examination, authorizing them to act as operator in any station, except as chief operator on vessels of the first class.

Operators now holding commercial first-class licenses, who have had less than six months' satisfactory service as an operator at stations open to public correspondence, will be issued a commercial second-class license without examination, authorizing holder to act as operator on any vessel except as chief operator on a vessel in the first or second class.

No renewals will be made of present commercial second-class licenses, and after January 1, 1929, licenses of this class still valid after that date will be valid only for the operation of broadcast, technical and training, experimental, limited commercial, or amateur stations. Holders of broadcast station operator licenses will be issued the new broadcast license provided they have the required service and pass the new code test.

All present licenses will be valid for the term indicated, but at any time during the term of the old license an operator may make application for and be issued a new license provided he can meet the requirements therefor. In any event, if a new license is issued the old license must be canceled.

Effective January 1, 1930, holders of present commercial first-class licenses are not authorized to act as chief operators on vessels in the first class. If they desire to obtain such authority, they must meet the requirements and make application for one of the new licenses. The regulations and instructions requiring that a first-class operator be the chief operator on a first-class vessel applies only in the cases of vessels in the international service and not to vessels plying between ports of the United States.

CORRECTION TO THE LIST OF AMATEUR RADIO STATIONS OF THE UNITED STATES

Page 91 of the above-named list, edition June 30, 1928, should be changed to show that the first letter (prefix letter) of the call signals for the stations of the Territory of Porto Rico is "K" in lieu of "W."

REVISED UNITED STATES AMATEUR REGULATIONS

(Superseding those dated September 1, 1928)

An amateur station is a station operated by a person interested in radio technique solely with a personal aim and without pecuniary interest. Amateur licenses will not be issued to stations of other classes.

Amateur radio stations are authorized for communication only with similarly licensed stations, except as indicated below, and on wave lengths or frequencies within the following bands and at all times unless interference is caused with other radio services, in which event a silent period must be observed between the hours of 8 and 10.30 p. m., local time, and on Sundays during local church services.

WHAT THE AMATEUR OPERATOR SHOULD KNOW

In addition to being able to copy the code at a speed of at least 10 words per minute, the prospective amateur operator should be able to draw a diagram of and explain the transmitter and receiver he desires to operate. A knowledge of radio laws, especially those answered in this book under the question numbers which follow, is required. Radio-law questions 288, 289, 296, 297, 298, 299, 313, 320, 330, and 335.

DIAGRAMS

The applicant for the first or second-class commercial operator's license is required to draw a diagram and explain the operation of a standard radio-station equipment, including receiver with vacuum-tube detector and amplifier; a spark, arc, or vacuum-tube transmitter with automatic motor-generator starter and auxilliary storage-battery equipment, such as is shown in Part I of this book.

In drawing diagrams, use only standard symbols, and label each part. A complete diagram, when first seen, looks difficult to draw, but if the student will study separately the various sections that go to make up the diagram, such as the automatic starter and motor-generator equipment, the transformer, and closed oscillating circuit (or the equivalent arc or tube components), the open oscillatory circuit, the auxilliary equipment, and the receiver, and then put these sections together, he will find the problem of drawing the diagram much simplified.

In taking any examination where the time allowed is unlimited, the applicant should not sacrifice clearness for brevity. Take all the time needed to say all you have in mind about a certain question. Observe particularly the rules of neatness, careful writing, and spacing. Read carefully the rules governing the examination. Be sure to read the question and stick to the point in your answer. When you have finished the entire examination, read it over very carefully for errors. A final review of this kind often means the difference between a passing and a failing mark.

APPENDIX II

Q CODE[1] AND OPERATING INFORMATION

LIST OF ABBREVIATIONS TO BE USED IN RADIO TRANSMISSIONS

TABLE I.—ABBREVIATIONS TO BE USED IN ALL SERVICES

Abbreviation	Question	Answer
QRA....	What is the name of your station?	The name of my station is ....
QRB....	At what approximate distance are you from my station?	The approximate distance between our stations is .... nautical miles (or .... kilometers).
QRC....	By what private company (or government administration) are the accounts for charges of your station liquidated?	The accounts for charges of my station are liquidated by the .... private company (or by the government administration of ....).
QRD....	Where are you going?	I am going to ....
QRE....	What is the nationality of your station?	The nationality of my station is ....
QRF....	Where do you come from?	I come from ....
QRG....	Will you indicate to me my exact wave length in meters (or frequency in kilocycles)?	Your exact wave length is .... meters or .... kilocycles).
QRH....	What is your exact wave length in meters (frequency in kilocycles)?	My exact wave length is .... meters (frequency .... kilocycles).
QRI.....	Is my tone bad?	Your tone is bad.
QRJ.....	Are your receiving me badly? Are my signals weak?	I cannot receive you. Your signals are too weak.
QRK....	Are your receiving me well? Are my signals good?	I receive you well. Your signals are good.
QRL....	Are you busy?	I am busy (or I am busy with ....). Please do not interfere.
QRM....	Are you being interfered with?	I am being interfered with.
QRN....	Are you troubled by atmospherics?	I am troubled by atmospherics.
QRO....	Must I increase power?	Increase power.
QRP....	Must I decrease power?	Decrease power.
QRQ....	Must I send faster?	Send faster (.... words per minute).
QRS.....	Must I send more slowly?	Send more slowly (.... words per minute).
QRT....	Must I stop sending?	Stop sending.
QRU....	Have you anything for me?	I have nothing for you.
QRV....	Must I send a series of Vs?	Send a series of Vs.
QRW....	Must I advise .... that you are calling him?	Please advise .... that I am calling him.
QRX....	Must I wait? When will you call me again?	Wait until I have finished communicating with ..... I will call you immediately (or at .... o'clock).
QRY....	Which is my turn?	Your turn is No. .... (or according to any other indication).
QRZ....	By whom am I being called?	You are being called by ....
QSA	What is the strength of my signals (1 to 5)?	The strength of your signal is .... (1 to 5).
QSB.....	Does the strength of my signals vary?	The strength of your signal varies.
QSC.....	Do my signals disappear entirely at intervals?	Your signals disappear entirely at intervals.
QSD....	Is my keying bad?	Your keying is bad. Your signals are unreadable.
QSE.....	Are my signals distinct?	Your signals run together.
QSF.....	Is my automatic transmission good?	Your automatic transmission fades out.
QSG.....	Must I transmit the telegrams by a series of 5, 10 (or according to any other indication)?	Transmit the telegrams by a series of 5, 10 (or according to any other indication).
QSH....	Must I send one telegram at a time, repeating it twice?	Transmit one telegram at a time, repeating it twice.
QSI.....	Must I send the telegrams in alternate order without repetition?	Send the telegrams in alternate order without repetition.
QSJ.....	What is the charge to be collected per word for .... including your internal telegraph charge?	The charge to be collected per word for .... is .... francs, including my internal telegraph charge.
QSK....	Must I suspend traffic? At what time will you call me again?	Suspend traffic. I will call you again at .... o'clock.
QSL.....	Can you give me acknowledgment of receipt?	I give you acknowledgment of receipt.

[1] The abbreviations take the form of questions when they are followed by question marks.

TABLE I.—(*Continued*)

Abbreviation	Question	Answer
QSM....	Have you received my acknowledgment of receipt?	I have not received your acknowledgment of receipt.
QSN....	Can you receive me now? Must I continue to listen?	I cannot receive you now. Continue to listen.
QSO....	Can you communicate with .... directly (or through the intermediary of ....)?	I can communicate with .... directly (or through the intermediary of ....).
QSP....	Will you relay to .... free of charge?	I will relay to .... free of charge.
QSQ....	Must I send each word or group once only?	Send each word or group once only.
QSR....	Has the distress call received from .... been attended to?	The distress call received from .... has been attended to by ....
QSU....	Must I send on .... meters (or .... kilocycles) waves of type A1, A2, A3, or B?	Send on .... meters (or on .... kilocycles) waves of type A1, A2, A3, or B. I am listening for you.
QSV....	Must I shift to the wave of .... meters (or of .... kilocycles) for the balance of our communications and continue after having sent several Vs?	Shift to wave of .... meters (or of .... kilocycles) for the balance of our communications and continue after having sent several Vs.
QSW....	Will you send on .... meters (or on .... kilocycles) waves of type A1, A2, A3, or B?	I will send on .... meters (or .... kilocycles) waves of type A1, A2, A3, or B. Continue to listen.
QSX....	Does my wave length (frequency) vary?	Your wave length (frequency) varies.
QSY....	Must I send on the wave of .... meters (or .... kilocycles) without changing the type of wave?	Send on the wave of .... meters (or .... kilocycles) without changing the type of wave.
QSZ....	Must I send each word or group twice?	Send each word or group twice.
QTA....	Must I cancel telegram No. .... as if it had not been sent?	Cancel telegram No. .... as if it had not been sent.
QTB....	Do you agree with my word count?	I do not agree with your word count; I shall repeat the first letter of each word and the first figure of each number.
QTC....	How many telegrams have you to send?	I have .... telegrams for you or for ....
QTD....	Is the word count which I am confirming to you accepted?	The word count which you confirm to me is accepted.
QTE....	What is my true bearing (or what is my true bearing relative to ....)?	Your true bearing is .... degrees (or your true bearing relative to .... is .... degrees at .... (o'clock).
QTF....	Will you give me the position of my station based on the bearings taken by the radiocompass stations which you control?	The position of your station based on the bearings taken by the radiocompass stations which I control is .... latitude .... longitude.
QTG....	Will you transmit your call signal for 1 minute on a wave length of .... meters (or .... kilocycles) in order that I may take your radiocompass bearing?	I am sending my call signal for 1 minute on the wave length of .... meters (or .... kilocycles) in order that you may take my radiocompass bearing.
QTH....	What is your position in latitude and longitude (or according to any other indication)?	My position is .... latitude .... longitude (or according to any other indication).
QTI....	What is your true course?	My true course is .... degrees.
QTJ....	What is your speed?	My speed is .... knots, or .... kilometers per hour.
QTK....	What is the true bearing of .... relative to you?	The true bearing of .... relative to me is .... degrees at .... o'clock.
QTL....	Send radio signals to enable me to determine my bearing with respect to the radio beacon.	I am sending radio signals to permit you to determine your bearing with respect to the radiobeacon.
QTM....	Send radio signals and submarine sound signals to enable me to determine my bearing and my distance.	I am sending radio signals and submarine sound signals to permit you to determine your bearing and your distance.
QTN....	Can you take the bearing of my station (or of ....) relative to you?	I cannot take the bearing of your station (or of ....) relative to my station.
QTP....	Are you going to enter the dock (or the port)?	I am going to enter the dock (or the port).
QTR....	What is the exact time?	The exact time is ....
QTS....	What is the true bearing of your station relative to me?	The true bearing of my station relative to you is ...., at .... o'clock.
QTU....	What are the hours during which your station is open?	My station is open from .... to ....

TABLE II.—ABBREVIATIONS MORE ESPECIALLY USED IN THE AIRCRAFT RADIO SERVICE

Abbreviation	Question	Answer
QAA....	At what time do you expect to arrive at ....?	I expect to arrive at .... at .... o'clock.
QAB....	Are you en route to ....?	I am en route to .... or Go to ....
QAC....	Are you returning to ....?	I am returning to .... or Return to ....
QAD....	At what time did you leave .... (place of departure)?	I left .... (place of departure) at .... o'clock.
QAE....	Have you news of .... (call signal of the aircraft station)?	I have no news of .... (call signal of the aircraft station).
QAF....	At what time did you pass ....?	I passed .... at .... o'clock.
QAH....	What is your height?	My height is .... meters (or according to any other indication).
QAI....	Has any aircraft signaled in my neighborhood?	No aircraft has signaled in your neighborhood.
QAJ....	Must I look for another aircraft in my neighborhood?	Look for another aircraft in your neighborhood (or look for .... (call signal of the aircraft station) which was flying near .... (or in the direction of ....) at .... o'clock).
QAK....	On what wave are you going to send the meteorological warning messages?	I am going to send the meteorological warning messages on wave length of .... meters (or .... kilocycles).
QAL....	Are you going to land at ....?	I am going to land at .... or Land ....
QAM....	Can you give me the latest meteorological message concerning weather for .... (place of observation)?	Here is the latest meteorological message concerning weather for .... (place of observation).
QAN	Can you give me the latest meteorological message concerning surface wind for .... (place of observation)?	Here is the latest meteorological message concerning surface wind for .... (place of observation).
QAO....	Can you give me the latest meteorological message concerning upper wind for .... (place of observation)?	Here is the latest meteorological message concerning upper wind for .... (place of observation).
QAP....	Must I continue to listen for you (or for ....) on .... meters (or .... kilocycles)?	Continue to listen for me (or for ....) on .... meters (or .... kilocycles).
QAQ....	Will you hasten the reply to message No. .... (or in accordance with any other indication)?	I hasten the reply to message No. .... (or in accordance with any other indication).
QAR....	Must I reply to .... for you?	Reply to .... for me.
QAS....	Must I send message No. .... (or in accordance with any other indication) to ....?	Send message No. .... (or in accordance with any other indication) to ....
QAT....	Must I continue to send?	Listen before sending; you are interfering; or Listen before sending; you are sending at the same time as ....
QAU....	What is the last message received by you from ....?	The last message received by me from .... is ....
QAV....	Are you calling me? or Are you calling .... (call signal of the aircraft station)?	I am calling you. or I am calling .... (call signal of the aircraft station).
QAW....	Must I cease listening until .... o'clock?	Cease listening until .... o'clock.
QAX....	Have you received the urgent signal sent by .... (call signal of the aircraft station)?	I received the urgent signal sent by .... (call signal of the aircraft station) at .... o'clock.
QAY....	Have you received the distress signal sent by .... (call signal of the aircraft station)?	I received the distress signal sent by .... (call signal of the aircraft station) at .... o'clock.
QAZ....	Can you receive in spite of the storm?	I can no longer receive. I am going off watch because of the storm.

TABLE III.—MISCELLANEOUS ABBREVIATIONS

Abbreviation	Meaning
C........	Yes.
N........	No.
P........	Announcement of private telegram in the mobile service (to be used as a prefix).
W........	Word or words.
AA.......	All after .... (to be used after a question mark to request a repetition).
AB.......	All before .... (to be used after a question mark to request a repetition).
AL.......	All that has just been sent (to be used after a question mark to request a repetition).
BN......	All between .... (to be used after a question mark to request a repetition).
BQ......	Announcement of reply to a request for rectification.
CL.......	I am closing my station.
CS.......	Call signal (to be used to ask repetition of a call signal).
DB......	I cannot give you a bearing, you are not in the calibrated sector of this station.
DC......	The minimum of your signal is suitable for the bearing.
DF......	Your bearing at .... o'clock was .... degrees, in the doubtful sector of this station, with a possible error of 2 degrees.
DG......	Please advise me if you note an error in the bearing given.
DI.......	Bearing doubtful in consequence of the bad quality of your signal.
DJ.......	Bearing doubtful because of interference.
DL......	Your bearing at .... o'clock was .... degrees in the doubtful sector of this station.
DO......	Bearing doubtful. Ask for another bearing later, or at .... o'clock.
DP......	Beyond 50 miles, possible error of bearing can attain 2 degrees.
DS......	Adjust your transmitter, the minimum of your signal is too broad.
DT......	I cannot furnish you with a bearing; the minimum of your signal is too broad.
DY......	This station is bilateral, what is your approximate direction in degrees relative to this station?
DZ......	Your bearing is reciprocal (to be used only by the central station of a group of radiocompass stations when it is addressed to other stations of the same group).
ER......	Here .... (to be used before the name of the mobile station in the sending of route indications).
GA......	Resume sending (to be used more especially in the fixed service).
JM......	If I may send, make a series of dashes. To stop my transmission, make a series of dots (not to be used on 600 meters (500 kilocycles)).
MN......	Minute or minutes (to be used to indicate the duration of a wait).
NW......	I resume transmission (to be used more especially in the fixed service).
OK......	We are in agreement.
RQ......	Announcement of a request for rectification.
SA.......	Announcement of the name of an aircraft station (to be used in the sending of indications of passage).
SF.......	Announcement of the name of an aeronautic station.
SN......	Announcement of the name of a coast station.
SS.......	Announcement of the name of a ship station (to be used in the transmission of indications of passage).
TR......	Announcement of the request or of the sending of indications concerning a mobile station.
UA......	Are we in agreement?
WA......	Word after .... (to be used after a question mark to request a repetition).
WB......	Word before .... (to be used after a question mark to request a repetition).
XS......	Atmospherics.
YS.......	See your service advice.
ABV.....	Shorten the traffic by using the International Abbreviations or "Repeat (or I repeat) the figures in abbreviation form.
ADR.....	Address (to be used after a question mark to request a repetition).
CFM....	Confirm (or I confirm).
COL.....	Collate (or I collate).
ITP.....	The punctuation counts.
MSG....	Announcement of telegram concerning ship service only (to be used as a prefix).
PBL....	Preamble (to be used after a question to request a repetition).
REF.....	Referring to .... (or Refer to ....).
RPT.....	Repeat or I repeat (to be used only to ask or to give repetition of all or part of the traffic by making the corresponding indication after the abbreviation).
SIG.....	Signature (to be used after a question mark to request a repetition).
SVC.....	Announcement of a service telegram concerning private traffic (to be used as a prefix).
TFC.....	Traffic.
TXT.....	Text (to be used after a question mark to request a repetition).

TWENTY-FOUR-HOUR TIME SYSTEM

The International Radio Regulations require that the filing time of radiograms originating in certain countries (which have agreed to this system) shall be indicated according to the 24-hour system of reckoning time. This system has been in use in Europe and in some other parts of the world for many years.

The system is very simple: Starting at midnight, the hours for the entire calender day are counted from 1 to 24. The minutes 01 to 59 are indicated after the hours, thus: 2:15 P.M. would be 1415; 5:37 A.M. would be 0537; 11:59 P.M. would be 2359. In this way, the abbreviations A.M. and P.M. are eliminated, and accuracy is increased. A conversion table showing the relation between the conventional 12-hour system and the improved 24-hour system follows.

Twelve-hour System	Twenty-four-hour System
12 midnight	2400
12:30 A.M.	0030
1:00	0100
2.00	0200
3.00	0300
4.00	0400
5.00	0500
6.00	0600
7.00	0700
8.00	0800
9.00	0900
10.00	1000
11.00	1100
12.00 noon	1200
1.00 P.M.	1300
2.00	1400
3.00	1500
4.00	1600
5.00	1700
6.00	1800
7.00	1900
8.00	2000
9.00	2100
10.00	2200
11.00	2300
11.59	2359

SCHEDULE OF STATIONS SENDING TIME SIGNALS

Call	Location	Time	WL	Frequencies kilocycles per second
FL.............	Eiffel Tower, Paris, France	0756 0800	32	9370
FL.............	Eiffel Tower, Paris, France	0926 0930	2650	113.1
FL.............	Eiffel Tower, Paris, France	1656 2000	32	9370
FL.............	Eiffel Tower, Paris, France	2226 2230	2650	113.1
NAA...........	Arlington, Va., U. S. A.	0255 0300	24.9	12045
NAA...........	Arlington, Va., U. S. A.	0255 0300	37.4	8030
NAA...........	Arlington, Va., U. S. A.	0255 0300	74.5	4015
NAA...........	Arlington, Va., U. S. A.	0255 0300	440.9	680
NAA...........	Arlington, Va., U. S. A.	0255 0300	2677	112
NAA...........	Arlington, Va., U. S. A.	1655 1700	24.9	12045
NAA...........	Arlington, Va., U. S. A.	1655 1700	37.4	8030
NAA...........	Arlington, Va., U. S. A.	1655 1700	74.5	4015
NAA...........	Arlington, Va., U. S. A.	1655 1700	440.9	680
NAA...........	Arlington, Va., U. S. A.	1655 1700	2677	112
WNBT.........	Elgin, Ill., U. S. A.	0555 0600	33.5	8950
WNBT.........	Elgin, Ill., U. S. A.	1655 1700	33.5	8950

RULES FOR RADIO OPERATORS

Take pride in the condition of your equipment.

Use close coupling for general listening in.

Use loose coupling when copying signals.

Be familiar with all connections on your set.

Use the least power necessary when communicating.

Avoid short and jerky sending.

File correct copies of all messages handled.

Where static is heavy, dots and dashes may be longer.

Turn over a clean and neat station to your relief

Do not send during CQ periods.

Remember, repeated and continuous calling may cause interference.

Before sending, make sure your wave band is clear of traffic.

For best results, regulate your sending to suit the receiving operator.

Keep all motors and generators well oiled.

Shut off all live circuits before making any adjustments on apparatus.

Inspect antenna and riggings occasionally.

Keep a log of stations heard on 600 meters every 15 min. while on duty.

Wave-length Allocations

Frequencies, kilocycles per second	Approximate wave lengths, meters	Services
10 to 100	30,000 to 3,000	Fixed services
100 to 110	3,000 to 2,725	Fixed services and mobile services
110 to 125	2,725 to 2,400	Mobile services
125 to 150[1]	2,400 to 2,000[1]	Maritime mobile services *open to public correspondence exclusively*
150 to 160	2,000 to 1,875	Mobile services
160 to 194	1,875 to 1,550	*a.* Broadcasting *b.* Fixed services *c.* Mobile services The conditions for use of this band are subject to the following regional arrangements: All regions where broadcasting stations now exist working on frequencies below 300 kilocycles per second (above 1,000 meters): broadcasting Other regions: Fixed services; Mobile services Regional arrangements will respect the rights of other regions in this band
194 to 285	1,550 to 1,050	*a.* Mobile services *b.* Fixed service *c.* Broadcasting The conditions for use of this band are subject to the following regional arrangements: Europe: *a.* *Air* mobile service *exclusively* *b.* *Air* fixed services *exclusively* *c.* Within the band 250 to 285 kilocycles per second (1,200 to 1,050 meters). Fixed service *not open to public correspondence.* *d.* Broadcasting within the band 194 to 224 kilocycles per second (1,550 to 1,340 meters) Other regions: *a.* Mobile services except commercial ship stations *b.* Fixed *air* services *exclusively* *c.* Fixed services *not open to public correspondence*
285 to 315	1,050 to 950	Radio beacons
315 to 350[2]	950 to 850[2]	*Air* mobile services *exclusively*
350 to 360	850 to 830	Mobile services *not open to public correspondence*
360 to 390	830 to 770	*a.* Radio compass service *b.* Mobile services, on condition that they do not interfere with radio compass service
390 to 460	770 to 650	Mobile services
460 to 485	650 to 620	Mobile services *(except damped waves and radiotelephony)*
485 to 515[3]	620 to 580[3]	Mobile services (distress, call, etc.)
515 to 550	580 to 545	Mobile services *not open to public correspondence (except damped waves and radiotelephony)*
550 to 1,300[4]	545 to 230[4]	Broadcasting:
1,300 to 1,500	230 to 200	*a.* Broadcasting *b.* Maritime mobile services, waves of 1,365 kilocycles per second (220 meters) exclusively
1,500 to 1,715	200 to 175	Mobile services
1,715 to 2,000	175 to 150	Mobile services Fixed services Amateurs

WAVE-LENGTH ALLOCATIONS.—(*Continued*)

Frequencies, kilocycles per second	Approximate wave lengths, meters	Services
2,000 to 2,250	150 to 133	Mobile services and fixed services
2,250 to 2,750	133 to 109	Mobile services
2,750 to 2,850	109 to 105	Fixed services
2,850 to 3,500	105 to 85	Mobile services and fixed services
3,500 to 4,000	85 to 75	Mobile services Fixed services Amateurs
4,000 to 5,500	75 to 54	Mobile services and fixed services
5,500 to 5,700	54 to 52.7	Mobile services
5,700 to 6,000	52.7 to 50	Fixed services
6,000 to 6,150	50 to 48.8	Broadcasting
6,150 to 6,675	48. 8 to 45	Mobile services
6,675 to 7,000	45 to 42.8	Fixed services
7,000 to 7,300	42.8 to 41	Amateurs
7,300 to 8,200	41 to 36.6	Fixed services
8,200 to 8,550	36.6 to 35.1	Mobile services
8,550 to 8,990	35.1 to 33.7	Mobile services and fixed services
8,900 to 9,500	33.7 to 31.6	Fixed services
9,500 to 9,600	31.6 to 31.2	Broadcasting
9,600 to 11,000	31.2 to 27.3	Fixed services
11,000 to 11,400	27.3 to 26.3	Mobile services
11,400 to 11,700	26.3 to 25.6	Fixed services
11,700 to 11,900	25.6 to 25.2	Broadcasting
11,900 to 12,300	25.2 to 24.4	Fixed services
12,300 to 12,825	24.4 to 23.4	Mobile services
12,825 to 13,350	23.4 to 22.4	Mobile services and fixed services
13,350 to 14,000	22.4 to 21.4	Fixed services
14,000 to 14,400	21.4 to 20.8	Amateurs
14,400 to 15,000	20.8 to 19.85	Fixed services
15,100 to 15,350	19.85 to 19.55	Broadcasting
15,350 to 16,400	19.55 to 18.3	Fixed services
16,400 to 17,100	18.3 to 17.5	Mobile services
17,100 to 17,750	17.5 to 16.9	Mobile services and fixed services
17,750 to 17,800	16.9 to 16.85	Broadcasting
17,800 to 21,450	16.85 to 14	Fixed services
21,450 to 21,550	14 to 13.9	Broadcasting
21,550 to 22,300	13.9 to 13.45	Mobile services
22,300 to 23,000	13.45 to 13.1	Mobile services and fixed services
23,000 to 28,000	13.1 to 10.7	Not reserved
28,000 to 30,000	10.7 to 10	Amateurs and experimental
30,000 to 56,000	10 to 5.35	Not reserved
56,000 to 60,000	5.35 to 5	Amateurs and experimental
Above 60,000	Below 5	Not reserved

[1] The wave of 143 kilocycles per second (2,100 meters) is the calling wave for mobile stations using long continuous waves.

[2] The wave of 333 kilocycles per second (900 meters) is the international calling wave for air services.

[3] The wave of 500 kilocycles per second (600 meters) is the international calling and distress wave. It may be used for other purposes on condition that it will not interfere with call signals and distress signals.

[4] Mobile services may use the band 550 to 1,300 kilocycles per second (545 to 230 meters) on condition that this will not cause interference with the services of a country which uses this band exclusively for broadcasting.

NOTE.—It is recognized that short waves (frequencies from 6,000 to 23,000 kilocycles per second approximately—wave lengths from 50 to 13 meters approximately) are very efficient for long-distance communications. It is recommended that, as a general rule, this band of waves be reserved for this purpose, in services between fixed points.

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	· — — — —
2	· · — — —
3	· · · — —
4	· · · · —
5	· · · · ·
6	— · · · ·
7	— — · · ·
8	— — — · ·
9	— — — — ·
0	— — — — —

Period	· · · · · ·
Semicolon	— · — · — ·
Comma	· — · — · —
Colon	— — — · · ·
Interrogation	· · — — · ·
Exclamation point	— — · · — —
Apostrophe	· — — — — ·
Hyphen	— · · · · —
Bar indicating fraction	— · · — ·
Parenthesis	— · — — · —
Inverted commas	· — · · — ·
Underline	· · — — · —
Double dash	— · · · —
Distress Call	· · · — — — · · ·
General inquiry call and general call to all stations	— · — · — — · —
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)	· · · — · —

INDEX

C

D

E

F