RADIO OPERATING

QUESTIONS AND ANSWERS

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PREFACE TO THE FIFTH EDITION

In this edition additional questions and answers on broadcasting have been included in the Addenda and a few errors, mostly typographical, corrected throughout the book. The authors continue to invite letters of criticism and suggestion addressed to them in care of the publishers regarding any part of the book.

THE AUTHORS.

February, 1933.

PREFACE TO THE FOURTH EDITION

New developments in radio, since the second edition of this book was published, make this completely revised edition necessary. While a large part of the third edition has been retained intact, extensive alterations and additions have been made throughout the entire book.

A large number of new Questions and Answers have been added to the chapters on Tube Transmitters and on Radio Laws. The chapter on Broadcasting Transmitters has been very largely rewritten and new material on the most recent model of Western Electric 1,000-watt broadcast transmitter included. A complete answer to the very important question of attenuation pad calculations is also included. A number of other new questions are also fully treated in this chapter.

The chapter on Amateur Station Operation has been entirely rewritten and a new chapter entitled Amateur Radiophone Operation, which gives information and data pertaining to the unlimited amateur telephone operator's license, has been added. A new chapter on Amateur Radio Laws and Regulations has also been added, making this book valuable to the amateur as well as to the commercial operator.

A large part of the chapter covering Aeronautical Radio, Part XIII, was written by Mr. R. L. Bibb of the American

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Airways, Inc., and edited by the authors. This section, therefore, like the remainder of the book, is written out of actual experience and is consequently practical and authentic to a maximum degree. It should prove particularly valuable to those interested in and preparing for aeronautical positions.

Useful operating information, regulations governing the issuance of all classes of radio operator's license examinations are to be found in the Appendix.

As it is the desire of the authors to make this book as useful as possible they will welcome any criticism or suggestions pertaining to any section of the volume.

THE AUTHORS.

June, 1932.

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 was 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.

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.**

<div align="right">A. R. N.</div>

New York City,
December, 1921.

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Modern ship radio installation.   Frontispiece

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RADIO OPERATING
QUESTIONS AND ANSWERS

PART I

TUBE TRANSMITTERS

Ques. 1. Draw a diagram of a Master-Oscillator-Power-Amplifier (MOPA) marine transmitter complete with an audio oscillator, automatic starter, auxiliary and "A" battery charging equipment, and a vacuum-tube receiver with two stages of audiofrequency amplification.

State the type and power rating of the transmitter. Label all parts. Explain briefly the parts and the operation of the complete installation.

Ans. Figure 1 illustrates a modern marine installation complete with an auxiliary power supply system.

The transmitter is of the Master-Oscillator-Power-Amplifier variety, type E T 3626-C, manufactured by the Radio Corporation of America. The transmitter is designed for a power output of 500 watts and provides for both CW and ICW signalling. This transmitter has two wave-length ranges, a long wave range between 1,250 and 2,500 meters and a medium wave range between 600 and 1,250 meters.

The receiver, type I.P. 501A, also manufactured by the Radio Corporation of America, is a combination intermediate- and long-wave tuner which is capable of covering the entire commercial bands from 600 to 8,000 meters. A two-stage audiofrequency amplifier is connected to the detector output for increasing the signal volume.

The auxiliary power supply system consists of two banks of 60-volt Exide storage batteries which can be connected in parallel or series for charging or discharging purposes. Overload and underload circuit breakers are also provided for pro-

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tecting the batteries from damage due to a possible short-circuit or decrease in the charging voltage.

A 4 P.D.T. charging and discharging switch for the "A" battery is also provided for the continuous operation of the vacuum tubes in the receiver.

The operation of the complete installation follows.

BRIEF THEORETICAL OPERATION
THE POWER SUPPLY

When the 6 P.D.T. main charging switch is in the downward position and the polarity reversing switch is at the proper point with respect to the ship's generator voltage, a charging current will flow through the holding coil and the contacts of the under-load circuit breaker, through the overload circuit breaker and main charging resistances, and finally through the battery banks "A" and "B" which are connected in parallel returning to the negative side of the line through the ampere-hour meter. During the charging process the ampere-hour meter reads in a counter-clockwise direction until the clock hand is in a vertical position at which point it closes a small contact and short-circuits the holding coil of the underload circuit breaker, opening the charging circuit.

The voltage readings on the two banks "A" or "B" may be determined by the voltmeter plugs located above the 6 P.D.T. charging switch. This is a two-unit 4 P.D.T. plug arrangement for connecting the voltmeter across any one of four positions for determining the various voltages. These positions are as follows: bank "A", bank "B", bank "A" and "B" discharging, and the ship's generator voltage.

If the batteries indicate full-charge voltage readings, the overload circuit breaker may be opened which disconnects the main charging resistances. When the main charging resistances are opened in this manner and the 6 P.D.T. switch is left in the charging position, the batteries receive a small floating or trickle charging current through two small lamps which are permanently connected in the charging circuit. The lamps keep the batteries in good condition and minimize discharge due to creepage and sulphation when the batteries are not in use.

The 4 P.D.T. switch located at the right of the main 6 P.D.T. charging and discharging switch serves to charge the "A" batteries

for the vacuum-tube receiver. This switch keeps one of the "A" batteries on charge at all times while the other is being used.

When the 4 P.D.T. switch is in a downward position, "A" battery 1 is operating the vacuum-tube receiver while "A" battery 2 is charging. The "A" charging resistance passes approximately 5 amperes which is the proper amount for the 100 ampere-hour Exide batteries. When the 4 P.D.T. switch is in an upward position, the conditions are reversed; namely, "A" battery 1 is placed on charge and "A" battery 2 is operating the vacuum-tube receiver.

When the 6 P.D.T. switch is placed in an upward position, the entire charging system is disconnected and the two 60-volt banks are connected in series to supply an output e.m.f. of 120 volts. This output voltage may now be supplied directly to the motor starter and generator by closing the D.P.S.T. line switch at the top.

If, on the other hand, it is desired to operate the motor starter and generator by the ship's generator, then place the 6 P.D.T. switch in a downward position again, which charges the batteries and connects the ship's generator voltage directly to the two left-hand blades of the 6 P.D.T. switch which feed out to the D.P.S.T. line switch to operate the motor starter and generator.

The Motor Starter and Motor Generator

When the motor starting switch is closed, the voltage from the batteries or the ship's line is applied to the motor and the generator units which results in a current flow through the motor armature, starting resistances and the motor field. No current will flow through the generator field until the generator-field switch is closed. The current which is now flowing through the motor armature and the starting resistances also flows through the first plunger coil of the automatic starter. After a few seconds this plunger rises and short-circuits the first resistance which allows more current to flow into the armature. The second plunger coil then becomes energized and after a few seconds it also rises and short-circuits the second resistance, allowing more current to flow into the armature. The third plunger coil then becomes energized and after a few seconds short-circuits the third and final resistance which allows the
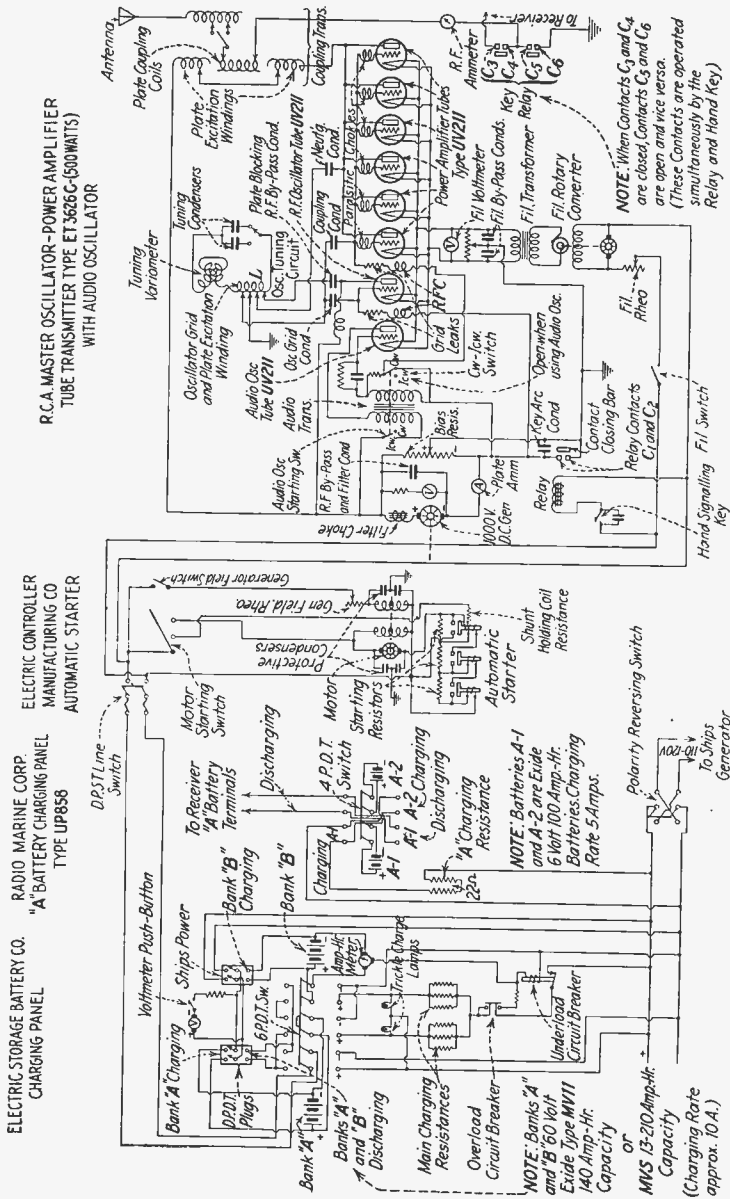
Fig 1.—Modern marine radio installation (transmitter and power supply apparatus) as used aboard American vessels.

R.C.A. IP50I-A COMMERCIAL RECEIVER
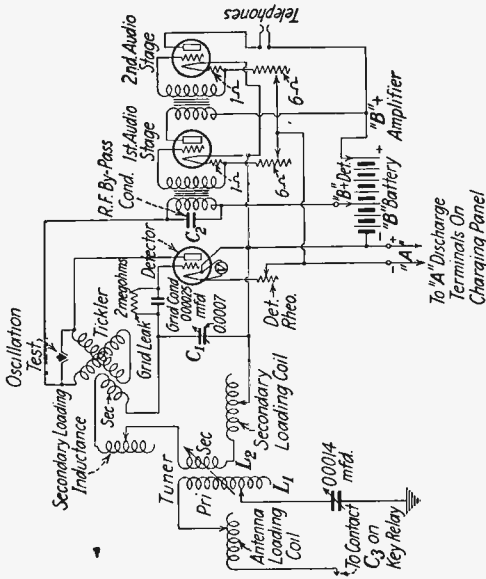
Fig. 1. (continued)—Receiver used with ET 3626-C transmitter.

HINT on studying diagrams: A complete diagram such as is shown in this figure may look difficult to draw. Much of this apparent trouble will disappear if the diagram is studied in sections. Study and draw first the power equipment up to and including the motor of the motor-generator, follow this by the high voltage generator and the transmitter proper, finally learn the receiver diagram. Practice drawing each part separately many times and then the parts may easily be joined to make up the complete installation. Always use standard symbols properly drawn.

full current to flow through the motor armature. The third plunger is also provided with an additional coil called the *shunt holding coil* which keeps this plunger in an upward position during the period in which the motor is operating. If this coil were not provided, the starting resistances would automatically fall in again as soon as the last plunger rises. (See Ques. 284 for a detailed operation of this starter. Also Fig. 69c.)

With the motor field and armature now fully excited and running at full speed the generator-field switch may be closed to excite the generator field. The direct-current generator armature revolving in this field will generate an e.m.f. of over 1,000 volts which may be regulated by varying the generator-field rheostat until the desired voltage is obtained. Do not close generator-field switch until filaments are lighted.

A 6-microfarad condenser is placed across the generator armature to bypass the radiofrequencies and also to filter out commutator ripples and sparking. A filter choke is also provided in series with the armature to filter out the commutator ripples. The choke coil and the condenser together form an efficient low-frequency filter for maintaining a steady e.m.f. to the plates of the vacuum tubes.

A direct-current voltmeter is connected across the high-voltage armature for determining the proper voltage adjustment to the tubes.

THE TRANSMITTER

When the filament switch is closed, a direct current passes simultaneously through the armature and field winding of the filament converter which sets it into operation. An alternating-current armature is on the shaft of the motor which is excited by the same field operating the motor. An alternating e.m.f. is induced into the alternating-current armature which causes an alternating current to flow through the primary winding of the filament transformer. Here the voltage is stepped down through the medium of a low-turn-ratio but a high-current-carrying winding. The voltage is carefully regulated by the filament rheostat until the voltmeter reads exactly 10 volts which is the proper operating voltage of the UV 211 type tubes.

When the filaments are assumed to be properly heated and emitting electrons, the generator-field switch is closed. Adjust the generator-field rheostat until the plate voltage reading at the generator voltmeter indicates 1,000 volts. With the hand signalling key now in an open position (up), the relay solenoid is demagnetized which causes the contact closing bar to be drawn away from the contacts by a small steel spring.

When the key is in the open position, no plate current will flow in the various tube-plate circuits, owing to a large negative grid bias which is applied to all the tube grids. This bias is maintained by a 40,000-ohm potentiometer which is connected across the 1,000-volt direct-current generator. The lower end of this resistance is disconnected from the ground and filament when the relay contacts are open, which consequently applies a negative bias to the grids of the oscillator and amplifier tubes, owing to the voltage drop across the potentiometer. In other words, the center tap of the potentiometer is at a higher potential than the bottom end and, since this end $(+)$ is connected to the ground or filament, the negative end $(-)$ of the resistance is said to be negative with respect to the filament. Hence the voltage between the point $(+)$ and $(-)$ on the potentiometer will be applied directly between filament and grids, with the grids receiving the negative end.

Thus the tremendous blocking action which is obtained, owing to the excessive negative grid potential on the grids, prevents any plate current from flowing when the key circuit is open. The bias voltage across the potentiometer is approximately 250 volts.

When the hand signalling key is closed and the energizing current flows through the relay winding, the relay contacts C_1 and C_2, C_5 and C_6 are closed while contacts C_3 and C_4 remain open. This simultaneous action closes the B-circuit in the transmitter, completes the antenna circuit to the transmitter, and disconnects the receiver. Furthermore, when contacts C_1 and C_2 are closed, the 250-volt negative bias is immediately eliminated through the short-circuiting of the bias portion of the potentiometer at the points $(+)$ and $(-)$.

A plate current is now flowing in each plate circuit of the oscillator and amplifier tubes.

With the audio-oscillator switch assumed to be opened and the antenna and plate-excitation circuits to be in resonance, a continuous wave (CW) will be emitted from the antenna during the period in which the key circuit is closed, provided the CW-ICW switch is at CW.

These waves are generated by the master-oscillator tube through the medium of an inductive feed-back system known as a Hartley or split-inductance method of generating oscillations. The action is briefly as follows.

When a momentary change in the plate-circuit current of the oscillator tube takes place (the instant when the key is closed), a displacement current flows through the plate blocking radiofrequency bypass condenser and the plate excitation winding of the tuning inductance L. This induces an e.m.f. across the grid-excitation section of the coil L and consequently to the grid of the radiofrequency oscillator tube. This starts the tube oscillating at a definite frequency dependent upon the constants of the oscillatory tuning circuits, the variometer, and the tuning condensers.

When the tube is oscillating, the high-frequency e.m.f. is fed to the grids of the power-amplifier tubes which are all connected in parallel through the medium of the coupling condenser. The proper values of grid bias for both oscillator and amplifier tubes is maintained by the grid leaks connected, respectively, from the grids of the oscillator and amplifier tubes. Radiofrequency chokes are also provided to keep the high frequencies out of the power-supply circuit. Small parasitic chokes are also connected in series with all the grids of the amplifier tubes to prevent self-oscillation at extremely high radiofrequencies due to coupling effects when connecting a number of tubes in parallel. The neutralizing condenser is of a fixed value and need not be varied since the capacity neutralization can be effected by varying the neutralizing section of the inductance on the main tuning inductance L.

The high-frequency currents returning to the filaments are properly bypassed across the filament transformer by the two filament bypass condensers.

The high-frequency oscillating currents present in the plate circuits of the amplifier during the period when the master-

oscillator tube is oscillating are then fed into the antenna radiating system from the plate-excitation winding through the plate-coupling coils and into the antenna tuning inductance. With careful adjustment of the circuits to resonance a maximum radio-frequency current may be obtained in the open radiating circuit.

For ICW signalling the CW-ICW switch must be thrown to ICW. This closes the audio-oscillator starting switch which supplies a positive potential to the audio-oscillator tube. When a plate current flows in this circuit, an e.m.f. will be induced from the primary winding into the secondary winding of the audio transformer which excites the grid of the tube and starts the low-frequency oscillations. Hence, if this tube is oscillating at some audible frequency, the continuous waves generated by the radiofrequency oscillator will be varied at an audible frequency (modulated) and will result in the emission of an interrupted continuous wave (ICW).

When the signalling key is again released, the contacts C_1, C_2, C_5 and C_6 will open and contacts C_3 and C_4 will close, connecting the antenna to the receiver.

The ET 3626-C transmitter is designed for operating on the intermediate- and long-wave commercial bands of 600 to 800 meters and 1,550 to 2,500 meters.

The normal operating plate voltage is 1,000 volts and the plate current at this voltage should be between 1.2 and 1.75 amperes. If the plate current reading is too low, the reactance of the plate circuit should be decreased by taking out some turns from the plate-excitation winding of the coupling transformer. If the current is too high, increase the number of turns in the winding.

When using the audio oscillator for ICW transmission, it is possible to change the tone frequency by varying a shunt capacity across the audio-oscillator transformer. A switch is provided for this purpose which can change the tone frequency in three steps to 500, 700, or 1,000 cycles.

See also Ques. 12 for the theoretical explanation of an oscillator tube. The audiofrequency oscillator operates upon the same principle as the radiofrequency oscillator with the exception that an iron-core transformer is used in place of an air-core transformer.

The Receiver

The receiver is the R.C.A. model IP501 A. Its range is 250 to 8,000 meters which may be increased to 20,000 meters by the addition of a long-wave attachment.

When the transmitting key circuit is opened and the relay contacts C_3 and C_4 are closed, the transmitting antenna will be connected directly to the primary winding of the receiver.

An incoming signal will then pass through the primary winding of the tuner through the antenna series condenser and to the ground. This complete circuit then oscillates at a definite radiofrequency depending upon the adjustments of the antenna inductances and the series condenser.

The varying magnetic field which will be present in the primary winding L_1 under these conditions will induce an e.m.f. across the secondary winding of the tuner L_2 and across the tuning condenser C_1. The inductance L_2 and C_1 together with the loading inductance forms the complete secondary tuning circuit.

When this circuit is carefully adjusted to resonance with the incoming signal by varying the inductance and the capacity, a maximum signal e.m.f. will be applied to the grid of the detector tube through the series-grid condenser. In other words the signal voltage variations across L_2 and C_1 will be applied between the grid and the filament of the detector tube which will vary the steady plate current flowing in the plate circuit and the primary winding of the first-audio-stage transformer. The high-frequency inaudible currents will be bypassed through the radio-frequency bypass condenser C_2 and the rectified currents will pass through the primary winding of the audiofrequency transformer.

The grid-condenser and grid-leak action affects the rectification signal so that it may be ultimately heard in the telephones. (See Ques. 131 for the detailed explanation of the rectifying action of a grid condenser and grid leak.)

The rectified signal variations in the primary winding of the first-audiofrequency transformer are then induced into the secondary winding and to the grid of the first audio tube. Here the signal variations are again amplified in the plate circuit of the tube and transferred to the second audio stage. The highly amplified variations now present in the plate circuit

of the last tube pass through the telephone windings in which the current and magnetic variations actuate the diaphragm which render the signals to audibility.

Regeneration and oscillation is obtained by a variometer connected in the plate circuit, in which a portion of its inductance is magnetically coupled to the secondary circuit. An oscillation test button is provided for determining if the receiver is oscillating properly for the reception of continuous wave (CW). When this button is closed, the circuit will stop oscillating causing a click to be heard in the telephones. If no click is heard, this indicates that the variometer has not been adjusted for oscillation. For CW reception the variometer should be varied until an oscillation click is heard in the telephones.

The Radiating System

This set is designed for operation with a conventional Marconi radiator consisting of elevated wires and a ground connection.

BRIEF PRACTICAL OPERATION

The practical operation of this set is simple. To tune the set, turn the field and filament rheostats to their lowest voltage positions. Close the main-line switch and press "start" button on operator's control unit which should bring the motor generator up to speed immediately. Adjust filament rheostat until filament voltage reads 10 volts. Then adjust generator-field rheostat until plate voltage reads 1,000 volts.

The next step is to throw the wave-range transfer switch up for long waves (1,250 to 2,500 meters) and down for medium waves (600 to 1,250 meters). Then set "exciter tuning" and "range switch" to the wave-length desired. Set CW-ICW switch to the CW position. Now adjust antenna inductance switches to range desired and adjust the proper "antenna-tuning" knob for a maximum reading on the radiation meter, while pressing the "test" push button. It is important to read the proper exciter wave-length scale corresponding with the position of "exciter range" switch. The set is now tuned and the telegraph key may be operated for the transmission of signals.

To shut down the transmitter, press "stop" button on operator's control unit.

For ICW transmission, throw CW-ICW switch to ICW. The ICW note may be varied by adjusting the three-point tone-frequency switch (not shown on diagram) to 500, 700, or 1,000 cycles, as desired. The set must be tuned on CW. The tone-frequency dial switch must not be touched while motor generator is running, as plate voltage is then on set.

The practical operation of a commercial receiver is described in Ques. 139.

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 tube; for a UV 211 (50-watt) tube?**

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

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 77 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.

Ques. 3. **What causes over-heating 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 over-heating. 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.

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.
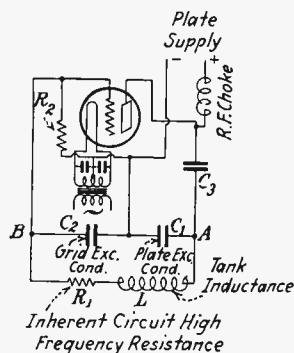
Fig.   2.—Theoretical tank circuit.

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_1/C_2, 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_2, 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. Plate voltage should be decreased below this point.

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.—F u n d a m e n t a l 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
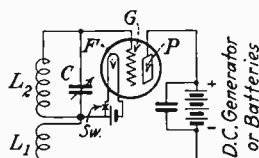
would cut the coil L_2, due to its inductive relation, and would, consequently, induce an e.m.f., or difference of potential, across it.   If then, the coils are wound in a direction in which L_2 would receive a positive potential at the top end and a negative potential at the bottom end, the grid which 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. A.C. with transformer and tube rectifiers and filters.

3. Storage batteries with suitable ampere-hour capacity.

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

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 blocking 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 direct-current voltages 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. A grid-leak and radiofrequency choke provides the bias in some oscillators.

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 these circuits. 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.

Fundamental Hartley Oscillator
A

Fundamental Colpitts Oscillator
B

Fundamental Tuned-Plate Tuned-Grid Oscillator
C
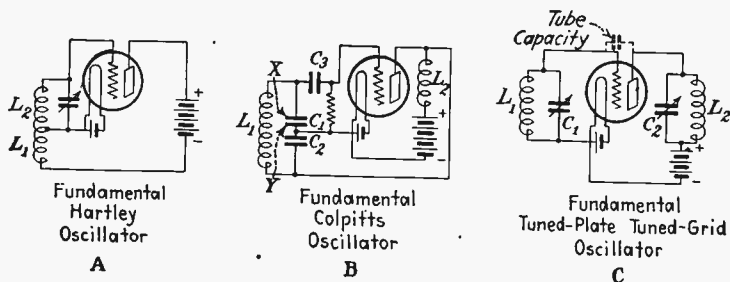
FIG. 4.—*A*. Hartley, *B*. Colpitts, and *C*. tuned-plate, tuned-grid oscillators.

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 even when the alternating-potential variations are applied to the grid, during the positive cycle, and there will eventually be a decrease in 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 corre-

sponding 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.

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.

Fig. 5.— Piezo-electric oscillator.

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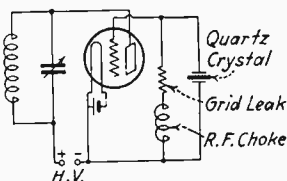
3. If a neon tube or a high-frequency ammeter is connected in the high-frequency portion of the plate circuit, an indication on either device will serve as an oscillation indicating method.

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 radiofrequency 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.
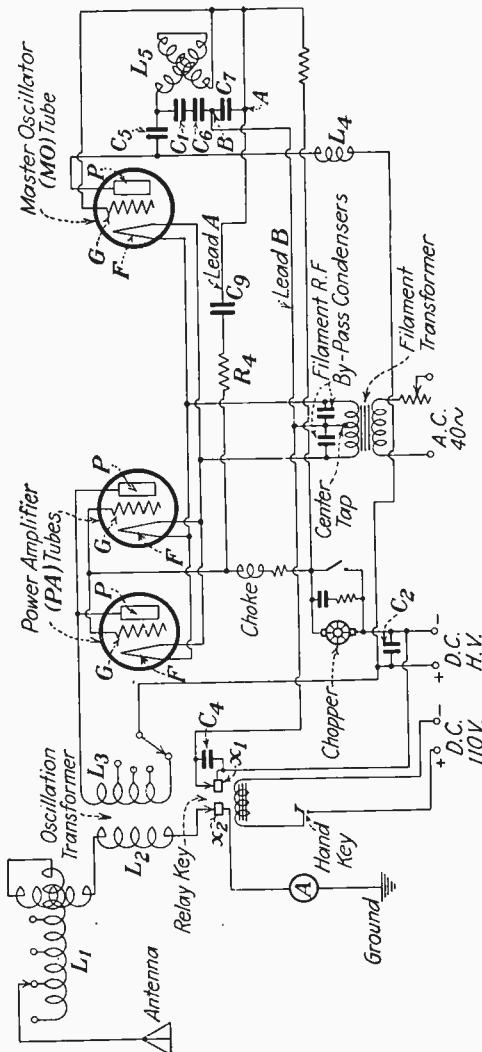
FIG. 6.—Vacuum-tube transmitter (master-oscillator type), R.C.A. Model ET 3627A, 200 watt CW and ICW.

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 77-volt 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

(b)

(c)
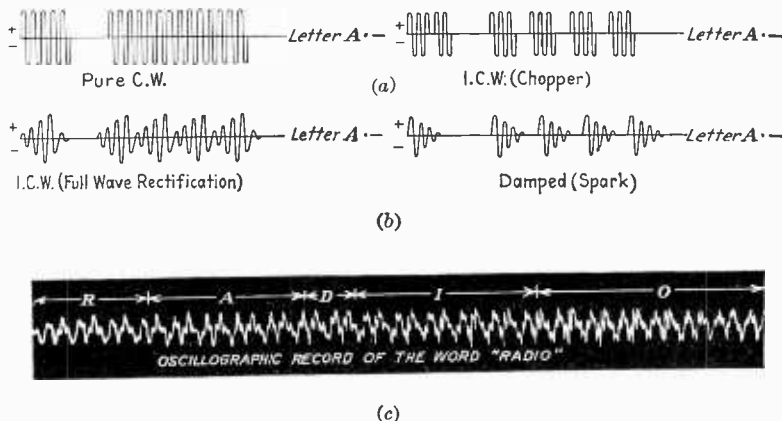
Fig. 7.—Characteristics of radio waves.

(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, (a), (right), 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 two steps 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*A* illustrates a complete diagram of the above parts.

Ques. 24. Draw a schematic wiring diagram of a commercial radiophone attachment.

Ans. This is shown in the diagram Fig. 7*A*. It may be shown separately to answer this question.

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
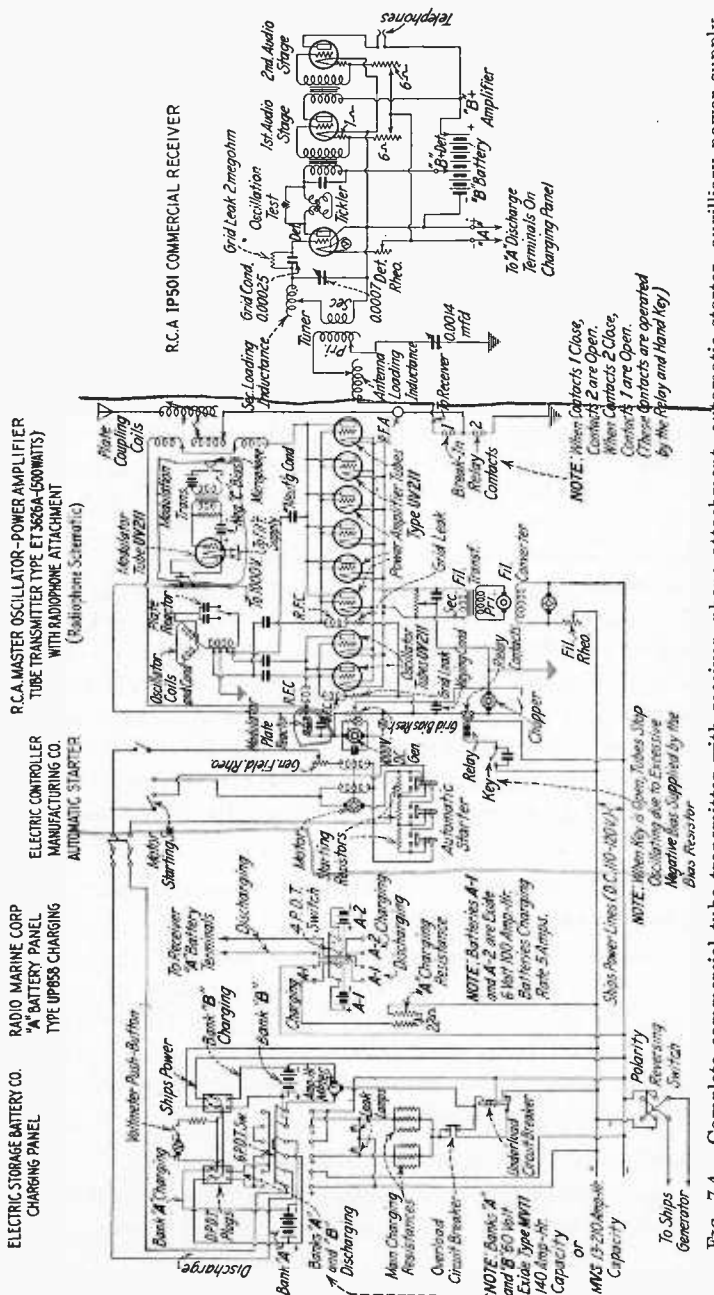
FIG. 7A.—Complete commercial tube transmitter with receiver, phone attachment, automatic starter, auxilliary power supply and charging equipment.

NOTE.—Protective condensers must be connected across the armature and field coils of the motor generator similar to Fig. 1. Also put series resistance in automatic starter as shown in Fig. 69c. It is preferable to draw the receiver as shown in Fig. 1.

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 $\frac{1}{8}$ 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 bypassing the undesirable harmonics to ground. 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. (See Fig. 79a.)

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 for a tube at its rated voltage.
  2. Improper bias voltage.
  3. Tube overloading.
  4. Unsteady oscillation.
  5. Soft tube.
  6. Indicates when tube is oscillating.

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 plate 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 $(B-)$, or in the case of the ACW 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. For a grid-bias method of keying, see Ques. 40*l*.

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

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 7*B* illustrates two ways in which alternating current may be used as a power supply for vacuum tubes.

Full wave rectifying circuit.

Full wave self-rectifying transmitter circuit.
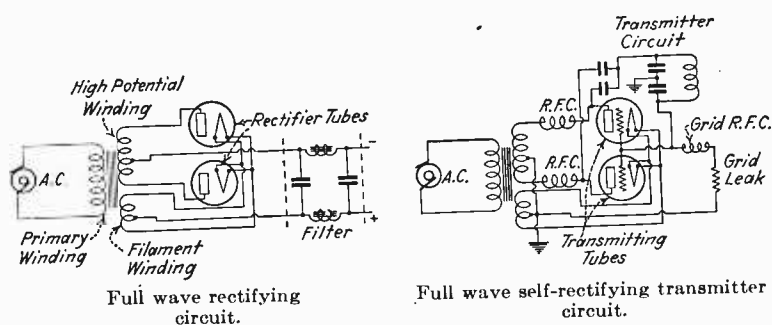
Fig. 7*B.*

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 high-frequency connections, also by connecting a biasing battery in series with the grid leak.

Ques. 37. State some principal causes of trouble encountered with tube transmitters.

Ans. 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.

Low radiation due to dirty or leaky insulators.

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.

Ques. 40a. What are three most general causes of trouble in a vacuum-tube transmitter?

Ans. 1. Defective tubes (low emission, gaseous).

2. Defective condensers.

3. Defective contacts (relays, safety switches, etc.). See also Ques. 37.

Ques. 40b. Why is it necessary to maintain the proper filament voltage on a tube transmitter?

Ans. The proper filament voltage must be maintained to insure the proper degree of electron emission, correct plate current, steady plate current, frequency stabilization, and maximum operating life. (See also Ques. 42.)

Ques. 40c. Explain how to place a vacuum-tube transmitter into proper operation.

Ans. See Ques. 1.

Ques. 40d. How is the power input and output of a tube transmitter measured?

Ans. The power input of a tube transmitter is calculated by the general power formula $W = EI$. For example, if the plate voltage of the power-amplifier tubes coupled to the antenna is 3,000 volts and the total plate current $\frac{1}{4}$ ampere, then the power input will be $W = EI$ or $3,000 \times 0.25 = 750$ watts.

The power output is calculated from the formula $W = I^2R$, where I is the antenna current and R the radiation resistance. Hence, if the antenna current is 3 amperes and the radiation resistance 55 ohms, then I^2R or $9 \times 55 = 495$ watts of radiated power. See also Ques. 394r.

Ques. 40e. If the primary circuit of a tube transmitter is out of adjustment, how could it be readjusted to the same frequency as the secondary circuit?

Ans. If it is assumed that the secondary circuit has previously been adjusted to resonance with the primary circuit and that the primary-circuit constants have been changed, it will be a simple matter to readjust the primary to resonance with the secondary by varying the inductance or the capacity,

or both, of the primary circuit until a maximum indication of resonance is obtained on the antenna ammeter.

It would also be possible to determine the proper primary adjustment by noting carefully the changes in the plate-current readings at the plate milliameter. For example, if the secondary circuit has been previously adjusted to a definite frequency, then the proper variation of L to C in the primary circuit will be denoted by a maximum dip on the plate-milliammeter reading as soon as a resonant condition with the secondary circuit is found.

Ques. 40f. How can it be determined if a tube transmitter is operating properly?

Ans. The proper operation of a tube transmitter can be determined by a careful check of the various circuit-voltage and current readings, for example, plate current in all tube circuits, grid bias on all grids, plate voltage on all plates and radiofrequency tank currents. All readings must correspond to certain definite readings as specified by the tube manufacturers and engineering designs.

Ques. 40g. What protective devices are used in the plate circuit of a tube transmitter?

Ans. Overload relays and fuses.

Ques. 40h. What makes a tube oscillate?

Ans. A vacuum tube may be made to oscillate through the medium of inductive or capacitive feed-back between the plate and grid circuits. (See Ques. 12.)

Ques. 40i. What instruments are used in filament circuits?

Ans. The voltmeter and rheostat. The voltmeter must always be connected across the filament terminals to determine if the filament voltage is properly adjusted for the proper emission and maximum efficiency.

The rheostat is usually connected in series with the filament to control the filament current and emission and to provide for the proper adjustment of the voltage as prescribed by the manufacturer.

Ques. 40j. What are two methods of reducing grid currents in vacuum-tube transmitting circuits?

Ans. Grid currents are usually reduced by increasing the negative bias on the grids of the tubes or by decreasing the grid excitation.

Losser methods such as series-grid resistances are sometimes used but more effective and efficient methods such as bias and excitation adjustments are preferable.

Ques. 40k. What is the usual plate voltage of a vacuum tube functioning as an oscillator or an amplifier as applied to tube transmission? Why?

Ans. The plate-voltage adjustment of an oscillator tube is usually below that when it is used as an amplifier. This is due to the difference, in the grid bias adjustments necessary, between oscillators and amplifiers.

When a tube is functioning as a self-excited oscillator, the grid swings must cover the entire portion of the $I_p - E_c$ characteristic curve. When functioning as an amplifier, the operation should be restricted to the straight portion of the characteristic curve. Hence amplifier tubes are usually operated with larger grid and plate voltages to obtain a better straight portion on the characteristic curve.

In the *class C* amplifiers, for example, the grid bias is adjusted beyond the plate-current cut-off point; hence a large plate voltage is essential in order to produce plate variations when grid swings are applied.

The plate voltage of oscillator or amplifier tubes varies from 250 to 5,000 volts depending on the type of tube and class of operation used.

Ques. 40l. Describe a grid-bias method of keying.

Ans. An excellent method of keying a transmitter is to apply a heavy negative voltage to the grids of the oscillator and amplifier tubes. This system, called the grid-bias system of keying, utilizes a high resistance across the high-voltage plate line and is so arranged that, when the key is up, a negative bias drop is secured across this resistance and applied to the grids which blocks the tubes. When the key is depressed,

this resistance is cut out of the grid circuit, only the normal operating bias remains, and the tubes function normally.

Ques. 40*m***.   Draw a diagram of an ACW tube transmitter complete with receiver, automatic starter, and emergency equipment.**

Ans.   Figure 7*D* illustrates a complete marine transmitter and receiver with auxiliary power equipment.

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*A* illustrates a complete wiring diagram of a commercial tube transmitter with a radiophone attachment.
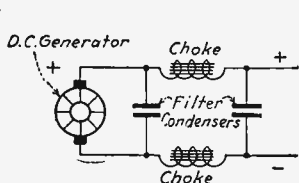
FIG. 7*C*.—D. C. filter system.

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.
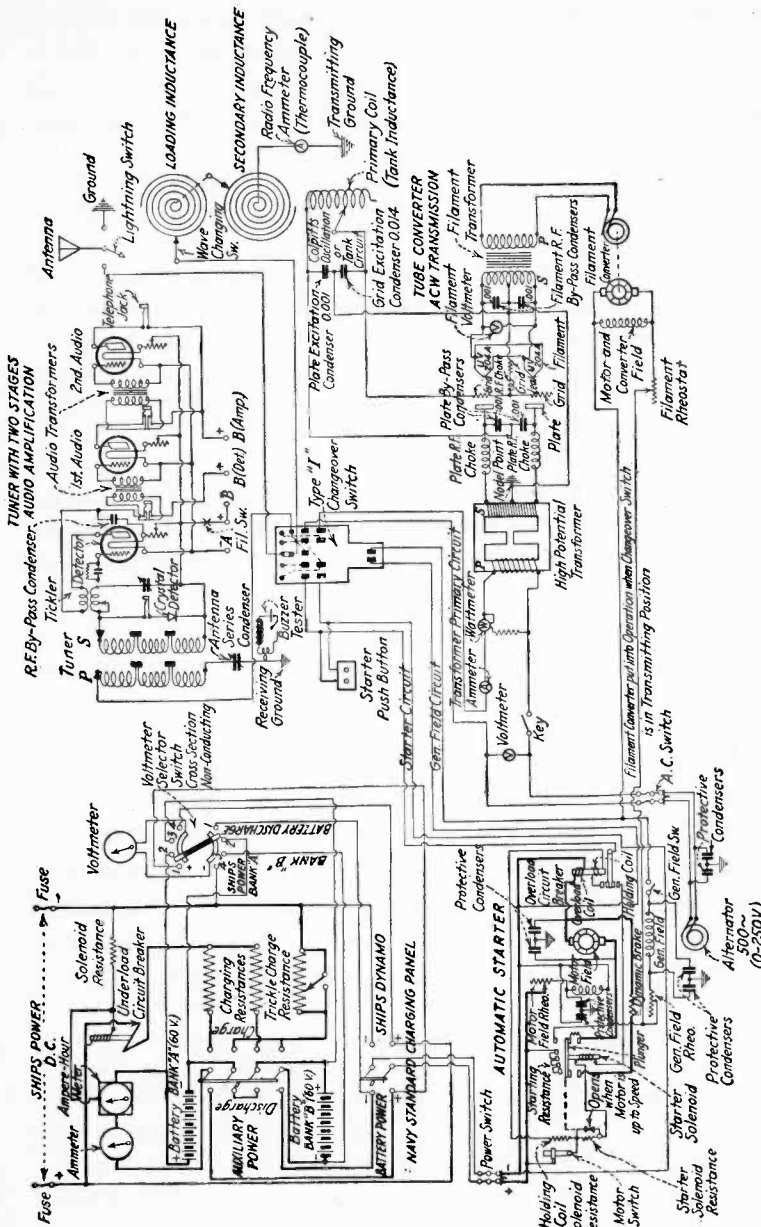
Fig. 7D.—Wiring diagram of complete commercial-type transmitter and receiver. Transmitter, R.C.A. Model ET-3628 500-watt ACW; Receiver, R.C.A. Model 106D.

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 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.

Ques. 45*a*. **How would you decrease the power of a tube transmitter for operation on a comparatively shorter wavelength?**

Ans. To decrease the power of a tube transmitter increase the generator field resistance at the generator field rheostat. In order to obtain the maximum efficiency of a tube transmitter when operating on a shorter wavelength, it is usually necessary to decrease the number of turns in the plate coupling coil.

Ques. 45*b*. **What are the purposes of blocking condensers in a vacuum-tube transmitter? How are they usually connected?**

Ans. Blocking condensers are used to prevent the flow of direct current, while at the same time allowing the flow of radiofrequency currents, in the circuits in which they are placed. Blocking condensers are also known as "stopping condensers."

They are usually placed in the radiofrequency plate or grid circuits, or both, depending on the circuit, to prevent the direct-current plate current and the direct-current grid biasing voltage from flowing into the radiofrequency portions of these circuits. They also prevent the direct current from being short-circuited through these circuits.

A study of transmitter diagrams will illustrate these points.

Ques. 45c. What is meant by a soft tube? How is it possible to tell if a tube is soft?

Ans. A soft tube is one in which there is a certain amount of gas present. This condition may be determined by the presence of a blue haze between the filament and the plate. A soft tube can usually be detected by an erratic operation of the plate milliammeter or an excessive flow of plate current.

Ques. 45d. Draw five simple diagrams of vacuum-tube transmitting circuits.

Ans. See Figs. 4, 5, 7B, and 88.

Ques. 45e. What is meant by the piezo effect of a quartz crystal?

Ans. See the first and second paragraphs of Ques. 17.

Ques. 45f. What are the power ratings and normal plate voltages of some of the transmitting tubes in common use?

Ans. When used as class A amplifiers the ratings are as shown below.

Type	Fil. volts (max.)	Fil. current, amp.	Plate voltage	Max. plate dissipation, watts	Max. plate current, amp.	Power output (nominal), watts
211	10	3.25	1,000 to 1,250	100	0.175	75
204A	11	3.85	2,000 to 2,500	250	0.275	250
845	10	3.25	1,000 to 1,250	100	0.175	75
849	11	5.00	2,000 to 2,500	400	0.350	350
851	11	15.50	2,000 to 2,500	750	1.000	1,000
861	11	10.00	3,000 to 4,000	400	0.350	500

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.

NOTE.—Part IX, Broadcast Transmitters, and the Addenda also contain questions and answers pertaining to tube transmitters.

PART II

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

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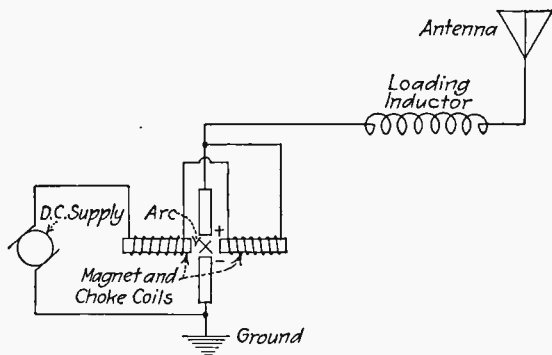
FIG. 8.—Elementary wiring diagram of arc transmitter.

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
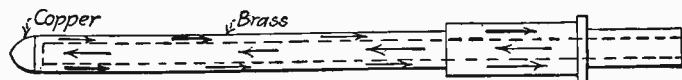
FIG. 9.—Water-cooled arc electrode.

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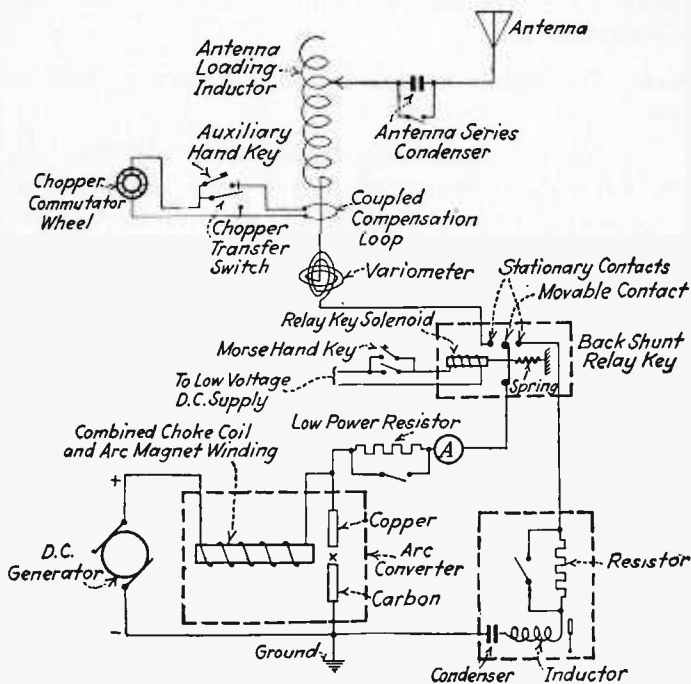
Fig. 10.—Wiring diagram "back-shunt" arc signalling system.

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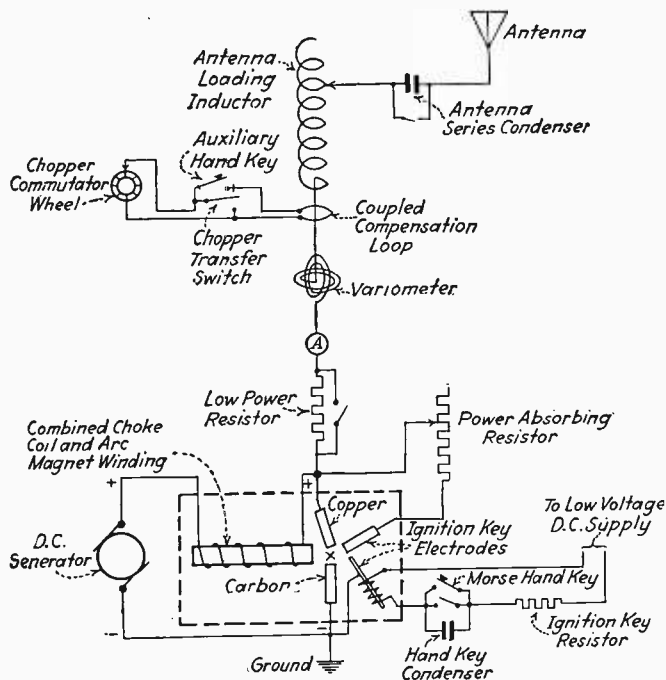
Fig. 11.—Wiring diagram "ignition-key" arc signalling system.

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 hydro-carbon gas, may become deposited evenly.   The cathode, due to this formation, will in time have a mushroom-like shape.
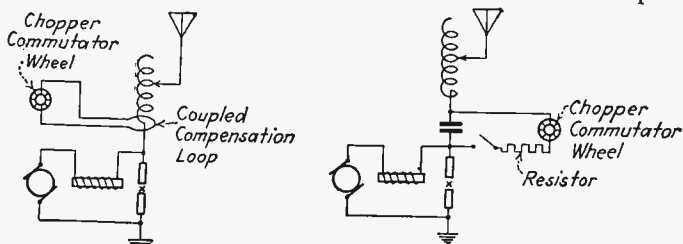
FIG. 12.—Wiring diagram "compensating-loop" and "chopper" arc signalling systems.

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 $\frac{1}{32}$ to $\frac{1}{8}$ 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.
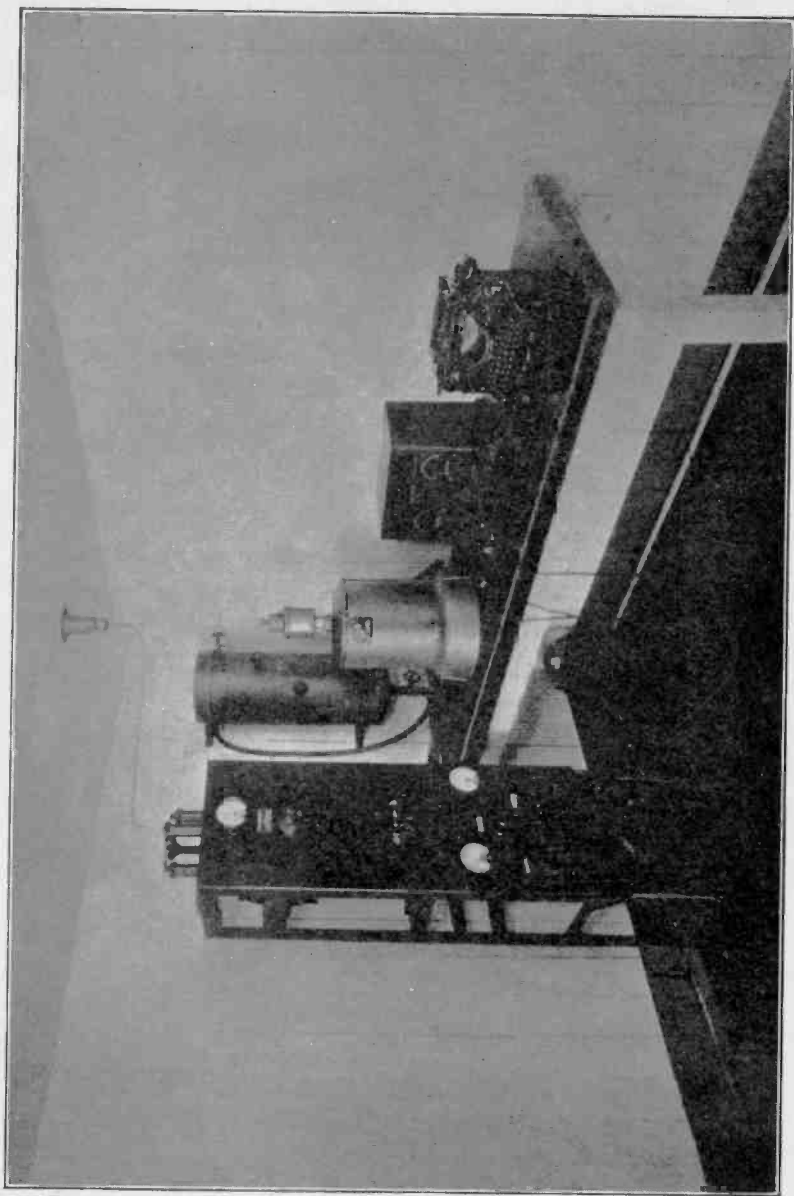
FIG. 13.—Two-kilowatts Federal arc installation. (*Courtesy*, Federal Telegraph Company.)

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 one stage 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.
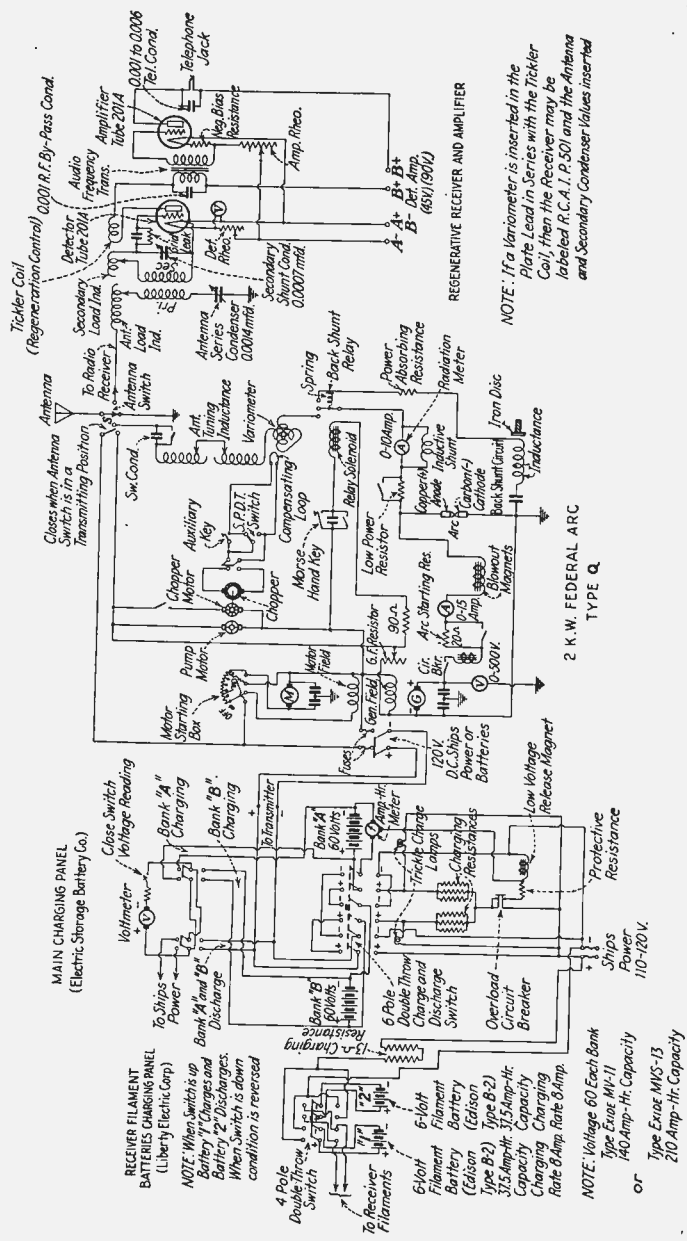
Fig. 13.A.—Complete commercial arc installation with receiver, hand starter, auxiliary power and charging devices.

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
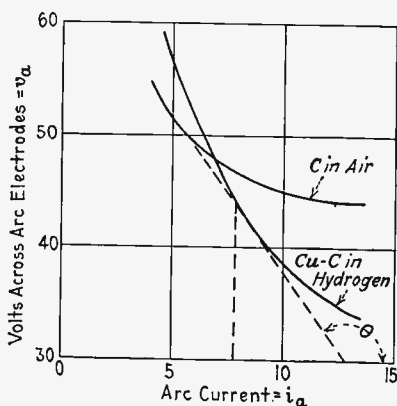
FIG. 13*B*.

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 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.
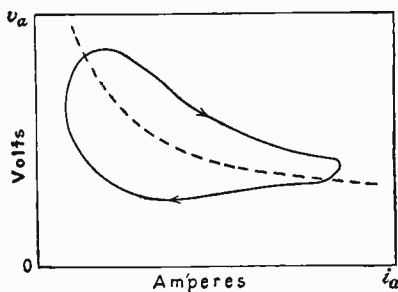
Fig. 13*C*.

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-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. 13D, which illustrates the various current
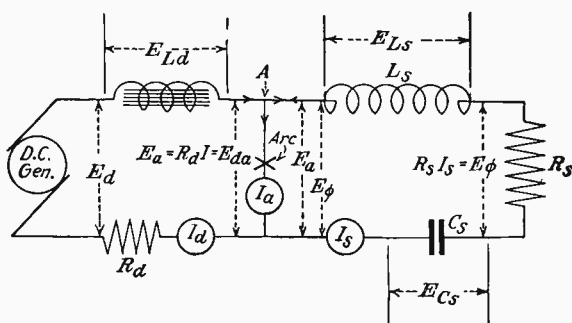
FIG. 13D.

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

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,
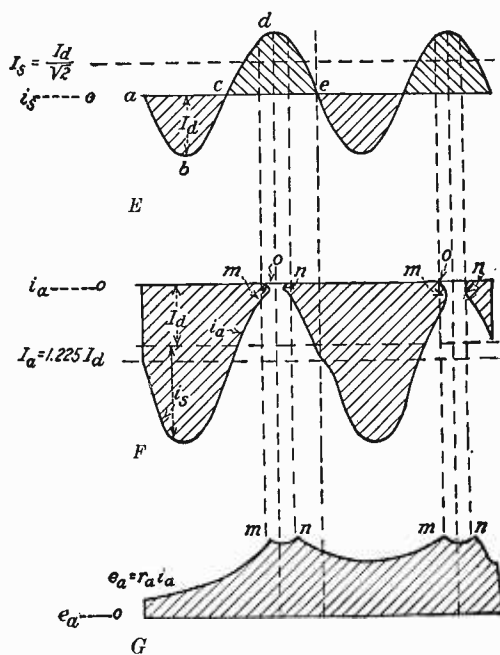
FIGS. 13E, F, G.

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. 13E) 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. 13F 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 L_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 con-

stantly 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
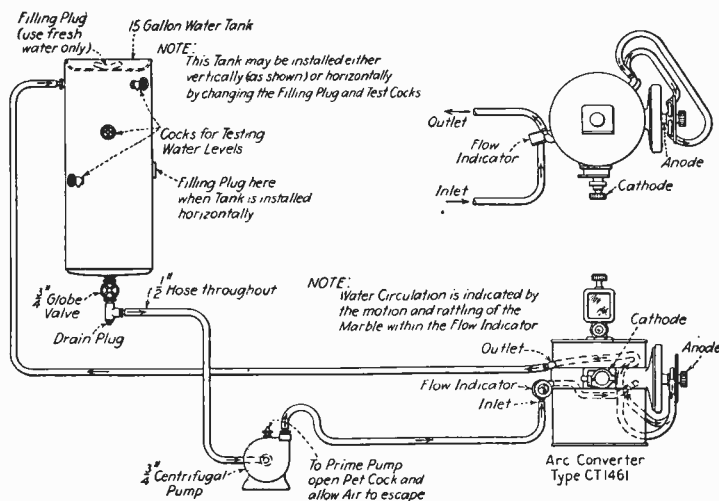
Fig. 13H.—Arc cooling system.

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.

Ques. 65a.   Draw a diagram and explain why the cooling system of the arc transmitter does not cause a short-circuit.

Ans.   The cooling system of an arc transmitter is illustrated in Fig. 13*H*.   The water circulating through the rubber-hose system which connects the anode and the upper and lower chamber of an arc converter is fresh water and will not serve as a conductor.   If, on the other hand, salt water is used, the entire arc system may become short-circuited, owing to the high electrical conductivity of salt water.   See also Fig. 9 for the cross-sectional structure of the water-cooled electrode.

Ques. 65b.   How can the steadiness of an arc signal be determined?

Ans.   The steadiness of an arc signal can be determined by coupling an absorption loop to the arc inductance together with a small neon glow tube.   Practically, the best results may be obtained by shunting the neon tube directly across one or two turns of the antenna loading inductance until a glow is obtained. Proceed to adjust the arc electrodes and voltage until a steady glow is obtained in the tube.   This usually indicates with fair accuracy the stability and quality of the arc signal.

It is also possible to adjust for the arc quality by tuning the receiver to the proper frequency but this usually results in receiver distortion and is therefore recommended only in cases where the neon tube is not provided.   Only the detector stage should be used when making the observation with the radio receiver.

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 III

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 tele-

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phone, a maximum reading of a hot-wire or thermocouple amme-ter 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. 352a).

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.
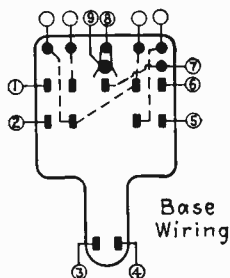
Fig. 14.—Antenna switch with connections.

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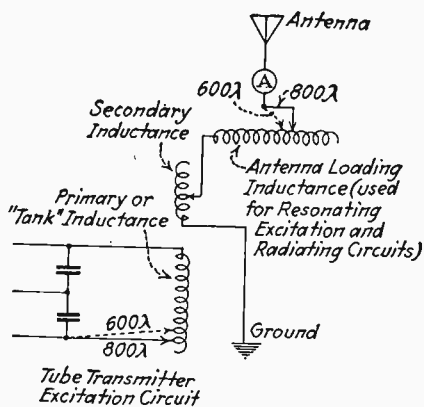
Fig. 15.—Sketch showing changes from 800 to 600 meters.

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 suffi-

ciently 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.

Heat
Radiating
Flanges

Inner
Insulating
Gasket

Outer
Insulating
Gasket

Insulated
Part of Bolt

Sparking
Surfaces

Assembly
Bolt

Outer
Insulating
Gasket

Inner
Insulating
Gasket

Cross-Section
of Gap Unit

Assembly of Gap Unit

G A P   U N I T   P A R T S
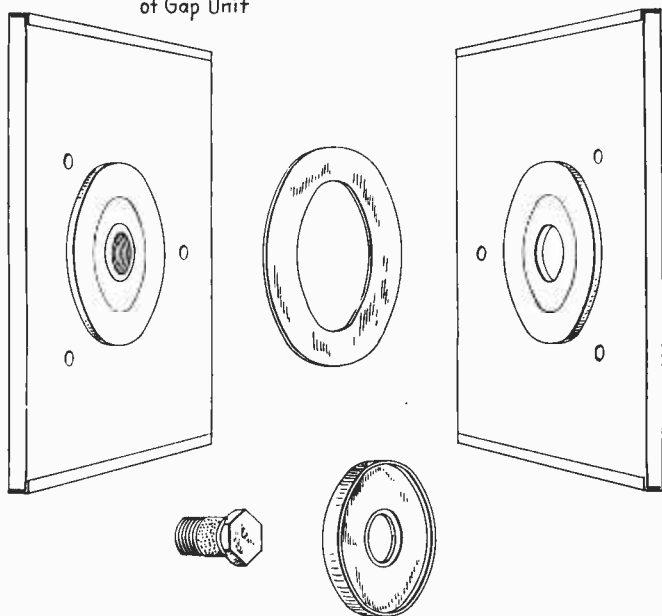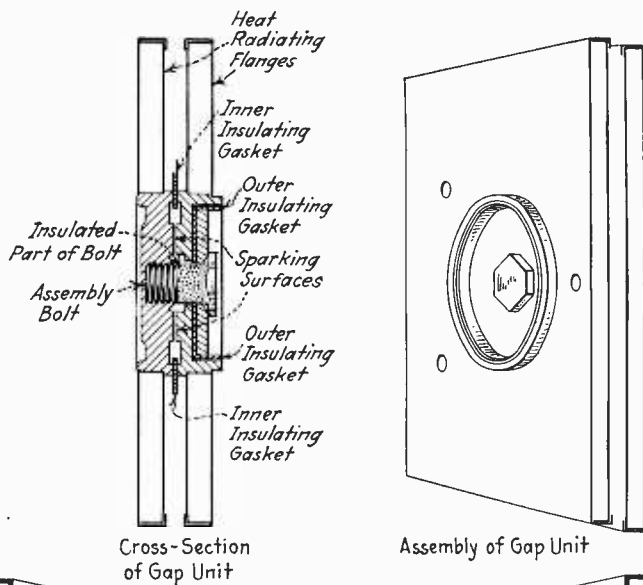
FIG. 16.—Quenched spark gap.

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.
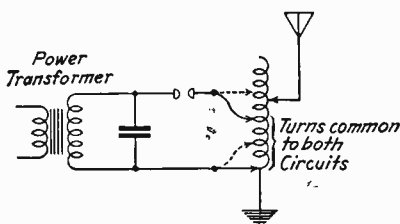
FIG. 17.—Conductively coupled transmitter.

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

Ans. 1. Glass plate (obsolete).

2. Leyden jar (obsolete).

3. Compressed air (obsolete).

4. Mica.

1. The glass-plate condenser consists of a number of plates of high-grade glass about $\frac{1}{4}$ 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
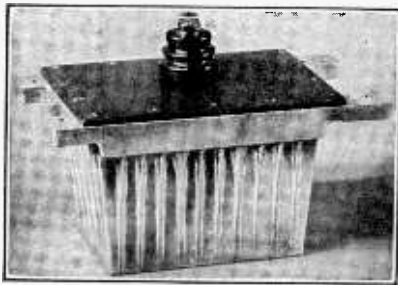
Fig. 18.—Mica transmitting condenser. (*Courtesy*, Dubilier Condenser Corporation.)

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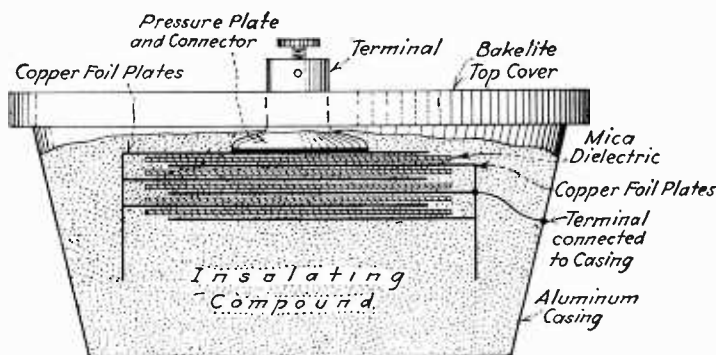
FIG. 19.—Cross-section of mica transmitting condenser.

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

Terminals Connected to Protected Apparatus
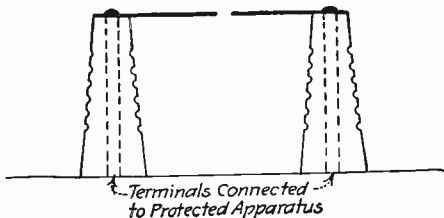
Fig. 20.—Protective safety spark gap.

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. 19a 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 thermoelectric 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
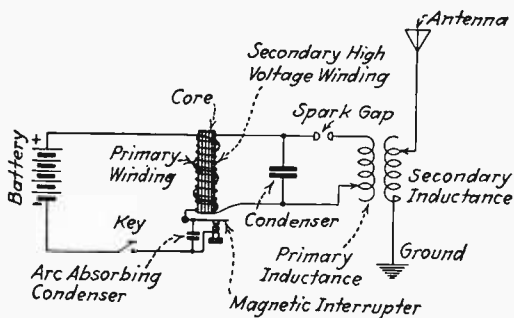
Fig. 21.—Induction-coil transmitter.

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; batteries.

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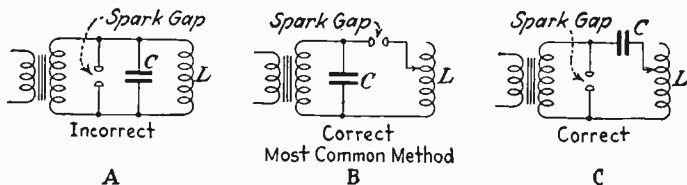
FIG. 22.—Correct and incorrect method of connecting spark gap and condensers to transformer.

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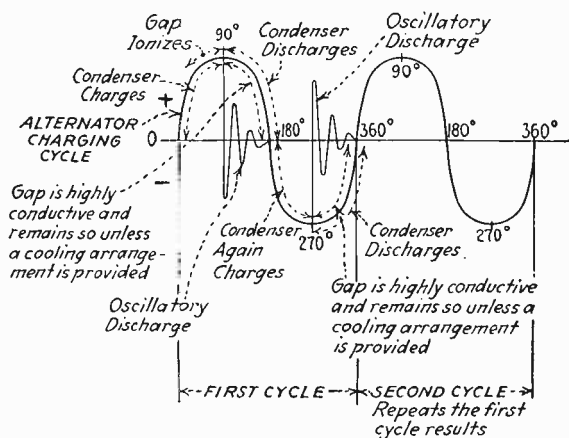
FIG. 23.—Cycle of events in the discharge of a condenser.

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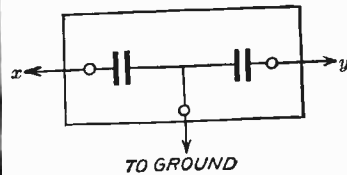
FIG. 24.—Protective condensers: (*left*) photo; (*right*) wiring diagram, terminals *x* and *y* connect to apparatus to be protected.

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 coupling for maximum radiation (see Fig. 31).

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

FIG. 24a.—Protective devices on receiver.

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. 24a).

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

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 trans-

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

former is used for both step-up or step-down purposes. Only the step-up type will be discussed here.

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.
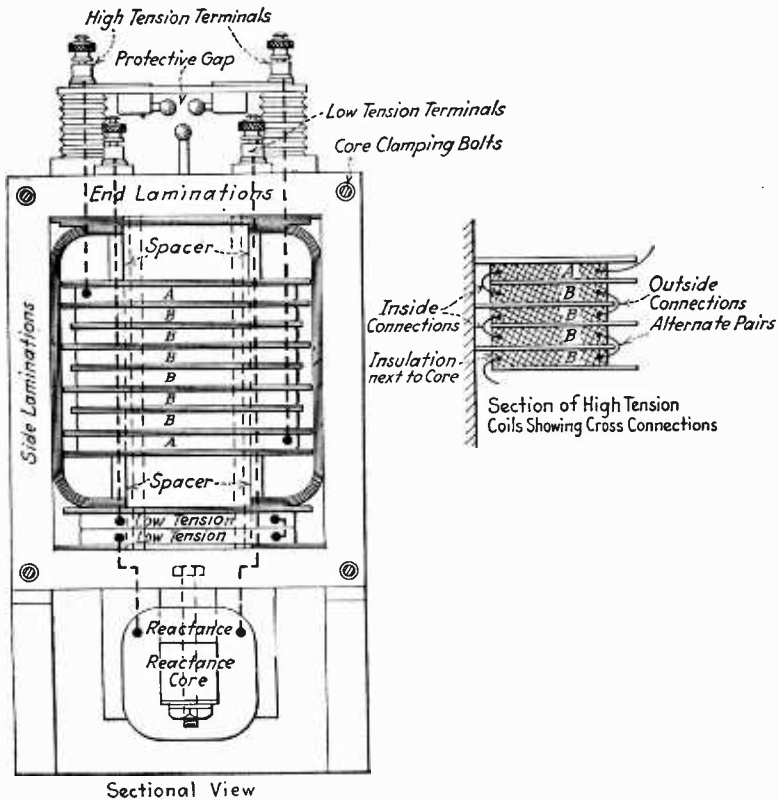
FIG. 26.—Assembly of a transformer.

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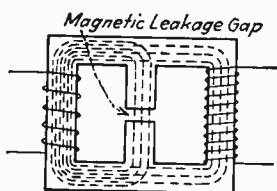
FIG. 27.—Closed-core transformer with leakage gap.

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.
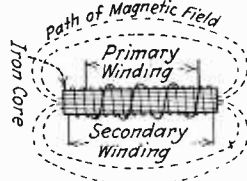
FIG. 28.—Open-core transformer.

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.

Qués. 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. For a step-down transformer the reverse is true.

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

Ans. Three types of antenna systems (transmitting) are the inverted L (T), the T, and the umbrella. Figure 29 illustrates these three types. These are all Marconi type radiators.
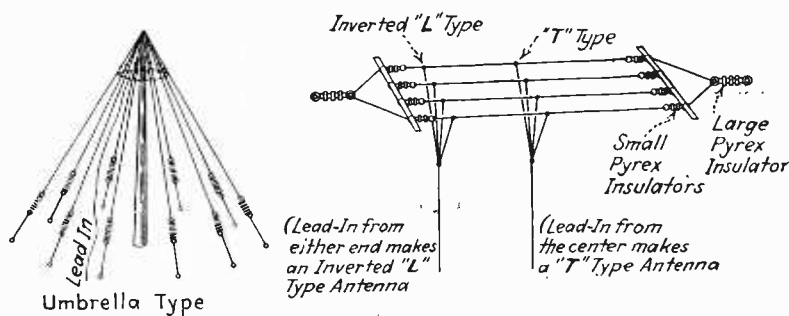
Fig. 29.—Antenna systems.

In the inverted-L (T) 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 (T) 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.

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. A graph of the oscillations in an impact transmitter is shown in Fig. 30.
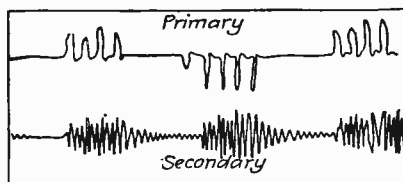
FIG. 30.—Impact-oscillations graph.

Ques. 123. What are the principal transmitting-condenser losses?

Ans. Dielectric losses and brush-discharge losses.

The dielectric losses are primarily due to the molecular reversals in the dielectric material called hysteresis. These losses, however, are greatly minimized in air-dielectric condensers.

Brush-discharge losses are due to surface creepage and excessive oscillating potential differences between the plates.

Ques. 123a. Draw a diagram of a spark transmitter with a simultaneous wave-changing switch.

Ans. Figure 31 illustrates a spark transmitter with a simultaneous wave-changing switch. See also Ques. 108.

Ques. 123*b*.   Draw a diagram of a spark transmitter complete with auxiliary power equipment, receiver, and automatic starter.
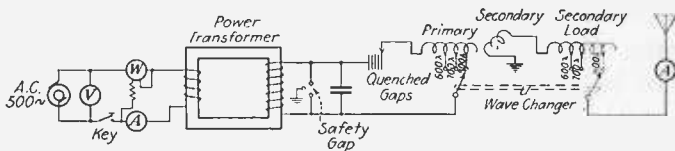
Fig. 31.—Spark transmitter with automatic wave-changing switch.

Ans.   See Figure 7*D* and make the following changes to convert the tube circuit into a spark transmitter.
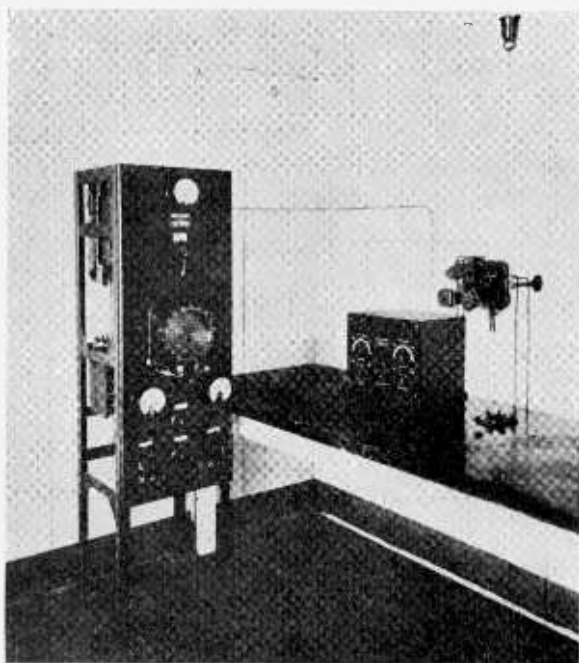
Fig. 32.—Three-quarter-kilowatt Federal spark transmitter, typical ship installation.   (*Courtesy, Federal Telegraph Co.*)

Disconnect the secondary winding of the power transformer from the two plates of the vacuum tubes and omit up to the antenna.   Take away filament supply.   Replace this with the diagram of a spark transmitter with a simultaneous wave changer illustrated in Fig. 31.   All other connections remain the same.

Ques. 124. How would you clean a quenched 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
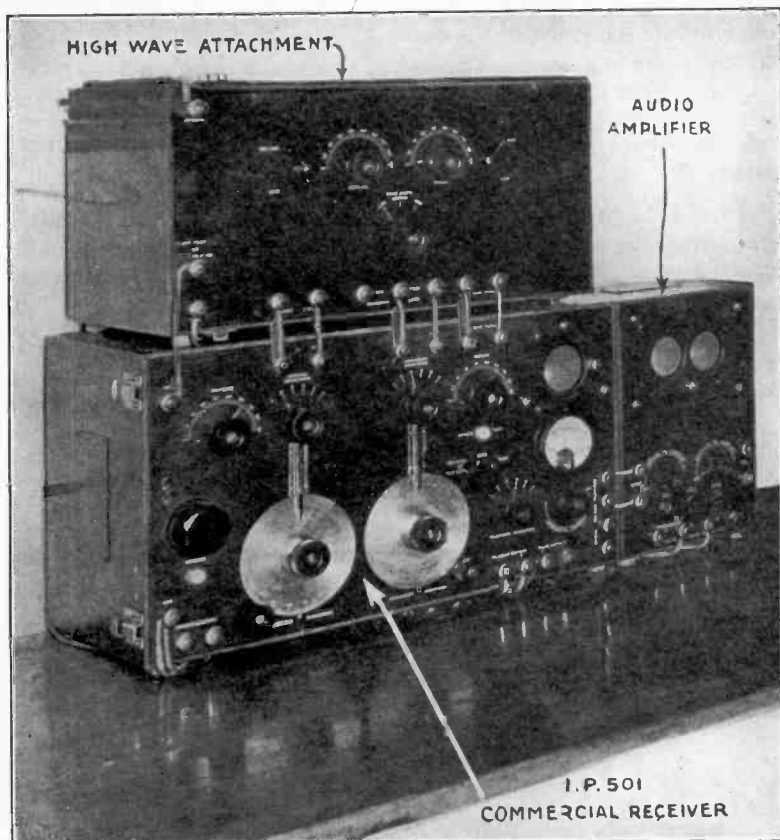
Fig. 33.—Modern ship-receiver installation. (*Courtesy*, Radio Corporation of America.)

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.

PART IV

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

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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.
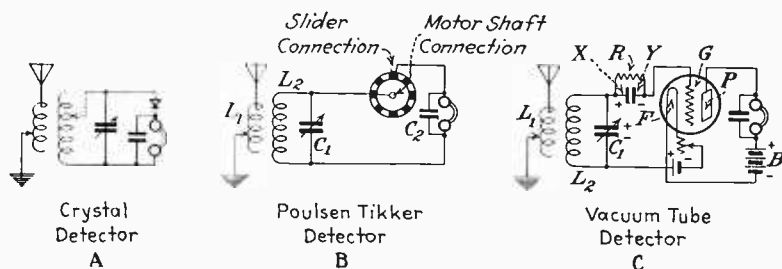
FIG. 34.—Three types of detector circuits.

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 posi-

tive 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
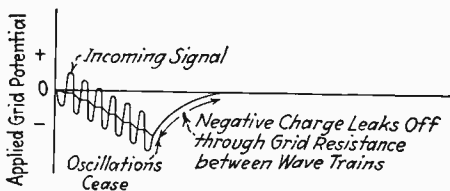
FIG. 35.—Graph showing grid rectification.

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*B*, 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. 34A 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. Storage batteries or 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.

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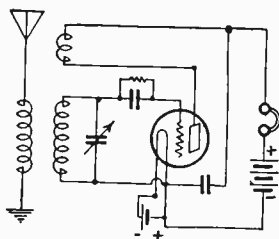
Fig. 36.—Inductively coupled tuner. Self heterodyne oscillator and detector.

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
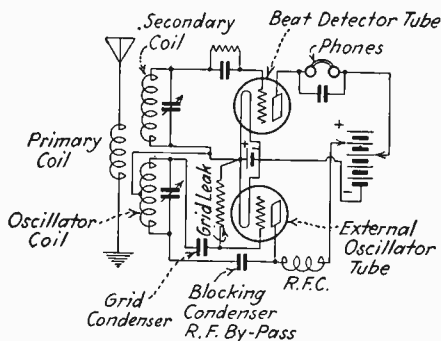
External Oscillator and Beat Detector

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. 24a).
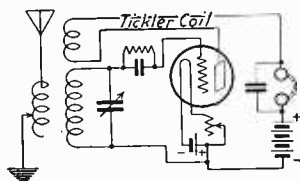
FIG. 38.—Detector circuit.

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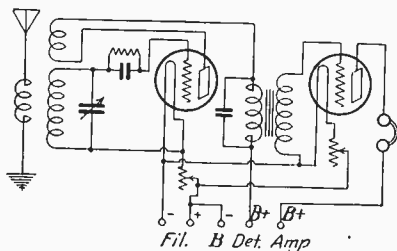
Fig. 39.—Detector circuit with one stage of amplification.

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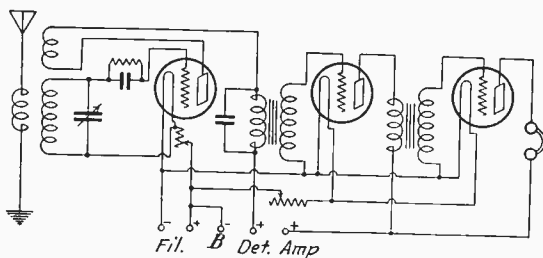
Fig. 40.—Detector circuit with two stages of amplification.

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.
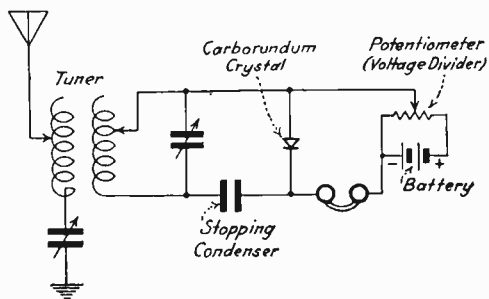
FIG. 41.—Receiving circuit with crystal detector.

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. Correct current gives long tube life.

Ques. 147. Explain the construction of the shielded-grid (screen-grid) 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 minimize 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 reduce

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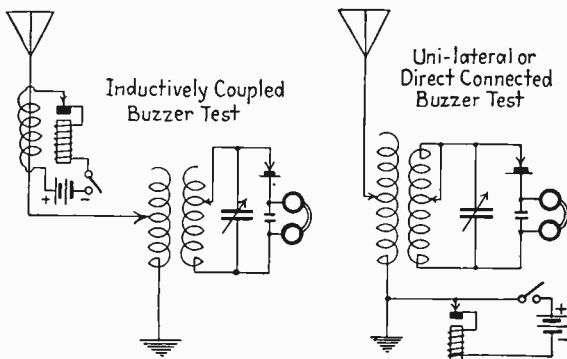
Fig. 42.—Test-buzzer connections to crystal receiver.

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
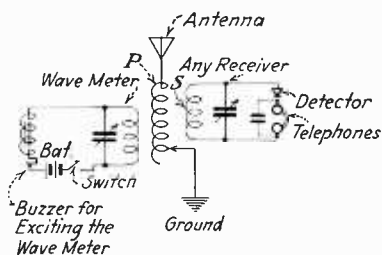
Fig. 43.—Tuning receiver with a wavemeter.

Wave Length	Primary	Primary Cond.	Secondary	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.

gone through. These operations are to be repeated for each successive wave length or frequency.

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.
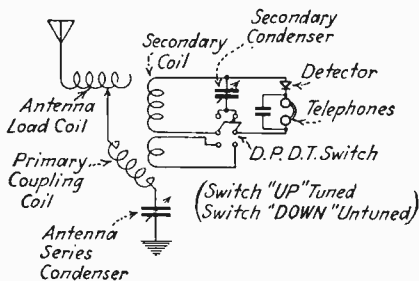
FIG. 45.—"Stand-by" circuit.

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, Ques. 131.

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.
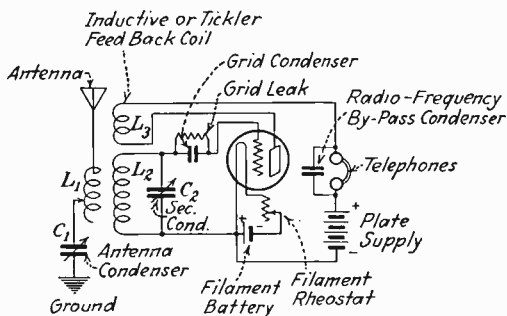
Fig. 46.—Wiring diagram of regenerative receiver.

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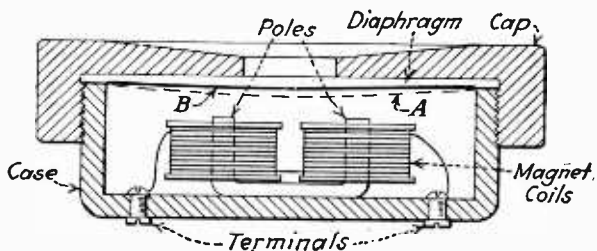
FIG. 47.—Cross-sectional view of telephone receiver.

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 coils, the position of the diaphragm is normal, as in position *B*.

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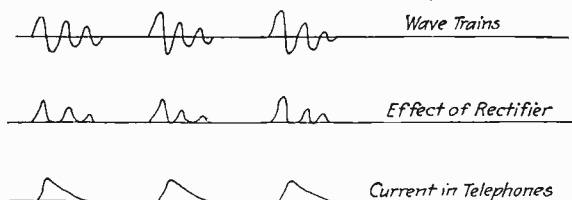
Fig. 48.—Wave train to telephone, current curve.

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 system is used 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.

In beat note receiver, heterodyne effect controls note tone.

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.
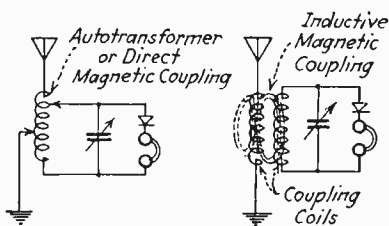
FIG. 49.—Magnetic coupling.   FIG. 50.—Static coupling.
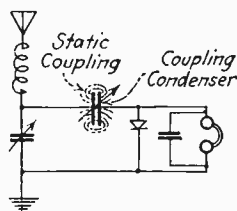
Electrostatic coupling takes place through a condenser, as shown in Fig. 50.   Here, the energy is passed from the antenna circuit to the rectifier in electrostatic form by means of the coupling condenser.   The lower the capacity of this condenser, the looser will be the coupling, and the greater the 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 con-

denser 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 station during heavy static or interference?

Ans. To receive in heavy static or QRM, 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) $0 - \frac{3}{4} - 1\frac{1}{2}$, 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

Minimum Inductance   Maximum Inductance
(Fields "buck"   (Fields aid each other)
causing neutralization)

THEORETICAL REACTIONS   COIL ARRANGEMENT   SYMBOL
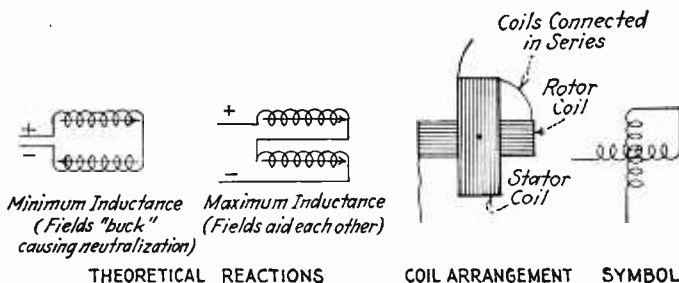
Fig. 51.—Variometer.

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, ampere-turns = current × turns. With a vacuum-tube detector or amplifier, a high resistance in the plate circuit is desirable for high efficiency.

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.   This latter method is most efficient.   See also Ques. 409.

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 for diagram of crystal detector.

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

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 closeness of the telephones and transformers.   Remedies are obvious.

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 201a-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 2 to 3 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 $22\frac{1}{2}$-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 without a vacuum tube?

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 in erecting a temporary antenna?

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 across the phones may 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 proper size loading coil in each of the above circuits. In modern commercial receivers, a high-wave attachment is usually provided for this purpose.
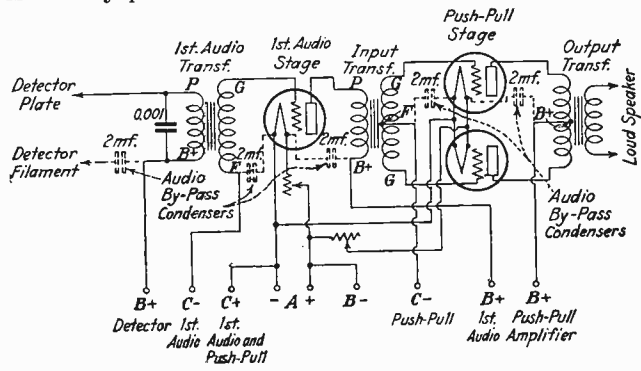
Fig. 51A.—Circuit diagram of a push-pull amplifier.

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 con-

nections, 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.

Ques. 195*a*. Explain the advantage of shielding a receiving set.

Ans. The advantage of shielding a radio set, particularly where two or more stages of radiofrequency amplification are used is as follows:

1. Owing to the removal of stray capacity and inductive coupling resulting in unwanted feed-back, the use of shielding makes possible the construction of three or four stages of tuned radiofrequency amplifiers.

2. With complete shielding, perfect tube-capacity neutralization can be obtained.

3. Magnetic or capacity pick-up of interfering signals on intermediate circuits is eliminated.
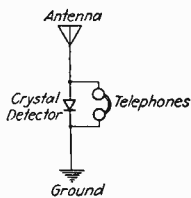
Fig. 51*b*.—Simplest receiving circuit.

Ques. 195*b*. What are the least number of parts necessary to receive signals? Draw a diagram.

Ans. The least number of parts that can be used to receive radio signals are a crystal detector and a telephone receiver, as illustrated in Fig. 51*B*.

Ques. 195*c*. What causes, and by what methods would you locate, audio howls?

Ans. Howls in audio-frequency amplifiers are generally caused by magnetic coupling between the audio-frequency

transformers, owing to the improper shielding or grounding of the magnetic cores. Close proximity of grid and plate leads may cause howling. Audio transformers with a high step-up ratio may cause "howling" or "singing" when the signal input gain is increased. This is particularly true in some broadcast amplifiers if the gain is increased excessively. Microphonic howls may also be caused by placing the loud speaker in the vicinity of the amplifier tubes. This may cause a tremendous microphonic reaction between the tubes and speaker. Howls due to coupling can usually be located by placing the finger on the grid of the amplifier tubes. If the howl ceases, the trouble is probably due to audio feed-back. Introducing resistance or leakage by placing the fingers across the secondary terminals of an audio transformer may locate the cause of howling. If this remedies the trouble, connect a resistance of 250,000 ohms or a small condenser capacity of 0.00025 microfarad across the secondary winding. Change the position of the loud speaker or place it on some shock-absorbing material such as felt or rubber.

Ques. 195d. How are stopping (blocking) condensers and choke coils used to advantage in receiving sets?

Ans. Stopping condensers are used in the grid and plate circuits of vacuum-tube receivers.

In grid circuits of resistance-coupled amplifiers, the stopping condenser serves to block the direct-current potential on the plate of a preceding tube from being applied to the grid of the following tube.

In plate circuits, particularly in the detector circuit, the plate radiofrequency bypass condenser, shunted across the primary winding of the audio transformer, serves to bypass the radiofrequencies around the primary winding of the audiofrequency transformer, thereby insuring a maximum rectified signal through the primary winding. Stopping condensers, or radiofrequency bypass condensers, as they are generally called, are usually connected in oscillating detector circuits to bypass the radiofrequency variations but at the same time to isolate the "B" supply from the radiofrequency circuit. The radiofrequency choke coils in radio receiving sets are used for two purposes; namely, in detector-plate circuits to keep

the radiofrequencies from dissipating through the high-impedance winding of the audio transformer, a lower reactance passage is provided through the bypass condenser; in the positive side of plate circuits, to keep the radiofrequencies out of the power-supply circuits thereby insuring circuit efficiency and stability.

Ques. 195e. What are the advantages of using cushion sockets, and why?

Ans. Cushion sockets absorb mechanical vibrations and minimize the tendancy of tube elements to jar.

Cushion sockets also minimize microphonic reactions between tubes and loud speakers thereby greatly reducing the microphonic noise-to-signal ratio.

Ques. 195f. Why are springs used in a radio receiver?

Ans. To absorb mechanical vibration, thereby insuring mechanical and electrical rigidity in the receiver.

Microphonic "singing" due to tube vibrations will also be greatly reduced.

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
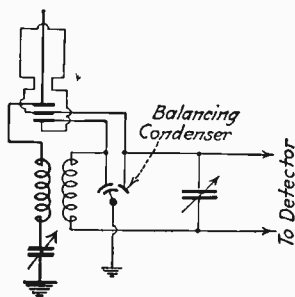
FIG. 52.—Elementary wiring diagram of direction finder.
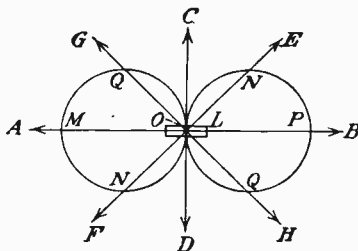
FIG. 53.—Bilateral characteristics.

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.
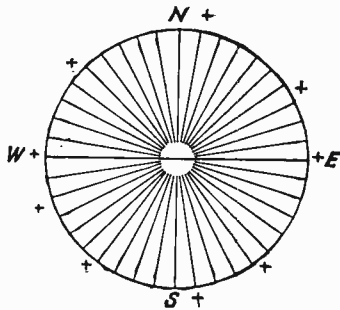
FIG. 54.—Single-wire vertical antenna characteristics.
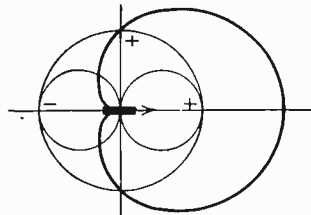
FIG. 55.—Unilateral characteristic.

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.

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.

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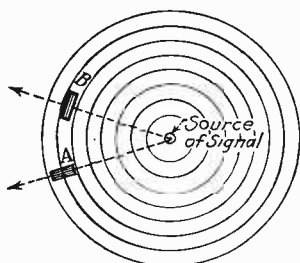
Fig.   56.—Sketch   showing loop in two positions relative to oncoming radio wave.

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.

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 radio-beacon, 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 radio-compass station?

Ans. The general instructions and rules of procedure for obtaining radiocompass bearings are given in Ques. 328, Part VII.

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 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 the minima and maxima with the Kolster 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.

Another type of radiocompass or direction finder is that type developed for shipboard use by the English Marconi Company and known as the Bellini-Tosi goniometer.

A schematic diagram of this type is shown in Fig. 56A. In the diagram two triangular loops are shown, although rectangular loops or coil aerials may be used.

The two loops are made as large as installation limitations permit. One loop is arranged fore and aft or along a line parallel to the keel of the ship. The other loop is arranged athwartship or at right angles to the first loop.

The goniometer is contained in an instrument box which is placed in the pilot house, chart room, or radio room, or wherever most convenient to the person taking the bearings.

The instrument box contains two sets of fixed coils A and B and a moveable coil C called the exploring coil. The coils A and B are fixed in the same relative position on the ship as the loop aerials a and b.

Let us assume for purposes of explanation that the coil aerial a is parallel to the keel of the ship or fore and aft, and that the coil aerial b is athwart-ship or at right angles to a.

In accordance with the well-known directional characteristics of loop aerials, a maximum signal is induced in a loop when the loop lies in a line of direction parallel to the direction of prop-
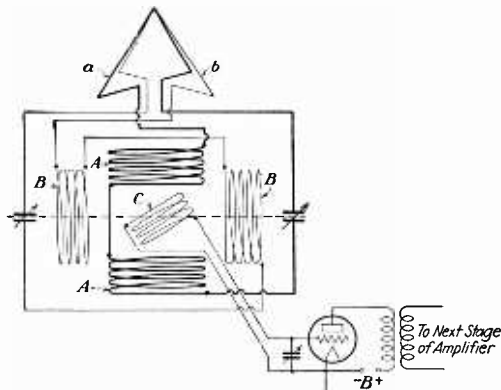
FIG. 56a.—Bellini-Tosi type radio compass.

agation of the oncoming wave. Also, a minimum signal is induced in a loop when the loop lies in a line of direction at right angles to the line of direction of propagation of the oncoming wave.

A study of the diagram will show that a current flowing in loop a must also flow in coil A. Likewise a current flowing in loop b must flow in coil B. Therefore, the e.m.f. induced in the coils A and B is in reality the current induced in the loops a and b. If a strong signal is induced in a a strong signal flows in A. If a strong signal is induced in b, then a strong signal flows in B. Therefore, the field set up in the space around

the exploring coil C is similar to the field set up around the loop aerials a and b.

A maximum e.m.f. is induced in the exploring coil when that coil is at right angles to the field set up around it.

Now suppose a signal comes from the direction in which the ship is headed. A maximum signal is induced in a and flows in A also. If the coil C is orientated so that it is parallel to A, then a maximum e.m.f. will be induced in it and a maximum signal will be passed on to the receiver. Likewise, if the coil C is placed at right angles to A or parallel to B, a minimum signal will be passed on to the receiver.

The same action takes place if a signal comes from abeam. In this case a maximum current flows in b and B and a minimum in a and A and the receiver responds accordingly as the exploring coil is turned parallel to B for maximum response and at right angles to B for minimum response.

Now supposing a signal approaches from 45 degrees off the port bow. There is now a current induced in both loops a and b. The field now set up by coils A and B are of such phase relationship that a maximum e.m.f. is induced in coil C when it lies 45 degrees off the parallel position to both coils A and B.

A pointer is attached to coil C which moves over a peloris card which shows the bearing of the transmitting station and its reciprocal with respect to the ship. If the ship is kept on the course and another bearing taken later, these relative bearings may be cross-plotted and the exact bearing of the transmitting station with respect to the ship determined.

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.

NOTE.—See Addenda for additional questions and answers on receivers.

PART V

STORAGE BATTERIES

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.
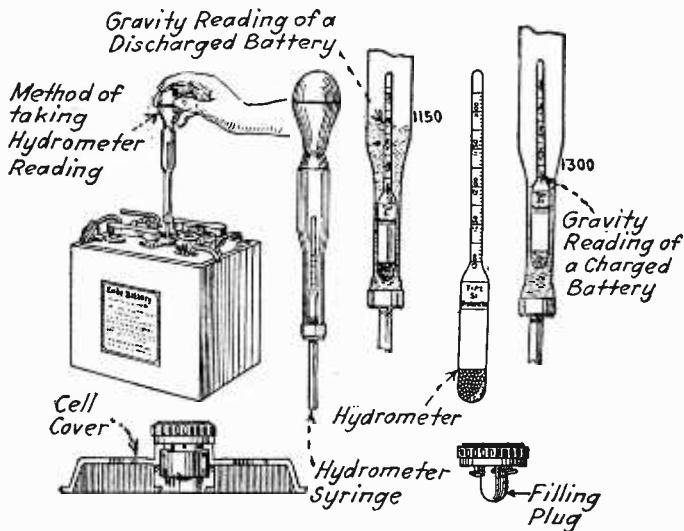
FIG. 57.—Hydrometer.

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. 213a.   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

STORAGE BATTERIES

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:

$$R = \frac{E_1 - E_2}{I} \text{ where } \begin{array}{l} E_1 = \text{the no-load voltage reading} \\ E_2 = \text{the full-load voltage reading} \end{array}$$
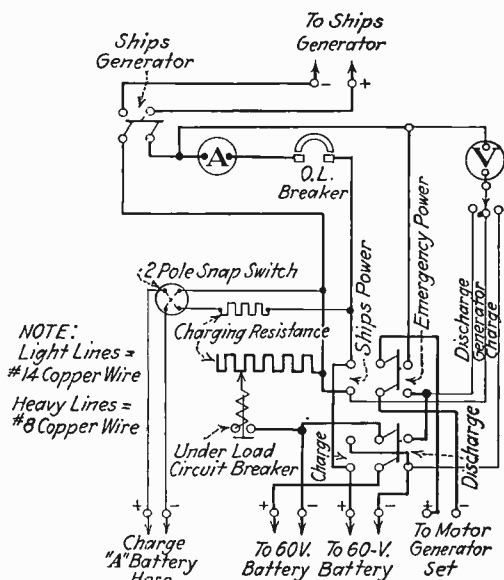
FIG. 58.—Wiring diagram of a modern charging panel (Ward Leonard) marine type.

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. See also Fig. 1, for another type of power-radio and A battery charging panel.

Ques. 215.   What is local action, its cause, and prevention? What is polarization and its effect on a cell?

Ans.   Local action is that phenomenon whereby small internal currents are set up in the cell, owing to impurities in the active
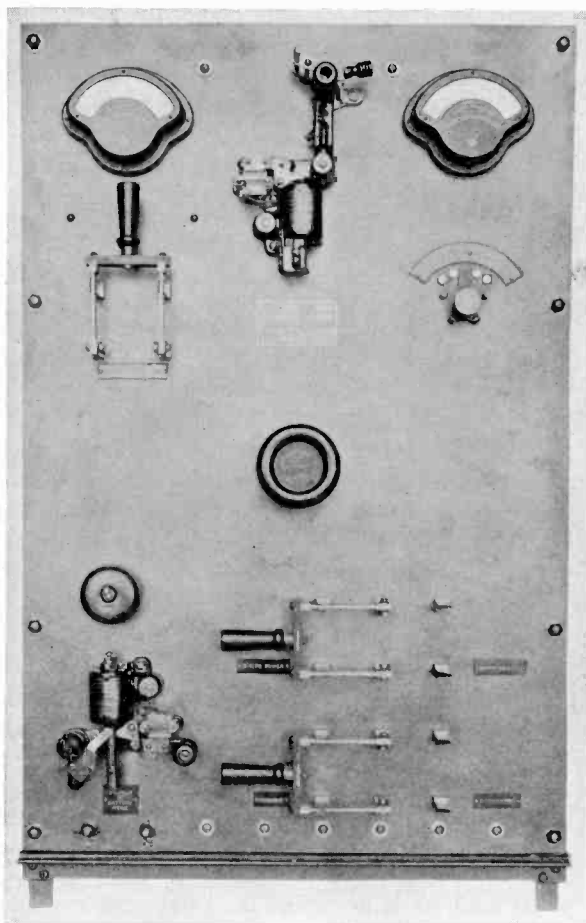
FIG. 59.—Modern marine-type charging panel. (*Courtesy*, Ward Leonard Electric Co.)

materials or the electrolyte.   These currents are independent of the normal internal chemical action and contribute nothing

to the voltage or capacity but seriously impair the life of the cell.

Local action is prevented, as much as possible, first, by the manufacturer in making the active materials as pure as they can be made and, second, by the operator in keeping the cells well charged and in good condition.

The polarization of a cell is the chemical change on the plates of a cell during discharge; it greatly increases the internal resistance of the cell. For example, during the discharge of a copper-zinc-sulphuric-acid cell, the formation of a hydrogen film on the copper plate is known as "polarization." This film greatly increases the internal resistance of the cell, thereby decreasing its voltage.

Ques. 215a. What determines the voltage of a lead cell; of an Edison cell?

Ans. The voltage of any storage battery varies from maximum (full-charged value) to minimum (complete-discharge value) directly with the state of charge. Therefore it can be said that the state of charge determines the voltage of a cell.

The full-charge voltage of a lead cell is 2.10 volts. The voltage drops very slowly to about 1.95 volts during four-fifths of the discharge time and then drops rapidly during the last one-fifth of the discharge period to the discharged value of 1.75 volts.

The full-charge voltage of an Edison cell is 1.20 volts. The voltage then drops in almost a straight-line curve during the entire discharge period until the discharged value of 0.9 volts is reached. The voltage decrease is somewhat accelerated during the last one-fifth of the discharge period.

The above data can be confirmed by referring to discharge curves of both of the above types of cells.

The discharge characteristics of any type of storage battery will vary somewhat with the age of the battery.

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 depends upon the rate of discharge; porosity, arrangement, and quantity of active material; and the strength, amount, and temperature of the electrolyte.

The unit of cell capacity is the ampere-hour.   An ampere-hour is 1 ampere flowing for 1 hour.

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. See also Ques. 489.

Ques. 222. At what temperature does a storage battery work best?

Ans. 70° F., air temperature. The temperature of the electrolyte of the lead cell 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 $\frac{1}{2}$ 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 $\frac{1}{4}$ 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

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:
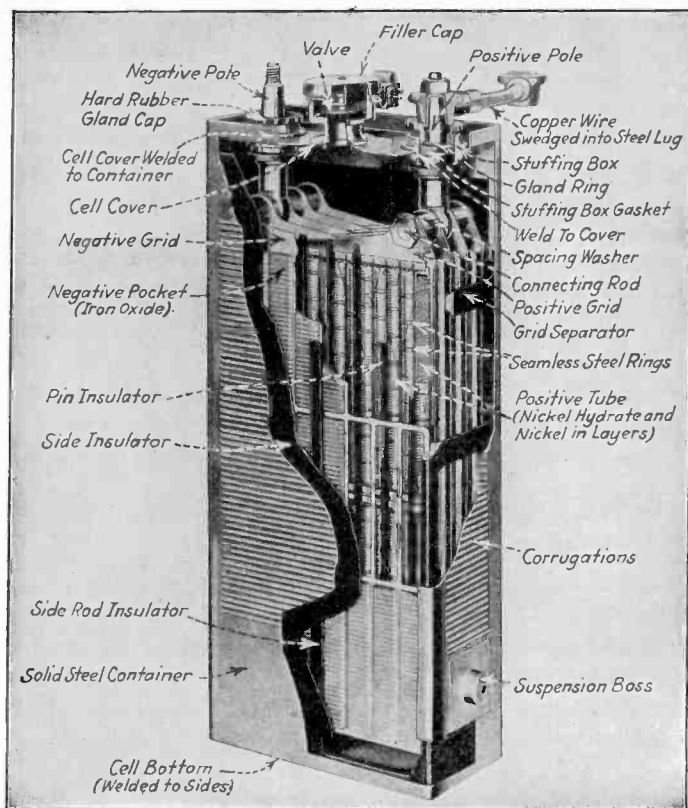
FIG. 60.—Cross-sectional view of the Edison cell.

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 shows the only measurable difference between the cell fully charged and discharged.   The ampere-hour meter, if available, on the charging panel will show directly the amount of charge in the battery regardless of type.   Voltmeter reading are taken only when the battery is discharging.

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 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. This is in the proportion of approximately four parts water to one part of acid.

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 or cell from the circuit. If at all possible, a temporary repair might be effected by greasing the leaky section with

paraffin or vaseline. If battery or cell is disconnected, a jumper must be used to close the circuit.

Ques. 247. What chemical neutralizes the effects of sulphuric acid?

Ans. Ammonia or sodium bicarbonate.

Ques. 247a. In the installation of storage batteries in a closed box or room what precautions should be taken?

Ans. The room or box should be well ventilated, moderate in temperature, and dry. On shipboard the room should be well ventilated to allow the escape of fumes due to the charging gases. Smoking must not be permitted, especially when the batteries are on charge. If covers are provided on the battery boxes, they should be removed during the charging period.

Ques. 247b. How would you charge a 120-volt bank from a 110-volt line?

Ans. See charging panel (Figs. 1 and 58).

Ques. 247c. How could the polarity of the ship's power supply be determined?

Ans. The polarity is determined by a direct-current voltmeter connected across the supply line. This meter is usually located on the battery-charging panel. If the meter is defective, a glassful of salt water may be used in the following manner: dip two wires from the supply line into the water about 2 or 3 inches apart, the wire around which excessive bubbling takes place is the negative terminal.

Ques. 247d. How can a leaking battery be repaired?

Ans. A leaking battery can temporarily be repaired by covering the defective section with paraffine, wax, or pitch. If the leak is very bad, the defective cell should be entirely drained and temporarily disconnected from the circuit until a new jar can be secured. If the defective cell is removed, a heavy wire jumper must be used to close the circuit which was broken by the removal of the cell.

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.

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.
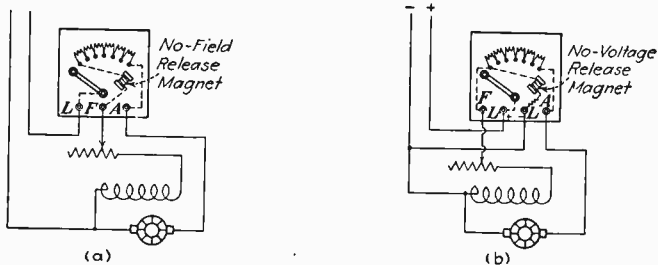

Fig. 61.

Cutler-Hammer s t a r t i n g 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.
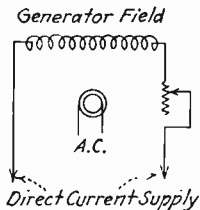
Generator Field

A.C.

Direct Current Supply

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, generator, and vacuum-tube plate 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. 61) 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. 63a).

Another method is illustrated in Fig. 63*b*.

If the lamp does not light, the resistance is open.

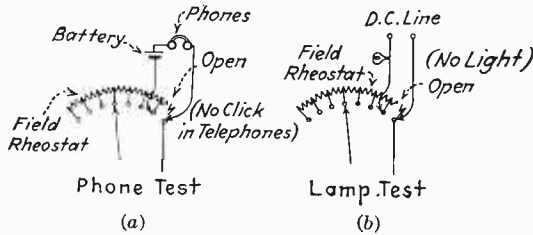Phone Test   Lamp Test

(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.
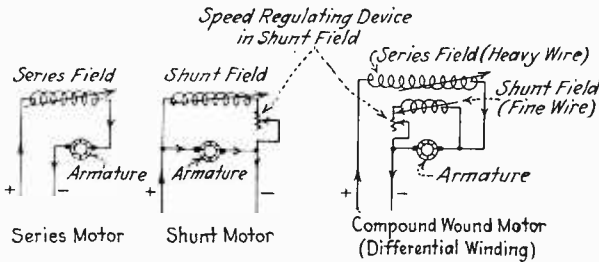
Ans. See Fig. 64.

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.
9. Open field 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
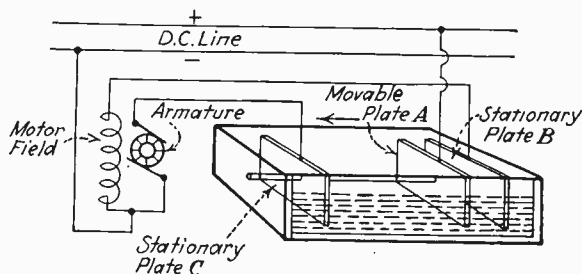

FIG. 65.—Water rheostat.

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.
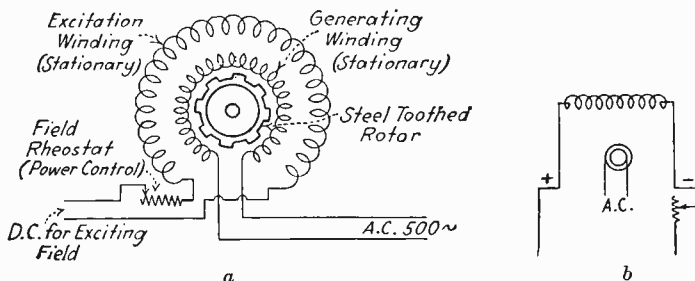

Fig. 66.—Elementary wiring diagram of alternating-current generators. *A.* Inductor type. *B.* Slip ring type.

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
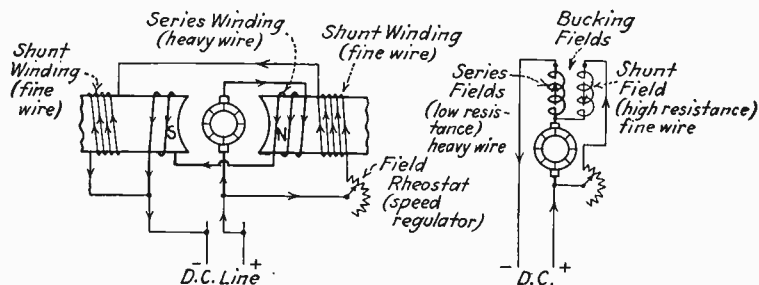

Fig. 67.—Wiring diagrams of a differentially compound-wound motor.

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 68a 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. 68b, 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. 68a and 68b. 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. 68c, everything is the same as in the previous Fig. 68b, except that less current flows through the coil CC with the result that there are not so many magnetic lines flowing through
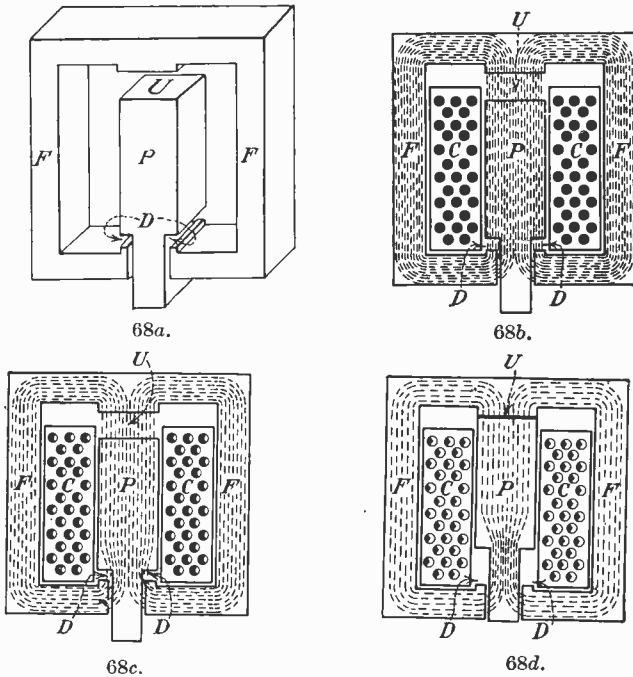

68a.   68b.

68c.   68d.

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. 68d, the current in the coil is still less, and, of course, the magnetic lines are less than they were in Fig. 68c. 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. 68d.

This is exactly what happens in the operation of this starter.

Figure 69a 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. 68a, 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. 69a is nearer the top of
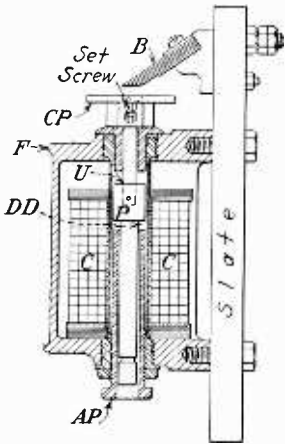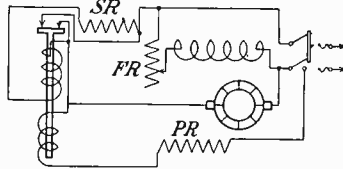

FIG. 69a.—Cross-section of series contactor.

FIG. 69b.—Main-coil arrangement of automatic starter.

the plunger than the air gaps DD of Figs. 68a, 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.

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. 69b. 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,
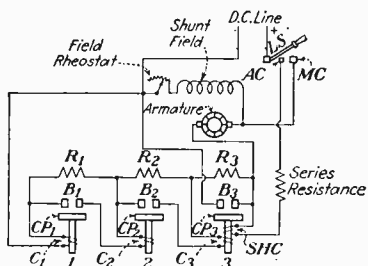

FIG. 69c.—Automatic starter showing steps of resistance used.

AC	auxiliary contact	1–2–3	contactors
MC	main contact	SHC	shunt holding coil
CP	contact plate	B	contacts
R	resistance coils	LS	line switch
C	solenoid operating coils		

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-circuit-

ing 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 69c 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.

Ques. 287a. What causes the bearings of a motor generator to "freeze?"

Ans. See Ques. 257.

Ques. 287b. If on pressing the motor starter button no response is obtained, what may be the trouble?

Ans. The trouble may be due to any of the following causes:

1. Defective starter switch.
2. Fuses blown or defective.
3. Circuit breaker open.
4. Starting resistor open.
5. Broken connection in starter circuit.
6. Bad contacts.
7. Armature open at the brush terminals.
8. Improper brush contact with the commutator.
9. Poorly soldered connection.
10. Motor-field winding open. This will cause the fuses to blow or the circuit breaker to trip, the moment the starter circuit is closed.

Ques. 287*c*. How would you take care of a generator equipment on shipboard?

Ans. 1. Keep the generator bearings well greased.
2. Keep the commutator clean.
3. Replace with new ones brushes worn close to the brush holder.
4. Keep carbon dust from around the brush holders. Clean with Carbona.
5. Do not overload the windings.
6 Inspect electrical connections frequently.
7. Keep the generator free from dampness.

Ques. 287*d*. How would you effect temporary repairs in a generator if one of the armature or field coils burned out?

Ans. If one of the armature coils burned out, it would be practically impossible to effect repair. It is, however, possible to operate the generator under this condition provided the open armature coil is located and bridged at the commutator segments.

An open field coil may be more easily repaired by locating the burned-out coil and removing it from the generator frame. The field coil may then be dismantled and the burned-out section located. The wires may then be carefully soldered and rewound on the core frame. If it is not possible to dismantle the field coil, it may be short-circuited with a length of heavy copper wire.

Ques. 287*e*. How could you detect a grounded condenser in a generator?

Ans. A grounded condenser could be located by a continuity tester consisting of a battery and voltmeter. If one side of the condenser is already grounded, as is the case in protective condensers, a continuous reading will be obtained when touching the other plate of the condenser with the continuity tester if the condenser is grounded. (See also Ques. 159.)

PART VII

RADIO LAWS AND TRAFFIC REGULATIONS

Ques. 288. Under what laws is radio communication in the United States governed?

Ans. The Radio Act of 1927, the Regulations of the Washington International Radiotelegraphic Convention of 1927, and the United States Ship Radio Acts of July, 1912 and June, 1910.

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 licensing authority.

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 for 4 hours 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 transmitting 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.

NOTE.—It is also advisable for applicants for a commercial class license to be familiar with Amateur Radio laws as given in Part XII of this book.

Ques. 291a. What does QSR mean?

Ans. See Q Code list of abbreviations and learn form.

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 penalties may be imposed for violation of radio laws and regulations?

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.

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.

Any operator who violates any law or regulation, wilfully damages apparatus, transmits superfluous signals or profane or obscene language, or wilfully or maliciously interferes, or who knowingly submits an incorrect or forged service record on his license may have his license suspended for not more than two years.

Ques. 300. 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. 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 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.

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 $\cdot - \cdot \cdot \cdot$ (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 $\cdot - \cdot - \cdot$ (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 $\cdots - \cdot -$ (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 international calling and distress frequency is 500 kc/s.   In the Great Lakes region the frequency 410 kc/s shall be used for calling and distress purposes in lieu of the international calling and distress frequency, 500 kc/s.

The international calling and distress frequencies specified in the preceding paragraph may be used for the transmission of operating signals (but in no case for working purposes) provided no interference is caused to 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 min. after each hr. G.M.T. (410 kc/s on Great Lakes).

Ques. 313.   What is the distress signal, and what does it indicate?

Ans.   The distress signal shall consist of the group $\cdots$— — —$\cdots$ 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.),[1] 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. 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

[1] 410 kc/s on the Great Lakes.

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.),[1] during other than the obligatory silence periods on the wave of 500 kc/s (600 m.),[1] 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?

[1] 410 kc/s on the Great Lakes.

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.)[1] 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

[1] 410 kc/s on the Great Lakes.

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 of_ces 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.)[1] 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) transmissions?

[1] 410 kc/s on the Great Lakes.

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. P 1 W 12 SS America 10:30 A.M. 16th

  To   Robert Smith
    143 West 73 St
     New York — · · · —
    Delay unavoidable arriving Saturday

     Manning

Ques. 334. What does CQ mean?

Ans. CQ is the general call "to all stations." It shall precede radiotelegraph broadcasts of general information. CQ is also a signal of inquiry and may be used in place of the call signal when the call signal is unknown. When CQ is used as an inquiry signal, the calling formula shall be followed by the letter K. (See Ques. 309.)

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. 309.

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.

Ques. 340. With whom does the responsibility for establishing communications rest?   Why?

Ans.   As a general rule, responsibility for establishing communication with the land station rests with the mobile station; the latter may call the land station, for this purpose, only after arriving within the range of action of said station.

The reason for the above rule is that, unless the mobile station signals its presence to the land station, the latter has no way of knowing communication with the mobile station in question is possible, unless the land station ·happens to hear the mobile station transmitting to some other station which may or may not happen.   Therefore, the ship must call the land station giving the signal QRU? or QTC? as soon as he (the mobile station) is in range of the land station.

Ques. 341.   What and when are the quiet periods?

Ans.   Quiet periods are those periods during which the transmitter must not be used.   (See Ques. 294, 312, 327.)

Ques. 342.   Explain the automatic alarm signal.

Ans.   Certain foreign governments (Great Britain especially) allow the use on their ships of an automatic radio receiver called an "auto alarm" which will respond to a special signal called the "alarm signal."   This signal is simply an alarm and must be followed by the regular distress signal (SOS) and distress message.

American vessels, or any other vessels, may take advantage of the auto alarm installed on certain ships which causes a bell to ring, thereby calling the operator to duty.

Vessels in distress who wish to signal a ship fitted with the auto alarm should use the following precedure:

1. On 600 meters send the alarm signal (explained below) after which send the International distress signal three times followed by DE and the call letters of the ship sent three times. As soon as possible thereafter send the distress message.

2. The alarm signal consists of a series of twelve dashes sent in 1 minute, the duration of each dash being 4 seconds, and the duration of the interval between two dashes, 1 second. This alarm signal will actuate any auto alarm within range, provided the dashes have a duration of not less than $3\frac{1}{2}$ or more than $4\frac{1}{2}$ seconds and provided the intervals are not less than $\frac{1}{5}$ second or more than $1\frac{1}{2}$ seconds.

The automatic alarm signal described above must be used only by ships in distress.   To insure the accurate transmission of the alarm signal the operator must have at his disposal a clock or watch equipped with a second hand.

Ques. 343.   What penalty may be imposed on the radio operator for violating the captain's orders?

Ans. For violating the orders of the captain an operator's license may be suspended for a period not to exceed two years. If at the same time the radio law is violated by the operator, the regular penalties for such violation may be imposed.

If the captain gives an order which the operator knows is a violation of the law, he shall so notify the captain. If the captain still insists that the order be carried out, the operator must carry out the order but should make proper record of the entire proceedings in the official station log.

Ques. 344.   How is the time of filing a message indicated?

Ans. To indicate the time of filing radiotelegrams accepted in mobile stations, the person in charge shall employ Greenwich Mean Time and shall use a notation according to the 24-hour system. This time shall always be expressed and sent by means of four figures (0000 to 2359).

The Administrations of countries located outside zone "A," however, may authorize ship stations following the coasts of their countries to use zone time to indicate, by a group of four figures, the time of filing, and in this case the group must be followed by the letter F.

Ques. 345.   What is the International regulation in regard to ships carrying emergency apparatus?

Ans. The Convention for the Safety of Life at Sea provides that all ships on which radio apparatus is compulsory shall also be fitted with emergency apparatus operated from a source of power independent of the ships main power plant.

The United States Ship Act of July 23, 1912, provides that all ships coming within the meaning of this Act shall have an auxiliary power supply, independent of the vessel's main electric power plant, which will enable the sending set for at least 4 hours to send messages over a distance of at least 100 miles, day or night, and efficient communication between the operator in the radio room and the bridge shall be maintained at all times.

Ques. 346. Explain fully how you would answer an SOS call.

Ans. An operator who has just received a distress call must first of all use judgement; listen for a few minutes for the distress message which should soon follow the distress call. When the station sending the distress call has finished his sending and terminated with the letter K indicating that he is listening for replies to the distress call, an operator who has received the call must, before answering, make sure he will not cause interference to replies from other ships which, by reason of being nearer to the ship in distress, are better able to render assistance. If no such interference will result and the receiving operator believes the situation can best be met by his answering the distress call, then he should answer the call, giving his ship's name and position and requesting any omitted but necessary information. He must then communicate with the bridge, giving the officer of the watch full information as received from the ship in distress. From then on he should keep in close touch with developments, working under his captain's or watch officer's orders.

If he has a radiocompass on board, the receiving operator should take bearings on the ship in distress as soon as practicable after receiving the distress call and message.

Ques. 347. How would you get a bearing from a radiobeacon transmitter?

Ans. If the radiobeacon is not in operation but transmits on request, call him and use the QTL signal.

' When radiobeacon is in operation, proceed as described in Ques. 199.

Ques. 347a. How would you find the nearest coast station if you were a ship operator?

Ans. Ask the captain for ship's position and consult Berne List of Radio Stations and map. Official maps showing the locations of government stations are furnished by the various governments. United States maps are furnished by the Hydrographic Office of the United States Navy.

Ques. 347*b*. What is the law in regard to wilful interference?

Ans. For wilful interference an operator's license may be suspended for two years.

Ques. 347*c*. What is the regulation regarding silence during time ticks, etc.?

Ans. See Ques. 327.

Ques. 347*d*. What is the International Abbreviation to express signal strength?

Ans. QSA followed by a numeral 1 to 5 on the Audibility Scale as follows:

1. Hardly perceptible; unreadable.
2. Weak; readable now and then.
3. Fairly good; readable but with difficulty.
4. Good; readable.
5. Very good; perfectly readable.

Ques. 347*e*. Under what conditions may the license of a radio operator be suspended?

Ans. The licensing authority may suspend the license of any operator for a period not exceeding two years upon proof sufficient to satisfy him that the operator has (*a*) violated any provision or regulation of any act or treaty binding on the United States; (*b*) has failed to carry out the lawful orders of the master of his ship; (*c*) has wilfully damaged or permitted radio apparatus to be damaged; (*d*) has transmitted superfluous radio communications or signals or radio communication containing profane or obscene words or language; or (*e*) has wilfully or maliciously interfered with any other radio communications or signals; (*f*) any improper alteration of the service record on the license or the forging of the master's or employer's signature thereon.

Ques. 347*f*. What are the International requirements that determine whether or not a vessel shall be equipped with radio?

Ans. That from and after October first, nineteen hundred and twelve, it shall be unlawful for any steamer of the United

States or of any foreign country navigating the ocean or the Great Lakes and licensed to carry, or carrying, fifty or more persons, including passengers or crew or both, to leave or attempt to leave any port of the United States unless such steamer shall be equipped with an efficient apparatus for radio communication, in good working order, capable of transmitting and receiving messages over a distance of at least one hundred miles, day or night.

That the provisions of this section shall not apply to steamers plying between ports, or places, less than two hundred miles apart.

Ques. 347*g*. How would you ·communicate with a ship if nobody on board that ship spoke your language?

Ans. By means of the Q Code, Miscellaneous Abbreviations agreed to by the Washington Convention, and by means of the International Signal Code which is a part of the navigational equipment on all ocean-going vessels.

Ques. 347*h*. What signal denotes "go ahead"; the "invitation to transmit"?

Ans. The letter K is the invitation to transmit. GA is the signal which means resume sending, and it is used more especially in the fixed service.

Ques. 347*i*. What does the signal TTT mean?

Ans. · This is the "safety signal." It indicates that a message concerning the safety of navigation or giving important information relative to meteorological warnings is about to be sent.

Ques. 347*j*. What are the International requirements regarding the non-delivery of a radiogram? What is meant by non-delivery?

Ans. When for any reason, a radiotelegram originating in a mobile station and destined to land can not be delivered to the addressee, a notice of non-delivery shall be addressed to the land station which received the telegram from the mobile station. This land station, after verification of the address,

shall, if possible, retransmit the notice to the mobile station, if need be through the intermediary of a land station of the same country or of a neighboring country, in so far as existing conditions·or special agreements, if any, permit.

When a radiotelegram received at a mobile station cannot be delivered, that station shall so inform the office or mobile station of origin by a service advice. In the case of a radiotelegram coming from land this service advice shall be sent, whenever possible, to the land station through which the radiotelegram passed or, if necessary, to another land station of the same country or of a neighboring country, in so far as existing conditions or special agreements, if any, permit.

Ques. 347*k*. What are the United States time and distance requirements for emergency apparatus?

Ans. The United States Ship Act of July 23, 1912, provides that all ships coming within the meaning of the Act shall be provided with an auxiliary power supply, independent of the vessel's main electric power plant, which will enable the sending set for at least 4 hours to send messages over a distance of at least 100 miles, day or night.

Ques. 347*l*. What are three penalties and how do they apply to operators?

Ans. Three penalties are (1) suspension of license for a period not to exceed two years; (2) $500 fine for each offense; (3) $5,000 fine or imprisonment for a term of not more than five years.

These penalties may apply as follows:

a. Suspension of license as explained in Ques. 347*e*.

b. Not more than $500 fine for violation of any *rule or regulation made by the licensing authority* under the Radio Act of 1927 or of any international treaty.

c. Not more than $5,000 fine or imprisonment for not more than five years for violation of *any provision of the Radio Act of 1927*, or for making false oath or swearing falsely to any material matter in any hearing authorized by this Act. See also Ques. 299.

Ques. 347*m***.** What is the regulation for standing watch on 500 KC/S?

Ans. See Ques. 312.

Ques. 347*n***.** Set up a radiogram giving the preamble, check time filed, address, text, and signature. If the land tax is $0.03, the ship tax $0.08, and the coast tax $0.10 what are the charges due on the radiogram.

Ans. Such a message is set up in the answer to Ques. 333. In this message the check is twelve words. If the total charge per word as given above is $0.21, then the charge for this message would be $2.52.

Ques. 347*o***.** What are the short-wave marine-telegraph frequency bands?

Ans. The following are the calling and working bands for short-wave marine communication.

Working Bands[1]	Calling Frequencies[1]
5,505 to 5,535	5,520
6,160 to 6,240	6,210
8,230 to 8,300[2]	8,280
8,320 to 8,340	
11,010 to 11,100	11,040
12,345 to 12,390	
12,420 to 12,480[2]	12,420
16,405	
16,460 to 16,520	
16,560 to 16,600	16,560
16,640 to 16,680	
22,000 to 22,200[2]	22,080

[1] Frequencies expressed in kilocycles.
[2] Shared by government.

Ques. 347*p***.** What is meant by the "zones of watch" and what are the zones?

Ans. The "zones of watch" are defined by a schedule agreed to by certain of the maritime nations. This schedule specifies the time periods during which a radio watch must be maintained on all ships within the zones indicated.

ZONES OF WATCH SCHEDULE

Zones		Duration of hours of service Greenwich Mean Time[1]	
		One operator ships	Two operator ships
A........	Eastern Atlantic Ocean, Mediterranean, North Sea, Baltic	From 8 to 10h 12 to 14h 16 to 18h 20 to 22h	From 0 to 6h 8 to 14h 16 to 18h 20 to 22h
B........	Indian Ocean, eastern Arctic Ocean	From 4 to 6h 8 to 10h 12 to 14h 16 to 18h	From 0 to 2h 4 to 10h 12 to 14h 16 to 18h 20 to 24h
C........	China Sea, western Pacific Ocean	From 0 to 2h 4 to 6h 8 to 10h 12 to 14h	From 0 to 6h 8 to 10h 12 to 14h 16 to 22h
D.......	Central Pacific Ocean	From 0 to 2h 4 to 6h 8 to 10h 20 to 22h	From 0 to 2h 4 to 6h 8 to 10h 12 to 18h 20 to 24h
E........	Eastern Pacific Ocean	From 0 to 2h 4 to 6h 16 to 18h 20 to 22h	From 0 to 2h 4 to 6h 8 to 14h 16 to 22h
F........	Western Atlantic Ocean and Gulf of Mexico	From 0 to 2h 12 to 14h 16 to 18h 20 to 22h	From 0 to 2h 4 to 10h 12 to 18h 20 to 22h

[1] Figures indicate time on the 24-hour time system. See Appendix II for explanation.

Ques. 348. What is the difference among Eastern Standard Time (EST), Greenwich Mean 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 Mean Time.

Ques. 348a. What is the regulation in regard to the broadcasting of mechanical reproductions of music?

Ans. A broadcasting station transmitting any mechanical reproductions of music must, at frequent intervals, make an announcement as to the character and origin of the transmitted. program. The announcer must state clearly and precisely the type of mechanical equipment used for the musical reproductions of music.

Ques. 348b. What is the law in regard to the rebroadcasting of programs from a radiophone transmitter?

Ans. No program shall be rebroadcast by any station unless special permission has been obtained from the station from which the broadcast originates. The origin or key station must also obtain special permission to carry on rebroadcast programs. In the case of European rebroadcasting it is not necessary for the foreign broadcaster to obtain special permission. The local station or stations rebroadcasting such programs must log each and every rebroadcast and forward a complete log every three months to the Federal Radio Commission.

Ques. 348c. What is the maximum frequency deviation permitted from a broadcast transmitter?

Ans. The regulation permits a frequency deviation not in excess of 50 cycles, plus or minus.

Ques. 348d. What are the United States regulations relative to distress communications?

Ans. Radio communications or signals relating to ships or aircraft in distress shall be given absolute priority. Upon notice from any station, government or commercial, all other transmission shall cease on such frequencies and for such time as may, in any way, interfere with the reception of distress signals or related traffic.

No station shall resume operation until the need for distress no longer exists, or it is determined that said station will not interfere with distress traffic as it is then being routed and said station shall again discontinue if the routing of distress traffic is so changed that said station will interfere. The status of

distress traffic may be ascertained by communication with government and commercial stations.

The commission may require at certain stations an effective, continuous watch on the distress frequency, 500 kc/s (410 kc/s in the Great Lakes area).

Brief Bibliography

"International Radiotelegraph Convention," 25 cents per copy (stamps not accepted); Supt. of Documents, Govt. Printing Office, Washington, D. C.

"Federal Radio Commission Rules and Regulations," 45 cent per copy (stamps not accepted); Supt. of Documents (address above).

DAVIS: "The Law of Radio Communication," McGraw-Hill Book Company, Inc.

NOTE 1.—Applicants for radiotelegraph operator licenses must qualify on the following points, in addition to the written examination on the theory and operation of radio apparatus:

Copy code reception at required speed.

Write out a radiogram in plain language, indicating check, and transmit same on buzzer.

Write out radiogram in code language, indicating check, and transmit same on buzzer.

Sending speed must be slow enough to be correct at required speed.

NOTE 2.—See Addenda for additional questions and answers on radio laws.

PART VIII

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.

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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
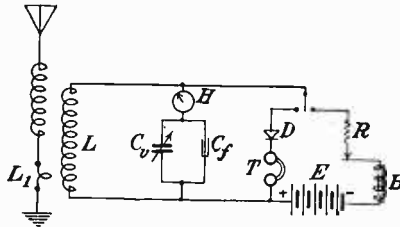
FIG. 70.—Wiring diagram of Kolster decremeter.

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. See also Ques. 386*f* and Ques. 404.
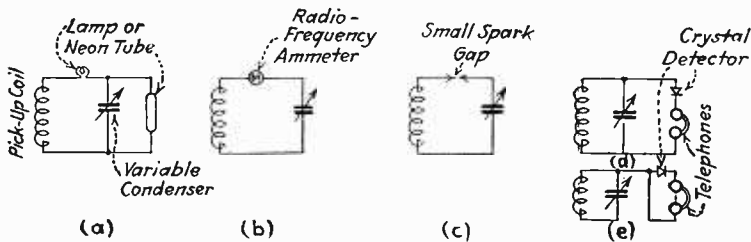
Fig. 71.—Methods of indicating resonance on a wavemeter.

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.
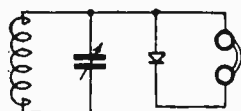
Unilateral Connection
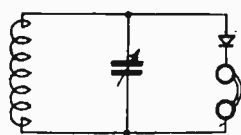
Bilateral Connection

FIG. 72.—Two methods of connecting phones and detector on wavemeter.

110 V. Line   To Test Antenna Insulation
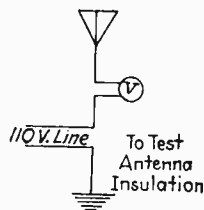
FIG. 73.—Method of testing an antenna for grounds.

Ques. 356.   Show by diagram how an antenna may be tested for grounds and explain.

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

$$C = \frac{1}{\dfrac{1}{c_1} + \dfrac{1}{c_2}}$$

Solution

$$C = \frac{1}{\dfrac{5 + 7}{0.035}} = \frac{1}{\dfrac{12}{0.035}} = \frac{0.035}{12}$$

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

$$C = \frac{1}{\dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}} =$$

$$C = \frac{1}{\dfrac{1}{0.002} + \dfrac{1}{0.002} + \dfrac{1}{0.002}} = \frac{1}{\dfrac{3}{0.002}} = \frac{0.002}{3} = 0.0006 + \text{mfd.}$$

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*).

Interrupted D.C.   A.C.
         A   B
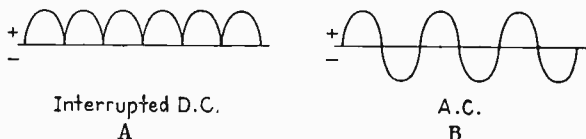
FIG. 74.—Interrupted direct current and alternating current.

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 high-frequency currents than a solid conductor.

Stranded copper wire when used for antennas accumulates an uneven coating of high-resistance corrosion which has an unstable effect on the high-frequency resistance of the conductor. It is, therefore, more desirable to use a larger size solid, ribbon, or tubular conductor on which the coating of corrosion will be evenly deposited.

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
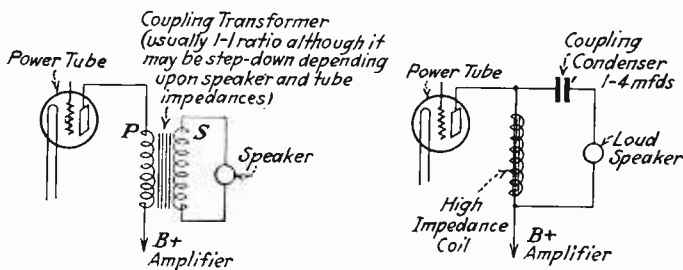
Fig. 75.—Two methods of connecting a loud speaker.

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,

$$\frac{300,000,000}{600} = 500,000 \text{ cycles or 500 kilocycles}$$

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.
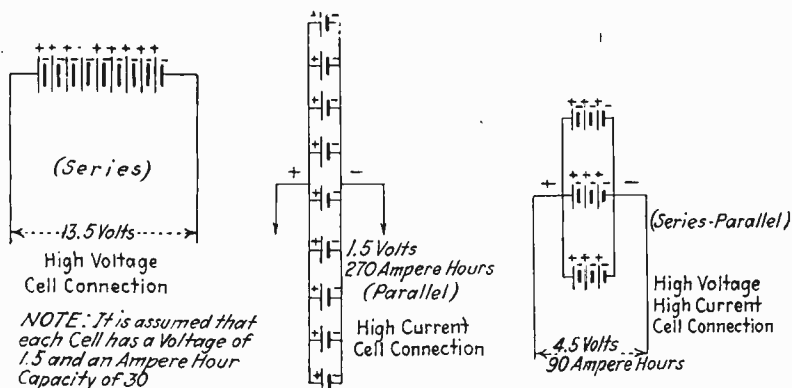
Fɪɢ. 76.—Methods of connecting dry cells.

Ques. 383. Draw a diagram of a voltmeter, ammeter, and wattmeter in an alternating-current power circuit.

Ans. See Fig. 77.
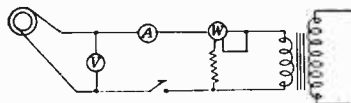
Fɪɢ. 77.—Meters in power circuit.

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 to the series and parallel groups.   The series-parallel group may be made up of two series banks of five cells each and the two banks then connected in parallel.
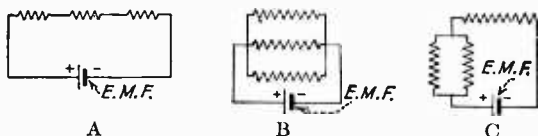
Fig. 78.—Methods of connecting resistances.   *A* series, *B* parallel, *C* series parallel.

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.
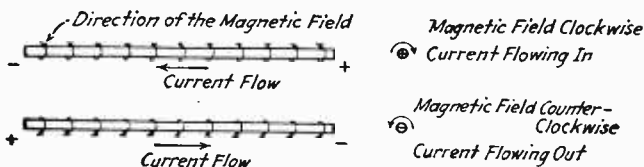
Fig. 79.—Wire carrying current showing lines of force.

Ques. 386a.   What is a counterpoise?

Ans.   A counterpoise constitutes a wire or a network of wires located in a capacitive relation to the antenna wire so as to serve as a suitable means of setting up an electrostatic field. Counterpoise systems are usually erected beneath the antenna wires, or in some position parallel thereto, to take the place of a poor earth ground.

Ques. 386b.   Why should an antenna be rigid and what effect does a swinging antenna have on the transmitted frequency?

Ans.   An antenna system must be securely fastened to prevent swinging.   A swinging antenna may have a decided effect upon the frequency of the emitted wave because of a change in the antenna to ground capacity.   It can readily be seen that any

swinging of the antenna wires will slightly alter the frequency period of the open radiating circuit and, consequently, may cause the received signal to have a fading characteristic. This is true only if the oscillator feeds the antenna directly.

Ques. 386c. What is a transmission line as used in connection with an antenna system? Give the reason for its use.

Ans. Figure 79a illustrates a typical transmission line or feeder system. This system is used in cases where it is impossible to erect an efficient antenna in a clear location near the transmitting apparatus. It is then possible, with an arrangement of this kind, to feed power to the antenna through the medium of the feeder wires without any appreciable loss in power. This is due to the fact that the transmission line is at low potential and not tuned to the frequency at which radiation is to occur. Furthermore, the resistance of the feeder line is extremely low at this frequency and, consequently, little power is lost in it.

It can readily be seen that a properly designed transmission line will permit the antenna radiating system to be located at a point some distance from the transmitter without any serious loss in the transmission of power from one point to the other.
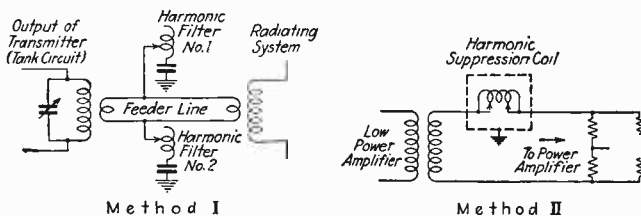
Fig. 79a.—I. Transmission line with harmonic suppressors. II. Harmonic suppressor in amplifier circuit.

Ques. 386d. Explain the construction of a radio-frequency choke coil and an audio-frequency choke coil. Explain their technical difference.

Ans. The essential differences between a radio- and an audio-frequency choke coil are the relative number of turns used and the character of the core. A radio-frequency choke coil for use in high-frequency circuits in which the frequencies are in excess of 100,000 cycles is usually made up in cylindrical form upon bakelite or hard-rubber tubing. The core is generally of air.

An audio-frequency choke coil for use in the low-frequency range is usually made up of many turns of wire wound upon a closed steel core similar to a transformer. The technical differences between the two types of choke coils may be readily seen if we consider the various frequencies in the radio- and audio-frequency range in which the two types may be used. It will be remembered that the strength of the current flowing in an alternating current depends upon the value of the applied e.m.f., the amount of D.-C. resistance in the circuit, and the reactance. The reactance offered to a flow of an alternating current by an inductance is dependent upon the number of turns in the coil, the diameter of the coil, the space between the turns (distributed capacity), the character of the core, and the frequency of the applied e.m.f. Hence it will be seen that an increase in turns and frequency will increase the value of the inductive reactance X_L. The reactance in ohms offered to an alternating current may be easily determined by the formula

$$X_L = 6.28 \times f \times L.$$

Where X_L = the reactance in ohms.

F = the frequency in cycles per second.

L = the inductance in henries.

Thus, if the value of the inductance L is large and the frequency f is small, a certain amount of opposition will be offered to the flow of an alternating current. If, on the other hand, F is increased to a higher value, the reactance will be even greater. Consequently, if either of the values f or L in the above formula are increased, the current flow at a given value of e.m.f. will decrease. Thus it can be seen that at certain high frequencies the value of L need not be very large to suppress, or choke out, the current flow through the coil. Similarly, if the frequency is low, then the value of L must be large to produce the proper choking or filtering effect. Choke coils designed to suppress frequencies between 16 and 10,000 cycles per second are called audio-frequency chokes and those designed to suppress higher frequencies are called radio-frequency chokes.

Briefly, an audio-frequency choke coil is one that offers a high reactance to a low-frequency e.m.f. and a radio-frequency choke coil is one that offers a high reactance to a high-frequency e.m.f.

Ques. 386e.   What would be the effect, in an electrical circuit, of adding capacities in series, in parallel; inductances in series, in parallel; resistances in series, in parallel?

Ans.   Connecting capacities in series reduces the total effective capacity but increases the breakdown voltage or the ability to stand a greater potential strain across the combined unit. Connecting capacities in parallel increases the total effective capacity only.

Connecting inductances in series will increase the effective inductance in a circuit and thus will increase the total circuit reactance.   Connecting inductances in parallel will reduce the effective inductance of a circuit, thereby reducing the total circuit reactance.

Connecting resistances in series increases the effective resistance, thereby increasing the total circuit resistance.   Connecting resistances in parallel reduces the effective resistance, thereby reducing the total circuit resistance.   The following formulas indicate the effective changes in resistances capacities and inductances when connected in series or parallel.

Resistances in series, $R_x = R_1 + R_2 + \cdots$

Resistances in parallel, $R_x = \dfrac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_2} + \cdots}$

Capacities in series, $C_x = \dfrac{1}{\dfrac{1}{C_1} + \dfrac{1}{C_2} + \cdots}$

Capacities in parallel, $C_x = C_1 + C_2 + \cdots$

Inductances in series (no coupling), $L_x = L_1 + L_2 + \cdots$

Inductances in parallel (no coupling), $L_x = \dfrac{1}{\dfrac{1}{L_1} + \dfrac{1}{L_2}} =$ (approximate value)

The formulas on inductances connected in parallel or in series are approximate since the coupling reactions are assumed to be negligible.

If the mutual coupling (M) is included the formula reads:

Inductances in series, $L_x = (L_1 \pm M) + (L_2 \pm M)$

or

$$L_x = (L_1 + L_2 \pm 2M)$$

The $+$ or $-$ sign depends upon whether the fields assist or oppose each other respectively.

Inductances in parallel, $L_x = \dfrac{L_1 L_2 - M^2}{L_1 + L_2 - 2M}$

where L and M are expressed in henries.

Ques. 386*f*.   Illustrate by diagrams two improved wavemeter circuits for tuning transmitters.

Ans.   Figure 79*b* illustrates two precision frequency meters for calibrating the wave length of a transmitter circuit.

(a)   *(b)*
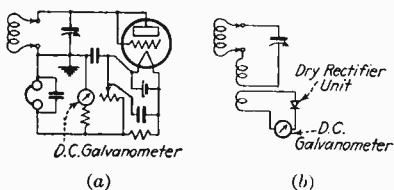
FIG. 79*b*.—Precision-type frequency meters with galvonometers.

Ques. 386*g*.   What is a Hertzian radiator?

Ans.   The Hertz antenna differs from the well-known Marconi antennas in that a ground system does not play any part in its radiation of energy.

The Hertz antenna does not connect directly to the ground but radiates directly through the medium of its own inductance, capacity, and resistance.   It is in reality equivalent to a simple oscillatory circuit in which the inductance, capacity, and resistance are in concentrated form, with the exception that the Hertz antenna is an open oscillatory circuit capable of radiating effectively the energy that is oscillating in it.

There are certain other factors, however, in which the Hertz oscillator differs from the ordinary closed-oscillator circuit. For example, if the oscillatory frequency of a simple closed circuit is to be found, then the formula $f = \dfrac{1}{2\pi\sqrt{LC}}$ must be used.   This requires a careful calculation of inductance and capacity values which is a relatively complicated procedure.

In the case of the Hertz antenna open-circuit oscillator the frequency or wave length can be more easily calculated, since

the natural period is dependent solely upon its physical length. The natural wave length of a Hertz antenna is practically figured to be between 2.07 and 2.1 times its physical length. For example, a Hertz antenna 100 feet (30.7 meters) long has a natural wave length of $30.7 \times 2.1 = 64.5$ meters or 4,651.2 kilocycles, approximately.

There are two distinct methods commonly used for exciting a Hertz antenna in order that it will radiate electromagnetic energy into space, namely, voltage-feed and current-feed systems.

The essential difference between these two methods is chiefly in the method of excitation.

For example, when a Hertzian radiator is set into oscillation there will be certain definite points along the wire system in which the current and voltage distribution will be maximum and minimum. These maximum or minimum voltage or current points are respectively called loops and nodes and refer to the point or points at which the current or voltage predominate or disappear respectively.

Hence the voltage-feed system of antenna excitation, as applied to Hertzian radiators, is one in which the energy is fed into one of the voltage loops (current nodes) of the antenna system and the current-feed system is one in which the energy is fed into one of the current loops (voltage nodes).

NOTE.—See Addenda for additional questions and answers on general theory.

BROADCASTING TRANSMITTERS AND DEFINITIONS

Ques. 387. Draw a diagram of a modern broadcast installation complete with speech-input and transmitter equipment and explain its component parts.

Ans. Figures 80 and 81 illustrate a complete diagram of a modern broadcasting transmitter manufactured by the Western Electric Co.

THE SPEECH AMPLIFIER

The speech-input equipment consists of a moving-coil type of microphone transmitter (No. 618A), a low-level speech amplifier (No. 69A), and a high-level speech amplifier (No. 70A), volume indicator or gain control (No. 220A), and a mixing panel (not shown).

The low-level speech amplifier is a two-stage, fixed-gain-transformer-coupled amplifier using Western Electric No. 262A tubes. This amplifier is entirely alternating current operated and has been primarily designed for building up the relatively feeble output variations of the moving-coil type microphone so that a suitable signal level may be delivered to the high-level amplifier.

The high-level speech amplifier is a two-stage, fixed-gain-transformer-coupled amplifier and uses one No. 262A and two No. 205D Western Electric tubes in push-pull.

This amplifier receives its energy from the output of the low-level amplifier through a master-gain-control potentiometer.

The output of this amplifier is sufficiently large to operate two loud speakers, a volume indicator, and an associated transmitter, or it may be used to feed energy over a telephone line to a transmitter or studio.

The amplifier operates from a 200-ohm impedance and may function into an output load impedance of either 200 or 500

ohms. It has a maximum gain of approximately 50 decibels and will deliver an undistorted signal level of approximately +16 decibels or 0.24 watts.

The entire unit is also operated directly from a well-filtered alternating-current power supply and has a hum level of over −41 decibels, which is practically inaudible to the human ear.

The output amplifier is a push-pull arrangement which functions into a telephone line or transmitter. It must, therefore, be attenuated and matched to the line impedance by a suitable pad system to get the proper decibel loss and impedance match between the amplifier circuit and the circuit into which it is to function (See Ques. 394*p* on pad calculation.)

THE TRANSMITTER

The transmitter is a 1,000-watt crystal-controlled system, employing grid-bias modulation in a class C radiofrequency amplifier, which functions into a balanced power-amplifier stage operating as a class B amplifier. The transmitter is of the most efficient design and is capable of modulating the carrier frequency at fully 100 per cent without distortion.

The crystal chamber is a sealed unit capable of maintaining the oscillator frequency to within ±12 cycles. The heater unit is controlled by an argon temperature-regulating tube (see Ques. 394*i*), which is kept in operation at all times to maintain a constant temperature in the chamber. The oscillator is a 5-watt tube and functions into another 5-watt tube operating as a radiofrequency amplifier and buffer. The output is then applied to the grids of a 50-watt radiofrequency amplifier through a small radiofrequency transformer of the fixed-tuned variety. The 50-watt output is then coupled to a pair of 250-watt amplifiers in a balanced arrangement. These tubes are biased as class C amplifiers. In addition, the grid returns of these tubes are connected in series with the secondary winding of a special modulating transformer for modulating purposes. The output of these tubes is then fed into a balanced amplifier and finally into the radiating system.

The power supply is divided into four units: (1) C bias for the first, second, and third amplifiers and plate supply for the crystal oscillator and first amplifier; (2) plate supply for the, second, and

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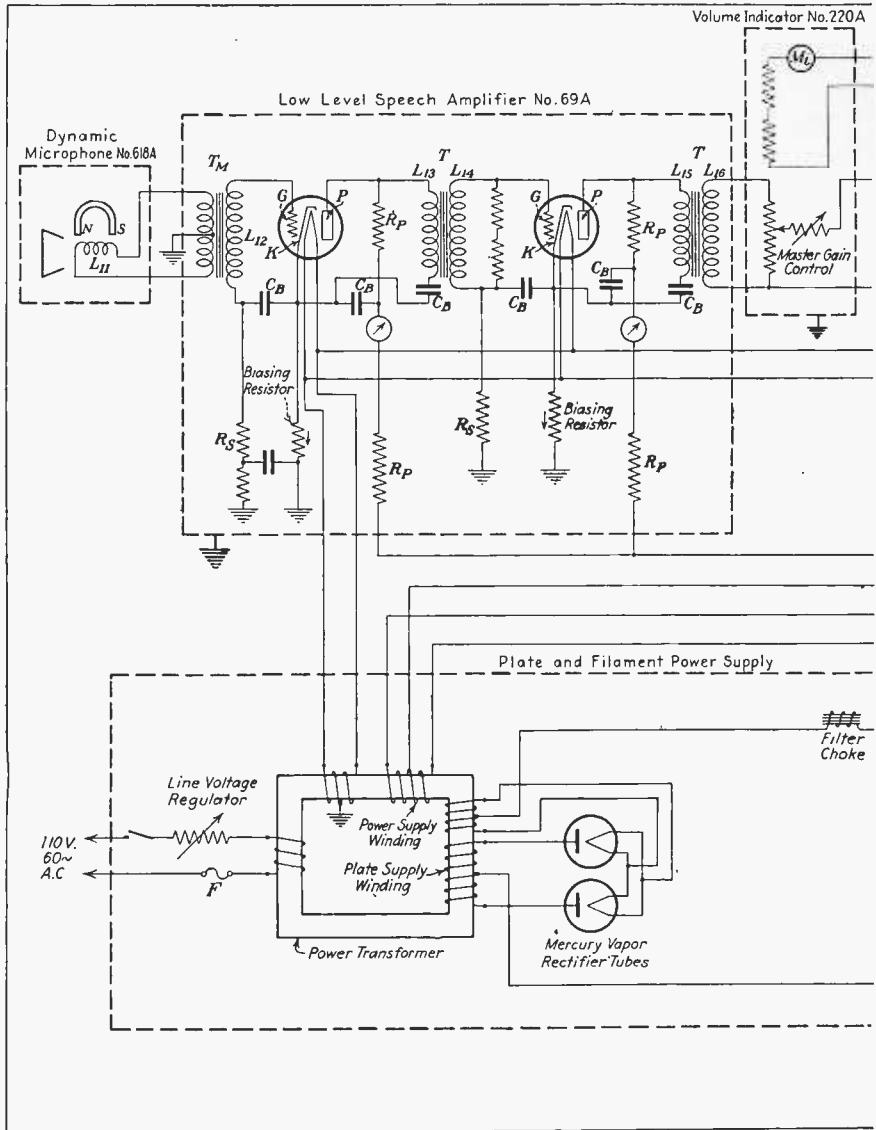
Fig. 80.—Speech input equipment type 9A for Western

High Level Speech Amplifier No. 70A

T = High Quality Audio Frequency Amplifying Transformers
T_M = Microphone Transformer (Primary Z = 25 ohms)
C_F = Filter Condenser
C_B = Audio Frequency By-Pass Condensers
R_P = Plate Voltage Supply and Isolating Resistors
R_S = Grid Filter and Stabilizing Resistors
F = Fuse
$\otimes$ = Milliammeter

Electric 1000-watt broadcast transmitter, type 12 A.

E¹
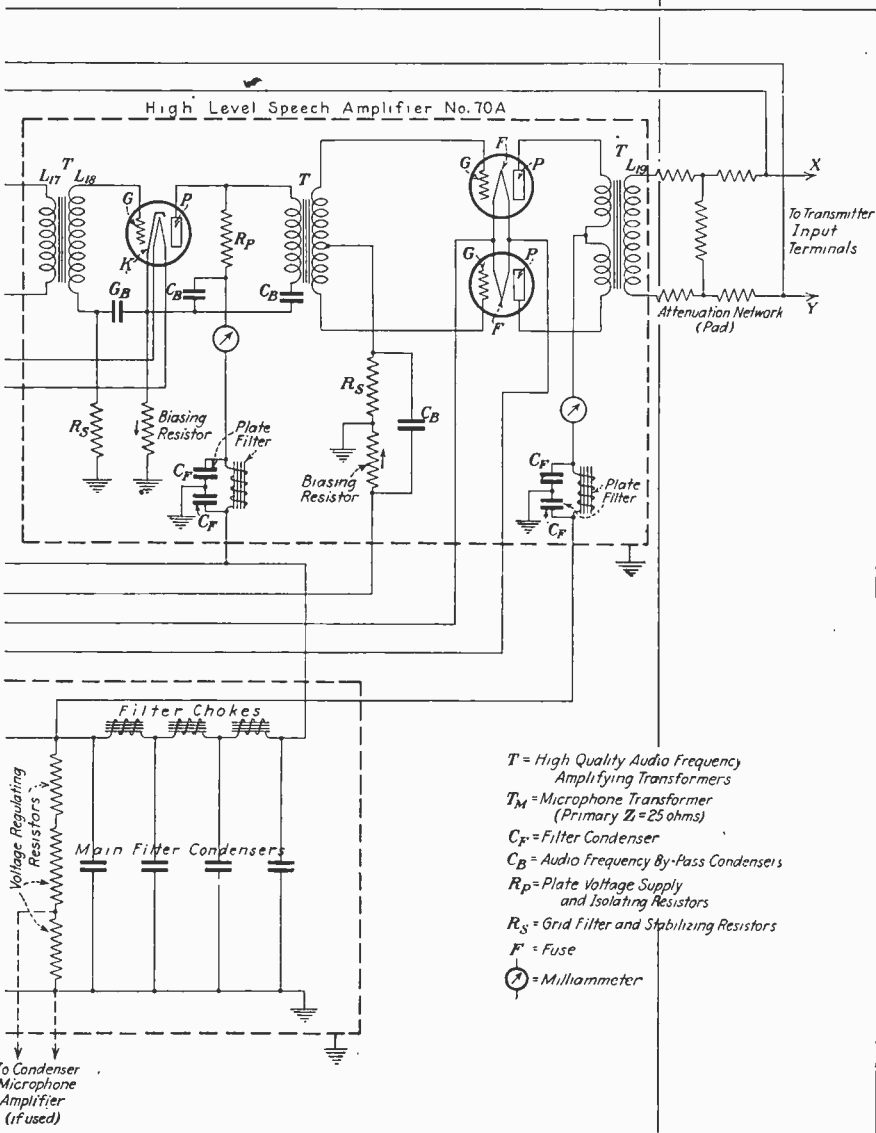
γ-271A Par
276A
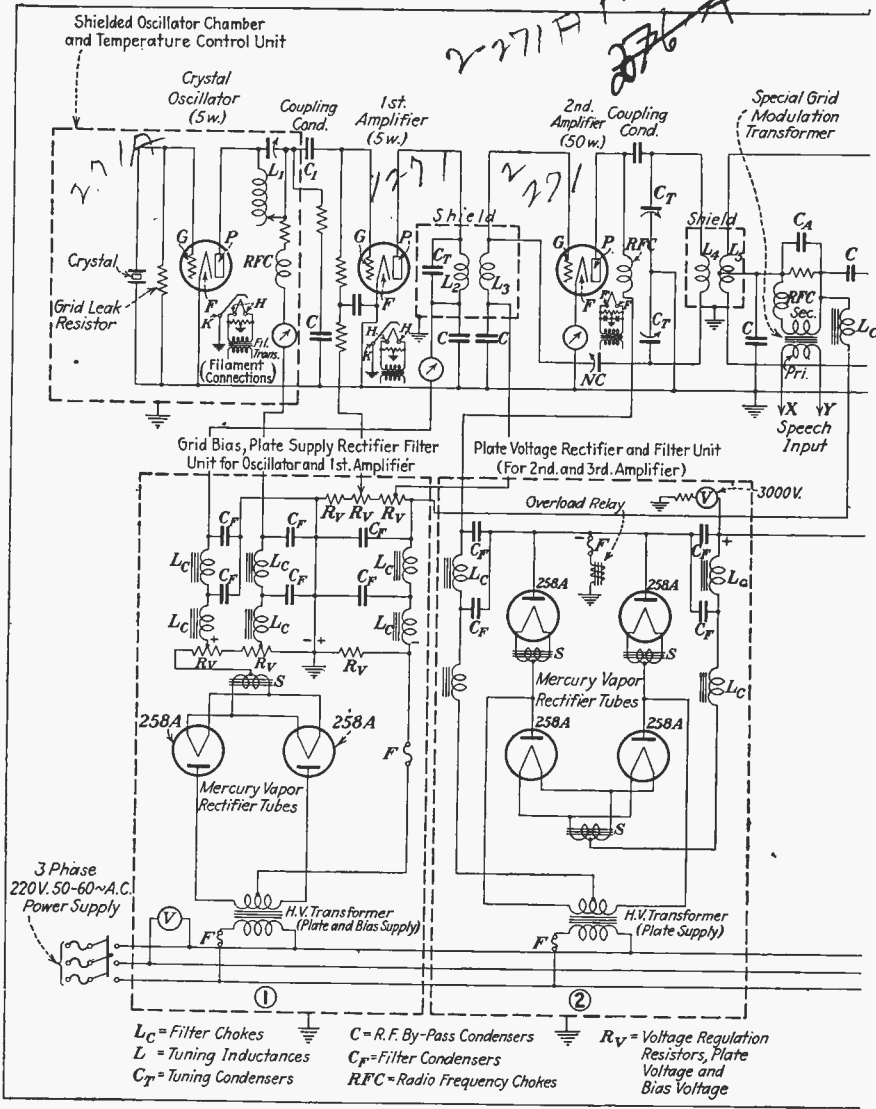
FIG. 81.—Western Electric broadcast transmitter,
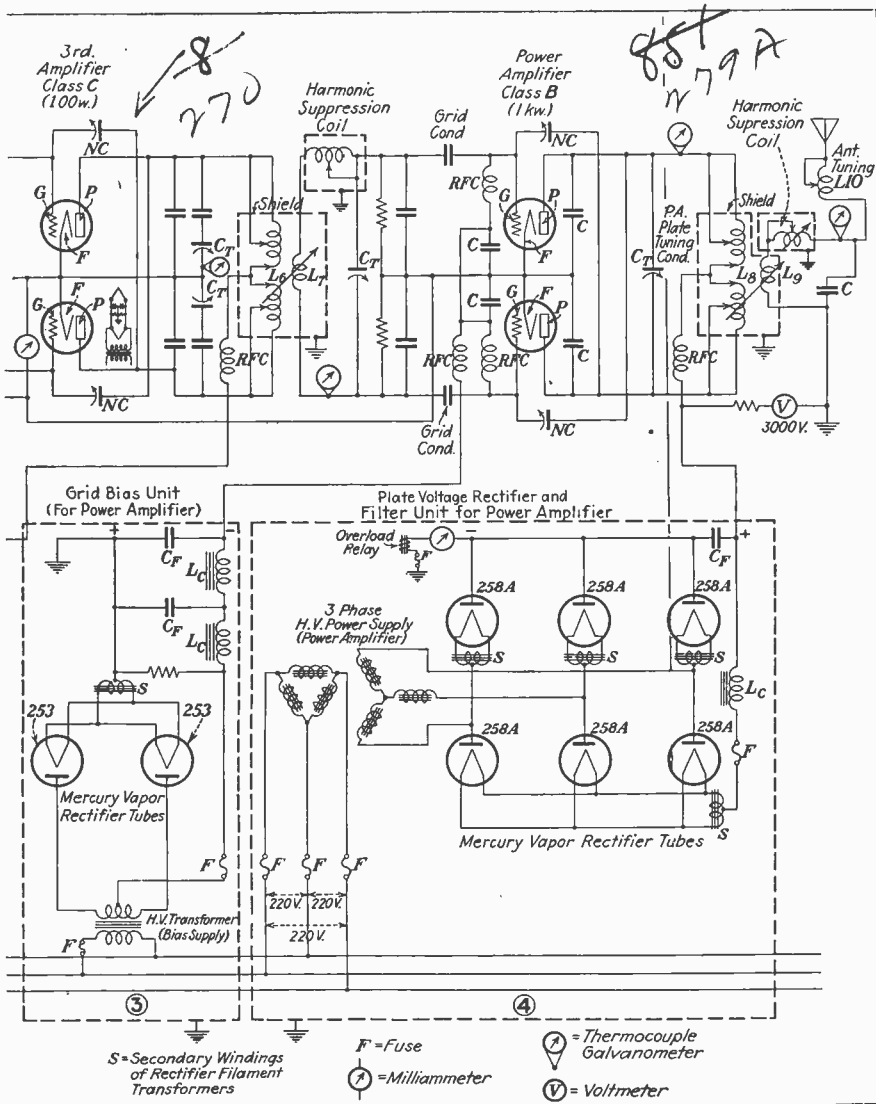
type 12 A, with amplifier type 71 A, 1000 watts.

71 ose   130 Ep, .007 Ip
71A βf₂   300 Ep, .006 Ip
an 71A   350 Ep, .012 Ip
270A   3000 V, .125 Ip

third amplifiers; (3) C bias supply for the final power stage; (4) plate supply for the final power stage.

The entire transmitter is protected with door switches, overload circuit breakers, fuses, and time-delay relays and is practically foolproof during operation.

No generators are used in the entire installation, which marks a new step in the design of broadcast transmitters.

See Addenda for further information.
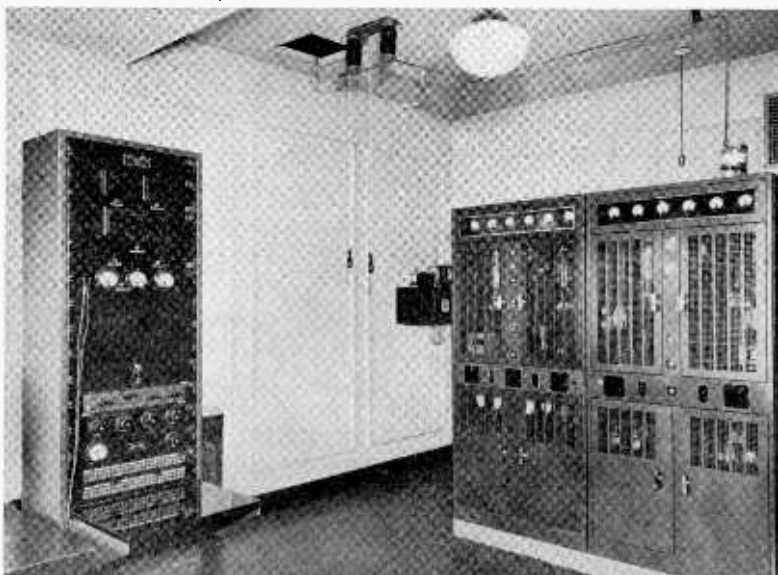
Fig. 81a.—Western Electric 1000-watt transmitter with speech input equipment of which circuit diagrams appear in Figs. 80 and 81. Station W I N S, New York. (*Courtesy*, Graybar Electric Co., Inc.)

BRIEF THEORETICAL OPERATION
Transmitter

Assuming all switches and relays to be closed in both speech amplifier and transmitter circuits, and all plate voltage and plate current readings to be correct, the theoretical operation will be as follows.

Radiofrequency oscillations of a definite frequency are generated in the plate circuit of the oscillator tube through the medium of the interelectrode grid-plate tube capacity and the

oscillatory constants of the variometer L_1 and the crystal, the exact frequency being dependent on the crystal thickness and temperature. These radiofrequencies are fed through the coupling condenser C_1 which applies an alternating e.m.f. across the grid and filament of the first amplifier tube. These variations will cause radio-frequency current changes of increased amplitude in the primary winding of the output transformer L_2 which will be transferred by induction into L_3 and across GF of the 50-watt second amplifier tube. The increased radiofrequency variations now in the plate circuit of the output transformer and mesh circuit C_T, L_4 will be applied to the grids of the third amplifier balanced stage through the medium of L_5. This results in a plate current variation in the third amplifier plate-mesh circuit C_T, L_6. From here these variations are applied to the grids of the balanced power-amplifier stage by induction through the medium of L_7 and the secondary tuned-mesh circuit L_7, C_T and the harmonic suppression coil. Hence the grid variations on the grids of the power-amplifier tubes will cause high-frequency plate variations in the final mesh or power-amplifier plate circuits C_T, L_8. Here the radiofrequency current variations about L_8 will be induced into L_9 and a maximum current will flow when the antenna mesh L_9, C, and L_{10} are properly adjusted to resonance with the driving frequency.

The proper adjustments of all drive and plate-mesh circuits must be carefully obtained to produce a maximum degree of efficiency. The plate load impedances must be accurately adjusted by obtaining the proper amount of reflection from output circuits. For tuning and operating instructions see Ques. 546 and 552.

SPEECH AMPLIFIER

Assuming all plate currents and filament voltages to be properly adjusted and the master gain control at an approximate level setting, then when sound impulses are applied to the microphone diaphragm, magnetic distortion will result, owing to the movement of the coil structure in a permanent magnetic field. This results in a displacement of electrons in the circuit L_{11}, the microphone coil, and the primary winding of the microphone transformer T_M, resulting in a moving magnetic

field of low frequency around L_{12}. This will induce an e.m.f. across GK (K = cathode) of the first tube in the low-level amplifier which will cause current variations in the output winding L_{13} and the condenser C_B. It will be noted that no direct-current component flows through this circuit but only the speech signal frequency. This is known as a parallel-feed system and is used to prevent the plate current from flowing through the primary winding of a transformer, saturating its core, particularly when high-grade core material such as permalloy is used. Core saturation would reduce the primary inductance of the transformer and would seriously impair quality. In this arrangement the plate current flow is maintained by the feed resistances R_p.

The speech variations now present around L_{13} will induce an e.m.f. across L_{14} and consequently across GK. The variations are then further amplified in a like manner through L_{15}, L_{16} and applied to the master gain-control resistance and the input winding of the high-level speech amplifier L_{17}. The speech variations are then amplified in a similar manner through the high-level speech amplifier and finally fed from the push-pull output transformer secondary winding L_{19} through the attenuating and impedance matching network into the volume indicator, monitor, loud speaker, and primary winding of the special modulation transformer shown in Fig. 81. Thus during the period in which low-frequency current variations are passing through the primary winding of the special modulation transformer, an e.m.f. of low frequency will be applied across its secondary winding. Hence, if we assume a steady radiofrequency potential to be present in the third amplifier grid circuit C_A, C (of the transmitter), during the period in which the crystal oscillator and succeeding amplifiers are driving it, then any low-frequency voltage variation due to the speech signals across the secondary winding of the special grid-modulation transformer and C_A will affect the steady current condition in this circuit and will cause the radiofrequency current in the grid circuit to be varied in accordance with the speech frequency.

Thus by varying the amplitude of the radiofrequency oscillations, the carrier frequency is said to be modulated. Since this takes place in the grid circuit and in a radiofrequency stage preceding a power stage, the system is called a grid-modula-

tion or grid-bias-modulation method and is classified as low-level modulation.

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. 82a.
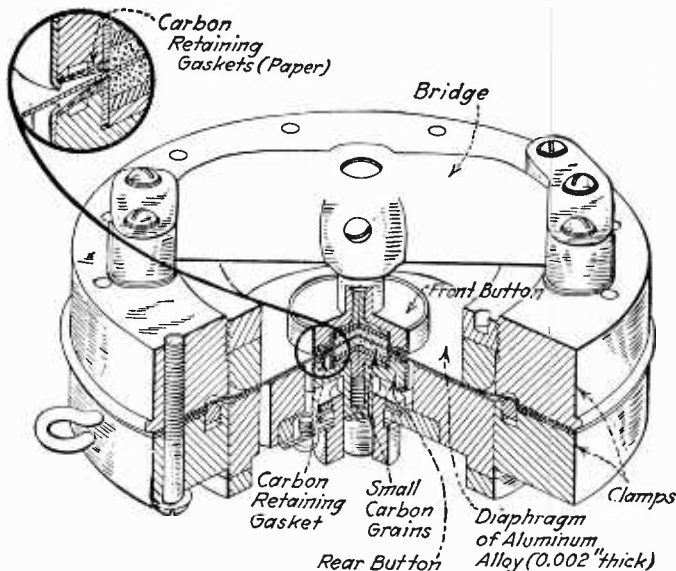
FIG. 82.—Cross-sectional view of carbon microphone (double-button type).

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.
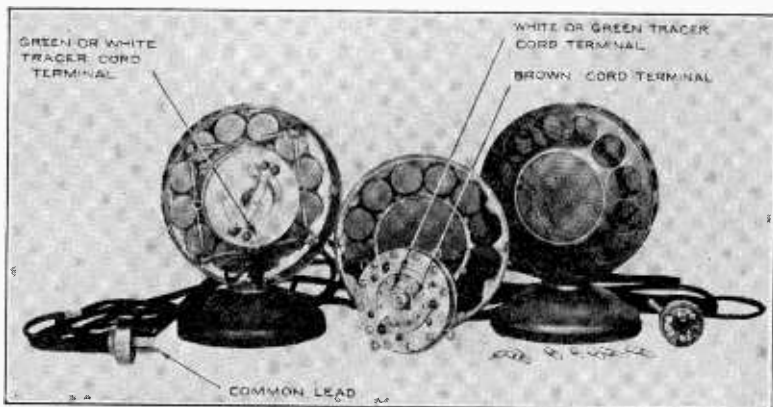
FIG. 82a.—View of parts, Western Electric broadcasting microphone transmitter No. 373-W and No. 387-W with 1-B transmitter mounting, No. 788 cord and plug.   (*Courtesy*, Western Electric Company.)
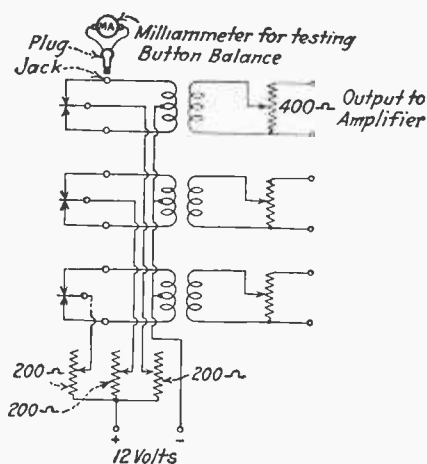
FIG. 83.—Mixing panel.

Figure 83 illustrates a telephone-mixing panel using three microphones and shows the variable-resistance units for adjusting

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 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 practice 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 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 the decibel, db. The db 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 dbs, 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 0.006 watt, then any amount of power less than 0.006 watt will be indicated by the negative $(-)$ on the panel contacts, provided, of course, the measurements are made in dbs. Thus, if the amount of power is more than 0.006 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 db, and the small ones are each 2 db and cover a range of 20 db from −10 to +10 db. Refer also to Ques. 456 and 466.
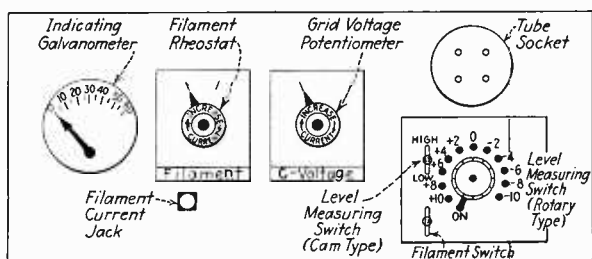
FIG. 84.—Volume indicator.

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 db.

A table showing the relative power, voltage, and current ratios corresponding to particular numbers in decibels follows:

Power Ratio		Transmission Units in Decibels (db)	
1	$(=10^0)$	0	$(=10 \log_{10} 1)$
1.259	$(=10^{0.1})$	1	$(=10 \log_{10} 1.259)$
10	$(=10^1)$	10	$(=10 \log_{10} 10)$
100	$(=10^2)$	20	$(=10 \log_{10} 100)$
1000	$(=10^3)$	30	$(=10 \log_{10} 1000)$

Voltage or Current Ratio	Transmission Units in Decibels (db)
0.001	-60.00
0.005	-46.02
0.01	-40.00
0.05	-26.02
0.1	-20.00
0.2	-13.98
0.5	-6.02
1.0	0.00
1.5	3.52
2	6.02
5	13.98
10	20.00
20	26.02
50	33.98
100	40.00
500	53.98
1000	60.00

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 $\frac{1}{2}$ 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.
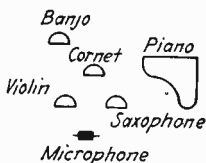
Fig. 85.—Instrument placement before microphone, small orchestra.
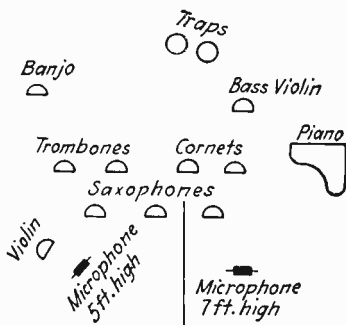
Fig. 86.—Instrument placement before microphone, jazz band.

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.
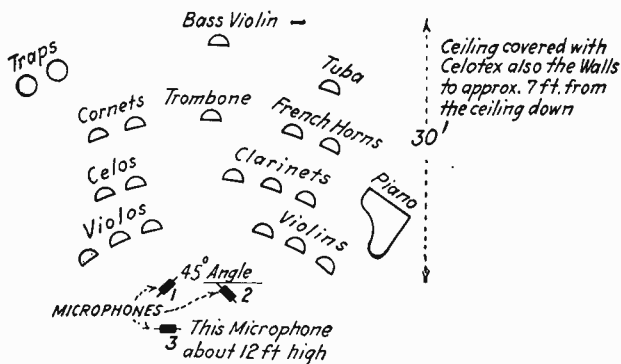
FIG. 87.—Instrument placement before microphone, large orchestra.

Ques. 394a. Explain the theory of the Heising or constant-current system of modulation (plate modulation). Why is this system so called? (See also Ques. 394n.)

Ans. Figure 87a illustrates two circuit arrangements of the Heising system of modulation.

Ordinarily when alternating e.m.fs. are applied to the grid of the modulator tubes from the speech input equipment, the plate currents in the modulator circuit vary accordingly. In the Heising system, however, the plate current is maintained very steadily by a high inductance (plate reactor) connected in the plate circuits of the modulator tube and the power-amplifier tube that is to be modulated.

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 amplifier tubes. The amplifier current, consequently, decreases. Then, when the modulator grids become negative, owing to the signal variation, the modulator plate current will tend to decrease, and the amplifier plate current will again increase, all of this being due to the choke coil maintaining steadily the current supply to both modulator and amplifier.

It is, therefore, quite obvious that the amplifier plate current is varied at an audio or speech frequency, and, consequently, the radiofrequency antenna current is correspondingly varied. From this, it can readily be seen that the "constant-current" scheme is so called because of the tendency of the total current through the plate reactor in Fig. 87a to remain practically constant, owing to its high inductive reactance.

Power
Amplifier
Modulator Tube
Tube RFC
Speech
Input
Equipment
Plate
Reactor
−C +

LOW PERCENTAGE MODULATION
To Power
Amplifier Drive
(Crystal Osc. and Int. Amp.)

Power
Modulator 4mf. Amplifier
Tube Tube
Speech R
Input RFC
Equipment Plate
Reactor
−C + C

To Power
Amplifier Drive
(Crystal Osc. and Int. Amp.)

HIGH PERCENTAGE MODULATION
(Modulator Tube Operating at Higher
Plate Voltage than Amplifier,
due to Resistance R)

FIG. 87a.—Heising systems of modulation.

Ques. 394b. How would you keep a radio telephone transmitter on its assigned frequency?

Ans. A radio telephone transmitter may be maintained on its assigned frequency by the use of a piezo crystal oscillator and an efficient system of automatic temperature control.

Ques. 394c. What effect does an audio-frequency wave have upon a carrier wave in a radio telephone transmitter?

Ans. See *Side Bands*, page 267.

Ques. 394d.   Describe the purpose and operation of a speech or input amplifier.

Ans.   A speech amplifier is essential in a broadcast transmitter to build up the feeble microphone current variations to larger values of potential variations so that the R.F. power tubes may be properly modulated.   A speech amplifier is really a high quality audio-frequency amplifier, not designed merely to increase the microphone variations but also to control the output range so that the quality of transmission will not be affected.   A specially designed volume indicator (vacuum-tube voltmeter) is provided with every speech amplifier to insure careful control of the signal voltage fluctuations before they are passed to the modulator tube grids (see Ques. 390).   The theoretical operation of a speech amplifier is similar to any high-quality audio-frequency amplifier.

Ques. 394e.   What change would you make to convert a broadcasting transmitter to a radio telegraph transmitter for CW and ICW transmitting purposes?

Ans.   When a broadcasting transmitter is put into operation, the oscillator or amplifier tubes coupled to the antenna radiating system are emitting a wave of a continuous character (CW) at a definite frequency, depending upon the oscillatory adjustments of L and C.   Hence, during the intervals that the microphone is not in operation a continuous wave of definite frequency is constantly emitted.   Thus, if it is desired to break up the continuous wave for telegraphic purposes, a telegraph relay key may be inserted in series with the negative lead of the power supply for signaling purposes.   If, on the other hand, it is desired to emit an interrupted continuous wave (ICW), a high-frequency buzzer and a telegraph key may be inserted in series with the microphone.   A switching arrangement should be included to short-circuit the microphone during buzzer operation and the buzzer and key during microphone operation.

Ques. 394f.   Explain the theoretical operation of a condenser-type microphone and describe its construction.

Ans.   Figure 87b illustrates the construction of a standard condenser microphone.   The condenser microphone consists

essentially of a very thin tightly stretched duraluminum diaphragm (1) and a flat brass disc, or back plate (2). These two plates constitute the capacitive area of the condenser microphone. The separation between these two plates is approximately 0.002 inch. All other parts are chiefly for protective purposes, insulation, and support. The general supporting and insulation construction is briefly as follows:

Two clamping rings (3 and 4) hold the diaphragm in place. These rings in turn are held together by 12 screws (5). The proper diaphragm tension is maintained by the pressure of the stretching ring (6). Two mica washers (7 and 8) insulate the parts (2, 9, 10, 11, 12, and 13) from the remainder of the microphone. The entire back-plate assembly is boiled in special wax to keep out moisture and dust.

The spacing washer (14) maintains the proper spacing between the diaphragm and the back plate. When the microphone is assembled, both sides of this washer are greased to insure a practically air-tight space between the diaphragm and the back plate. Variations in atmospheric pressure are equalized through a small hole in the center of the back plate and a thin rubber diaphragm (11). The entire back-plate assembly is held in by means of a rubber washer (15) and a ring (16).

The electrical connections are made to the screw (12) in the center of the back plate and to the frame of the microphone.

Part 17 is the microphone cover and is suitably arranged with a metal screen (18) to permit the vibrations to actuate the diaphragm. The cover also prevents possible injury to the tightly stretched duraluminum diaphragm.

The theoretical operation of the condenser microphone is briefly as follows:

When a high voltage is applied to the two plates of the condenser (1 and 2) through the high resistance R (approx. 20 megohms), the area between the two plates will be in a strained or charged condition. The voltage drop across R is also applied to the input circuit of the vacuum tube but not during the period when the diaphragm is idle. Hence, the normal drop across R is practically balanced out by the C biasing effect due to that portion of the high voltage supply connected between R and F. A similar biasing condition may be obtained by connecting a

condenser between the points X and G and a high value of grid leak (20 megohms) between G and F.
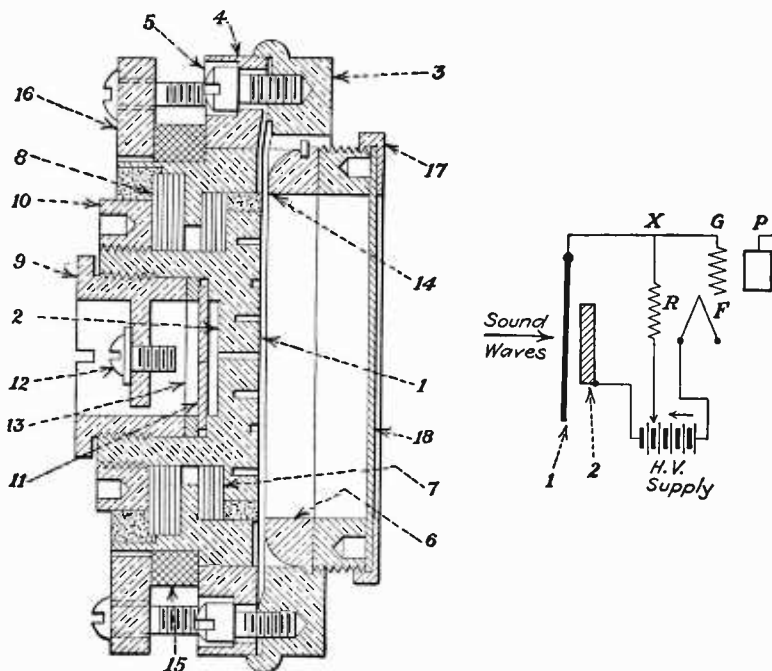
Fig. 87b.—Condenser microphone and scheme of connections.

Now, as sound vibrations are impressed upon the tightly stretched diaphragm (1), the distance between the two condenser plates (1 and 2) will be correspondingly changed, consequently causing a change in the capacity of the condenser. This action results in a pulsating current flow in the charging circuit, and consequently, causes the voltage changes (RI drop) in the high resistance R to follow the fluctuations in the sound pressure on the diaphragm I, thus causing corresponding voltage changes to be applied to the grid of the tube. These voltage fluctuations may then be amplified through a number of audio-frequency stages, preferably resistance coupled, until the desired signal output is obtained.

Ques. 394g. Why is a speech or input amplifier used?

Ans. The speech amplifier in broadcasting is used to build up the feeble current variations set up by the microphone to greater amplitudes. The modulator tubes in a broadcast transmitter must receive the proper amplitude of grid-voltage swings to effectively modulate the carrier frequency. Thus, a number of tubes functioning as voltage amplifiers are used following the microphone to build up the signal voltages to their proper amplitude to modulate effectively the radiofrequency carrier. These amplifiers preceding the modulator tubes are called speech amplifiers. Speech amplifiers are also used in the broadcasting studios to feed the microphone output variations into the telephone lines with the proper signal level.

Ques. 394h. Explain briefly what frequencies are in the antenna and side bands in a radiotelephone transmitter.

Ans. See *Side Bands* page 267.
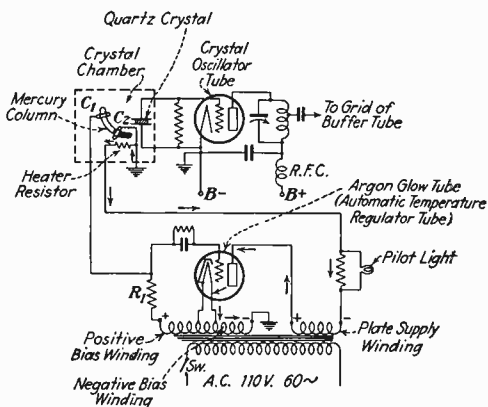
Fig. 87c.—Western Electric crystal temperature-control box circuit.

Ques. 394i. Draw a diagram of a crystal oscillator with an automatic temperature control and explain its operation.

Ans. Figure 87c illustrates an automatic temperature-control unit used by the Western Electric Co. in their broadcast transmitters. This automatic temperature-control unit is capable of maintaining the crystal frequency to within ± 12 cycles of the assigned frequency.

The theoretical operation of the automatic temperature control is as follows:

When the alternating-current plate supply and filament supply switch SW is closed, the filament will be heated and a positive potential will be applied to the plate and to the grid of the tube by the special arrangement of the transformer windings. The positive potential on the plate will cause a plate current to flow in the direction of the arrows in accordance with the conventional theory of current flow. However, owing to the positive potential on the grid at this instant and the presence of the inert gas, the plate current will be of a relatively larger proportion than ordinary vacuum-tube circuits, approximately 500 milliamperes. This current will pass through the pilot light and its shunt resistance and the crystal heater resistance unit.

As the heat in the resistance unit increases, the mercury column in the crystal chamber will expand and rise upward eventually connecting contacts C_1 and C_2 through the medium of the conducting mercury. At the instant that these contacts are closed, the voltage drop across the negative bias winding will be directly applied to the grid through the mercury column, resulting in a blocking action of the plate current, extinguishing the pilot light and causing the heater resistance to cool off. When the temperature of the chamber begins to cool off, the mercury will contract causing the contacts C_1, C_2 to be broken and the plate current to be restored and again lighting the pilot light and heating the heater resistance unit.

The function of the resistor R_1 is merely to prevent a short-circuiting of the filament and bias windings on the transformer when the contacts C_1 and C_2 are closed.

Ques. 394*j*. What is meant by a "buffer" stage, in a broadcast transmitter? Why is it used?

Ans. The buffer stage is a radiofrequency amplifier tube following the crystal oscillator. This tube is biased negatively up to the point at which no grid current will flow.

The buffer or isolation stage is used to prevent frequency fluttering due to reactions between the modulated radiofrequency amplifier and the oscillator during the process of modulation.

A screen-grid tube is usually used in the buffer stage on account of its low internal grid-plate capacity which prevents self-oscillation.

Ques. 394k. How can frequency fluttering due to modulation be determined?

Ans. By an oscillating monitor placed near the transmitter during modulation.

Tune the oscillating monitor to zero beat with the carrier frequency of the transmitter and listen to the quality. The music or speech should be absolutely clear and free from distortion.

Ques. 394l. What is meant by class A and class B modulation?

Ans. The *class A* modulator system operates in a similar manner to the ordinary power-amplifier stage in an audio-frequency amplifier. That is to say, the grid bias voltage is adjusted so that the signal voltage will operate on the straight portion of the $I_p - E_c$ characteristic curve. During the modulation process the positive and negative peaks must not extend into the upper and lower curved portions of the characteristic curve if high quality is to be obtained.

The *class B* modulator system operates with a negative grid bias adjustment at the lower portion of the I_p and E_c characteristic curve. This adjustment results in a very small plate-current flow during the period in which no signal is applied to the grid. Operating at almost the cut-off point of the plate current enables a comparatively higher power output without exceeding the rated plate dissipation of the tube.

When a *class B* modulation system is used, the modulator tubes generally operate in a balanced or pushpull circuit arrangement.

Ques. 394m. What is the difference between a class A, a class B, and a class C amplifier?

Ans. The essential difference between the three classes of amplifier system is almost entirely in their respective operating points of the $I_p - E_c$ characteristic curve.

The *class A* amplifier operates in an identical manner with the power amplifier in a radio receiver, as follows: The negative grid bias voltage is adjusted to operate at the straight portion of the $I_p - E_c$ characteristic curve so that when a signal voltage

is applied to the grid the plate current will remain constant and the alternating-current plate-voltage changes will be symmetrical reproductions of the input signal voltages. If excessive grid swings are applied so that the variations extend into the curved portions of the characteristic curve, serious distortion will result. The *class A* amplifier, therefore, is limited to operation on the straight portion of the curve only to minimize distortion, consequently reducing the effective power that may flow in the plate-load circuit.

A *class B* amplifier, on the other hand, permits a greater output variation, owing to the fact that it is operated with a negative grid bias which drives the plate current almost to zero. When operating a tube in this manner near the cut-off point, the amplifier operates so that its power output is proportional to the square of the grid-excitation voltage. Assuming the *class B* amplifier to be modulated at fully 100 per cent, then the carrier output when unmodulated is one-fourth of the peak output. For example, if the rated carrier output is 250 watts, then the peak power during modulation will be 4×250 or 1,000 watts of peak power.

The *class B* amplifier is generally called a linear amplifier, owing to the plate-current cut-off adjustment. For example, when operating as a *class B* amplifier, a plate current will flow only during the period in which positive peaks are applied to the grid, consequently the wave shapes for each positive excitation are half cycles. Hence, if the grid-excitation voltages are steadily applied, the dynamic characteristic will represent a linear characteristic of wave shapes.

The *class C* amplifier is perhaps one of the most commonly used and is practically the same as the *class B* amplifier with the exception that the negative grid bias adjustment is far beyond the cut-off point on the $I_p - E_c$ characteristic curve.

With this type of amplifier it is possible to present the maximum degree of modulated amplification without distortion, since the efficiency is so high and the output power varies as the square of the plate voltage within limits.

When operating a *class C* amplifier, the grid excitation must be greatly increased since it will be necessary to overcome the heavy negative bias to produce any plate-current peaks at all.

Ques. 394*n*. Explain the following systems of modulation: grid modulation, absorption modulation, and plate modulation.

Ans. Figure 87*d*, (*a*) illustrates a grid system of modulation as used by the Western Electric Co. Here the output from the speech amplifier is fed directly into a primary winding of a specially constructed modulation transformer. The secondary winding excites alternately the two grids of the radiofrequency amplifier, thereby modulating the carrier frequency present in the plate circuits.

ICW oscillations are usually produced by grid modulation in telegraph transmitters, see Fig. 1.
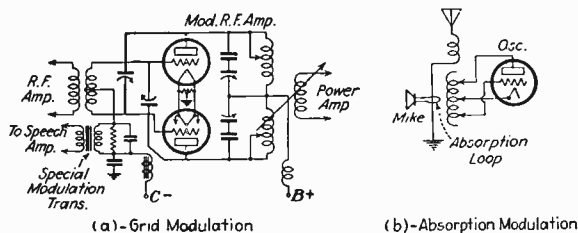
FIG. 87*d*.—Modulation methods.

Absorption modulation is illustrated in Fig. 87*d*, (*b*). Here the radiofrequency currents flowing in the high-frequency circuits are varied by the low-frequency current variations in the microphone loop circuit, thereby modulating the carrier frequency.

For plate modulation, see Ques. 394*a*.

Ques. 394*o*. What is the transmission unit or the decibel (abbreviated db) and how is it used?

Ans. The transmission unit or decibel is a term used for expressing the ratio between two quantities, either of electrical or sound energy. It is important to bear in mind that the terms are used merely to indicate a relative measurement of electrical or sound energy levels and does not specify any definite current, voltage, or power. Although the transmission unit and the decibel mean precisely the same thing, the latter unit has been adopted at an international convention by telephone engineers in honor of the work of Alexander Graham Bell.

When we wish to express the ratio of one power to another, in circuits of equal impedance, the decibel is measured by the formula:

$$\text{db} = 10 \log_{10} \frac{P_1}{P_2} \text{ or } \log_{10} \frac{P_1}{P_2} = \frac{db}{10}$$

When, on the other hand, we wish to express the ratio of voltages or currents in decibels, then the formula must read db = 20 $\log \frac{E_1}{E_2}$ or db = 20 $\log \frac{I_1}{I_2}$. Simplifying further $\log_{10} \frac{E_1}{E_2} = \frac{DB}{20}$ or $\log_{10} \frac{I_1}{I_2} = \frac{DB}{20}$. The change in the formula is due to the fact that power is proportional to current squared or voltage squared; hence for voltage or currents the logarithm of the ratio must be multiplied by 2. That is to say, twice the logarithm of a number squares the number.

Logarithms are used in these formulas to express numbers in terms of 10 raised to a certain power. In other words, instead of writing 10 with an exponent, we write only its exponent, which will denote the power to which 10 has been raised.

For example, 100 is equal to 10 to the second power (10^2) and the logarithm of 100 is the exponent 2. Thus the logarithm of 10 (10^1) is 1. If the number should be less than 10 but greater than 1, the logarithm will be some decimal part of 1.

From this it can readily be seen that the logarithm of a number is the exponent by which 10 must be raised in order to equal the given number. For example,

$$1 = 10^0, \text{ therefore, } \log 1 = 0$$
$$10 = 10^1, \text{ therefore, } \log 10 = 1$$
$$100 = 10^2, \text{ therefore, } \log 100 = 2$$
$$1,000 = 10^3, \text{ therefore, } \log 1,000 = 3$$
$$10,000 = 10^4, \text{ therefore, } \log 10,000 = 4$$
$$100,000 = 10^5, \text{ therefore, } \log 100,000 = 5$$
$$1,000,000 = 10^6, \text{ therefore, } \log 1,000,000 = 6$$

The practical use of the decibel may readily be apparent if we take for an example two amounts of power, one which shall be called the input power of an amplifier and the other the output power of the same amplifier. Now in order to compute the number of decibels gain in this amplifier, it will merely be neces-

sary to take the ratio of the larger power and the smaller power and multiply by $10 \times \log$, or

$$\text{db} = 10 \times \log \frac{P_2 \text{ (larger power)}}{P_1 \text{ (smaller power)}}$$

In computing the gain in any amplifying or transmitting system, P_1 will represent input power and P_2 the output power.

For example, a certain amplifier has an input of 0.002 watt and an output of 0.9 watt. What is the gain of the amplifier in db?

$$\text{db} = 10 \times \log \frac{P_2}{P_1}$$

$$= 10 \times \log \frac{0.9}{0.002}$$

$$= 10 \times \log 450 \ (\log 450 = 2.65321)$$

$$= 10 \times 2.65321$$

Gain in db $= 26.53 + Ans.$

(The log of any number may be obtained from a book of logarithmic tables.)

Ques. 394p. **Explain how a pad (attenuating network) may be calculated for a proper impedance match in a line and for a certain attenuation in decibels (db).**

Ans. The characteristics of attenuation networks are as follows:

"T" Pad
where Z = *Impedance in Ohms*

"H" Pad
(Preferred)
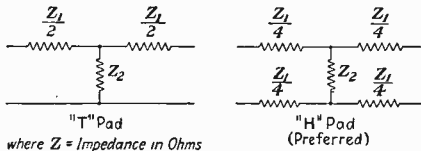
Fig. 87e.—Attenuation networks.

Attenuation in db	200-ohm line		600-ohm line	
	Z_1	Z_2	Z_1	Z_2
1	22.6	1,760.0	67.95	5,280.0
2	46.0	858.0	138.0	2,575.0
3	68.0	571.0	204.0	1,714.0
4	89.9	422.0	269.7	1,266.0
5	112.0	328.0	336.5	986.0
10	207.5	140.6	624.0	421.0
20	327.0	40.4	982.0	121.4
30	380.0	13.5	1,140.0	40.5
40	396.0	2.0	1,180.0	6.0
50	400.0	1.274	1,200.0	3.822

To determine the values of Z_1 and Z_2 for a line of any other impedance, multiply the values for 200-ohm line by the ratio of the impedance of the new line to the 200-ohm impedance. For example, 600-ohm line values are all just three times 200-ohm line values, and so on.

The following formula and method is perhaps the most simple method for determining the resistance values of a H-type pad.
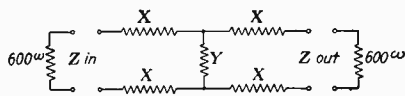
Fig. 87f.—Attenuation network.

Example I.—Let us assume that an impedance of 600 ohms is to function into a line of similar resistance and that it is to terminate into an impedance of 600 ohms. In addition we desire to attenuate the signal 10 db.

$$X \text{ (series resistance)} = \frac{Z}{2}\left(\frac{K-1}{K+1}\right) \tag{1}$$

$$Y \text{(shunt resistance)} = 2Z\left(\frac{K}{K^2-1}\right) \tag{2}$$

Where $K = \dfrac{I_o}{I_a} = \dfrac{E_o}{E_a} = $ (voltage or current ratio)

Where I_o or $E_o = $ initial E or I

and I_a or $E_a = $ the attenuated E or I

Thus, a 10-db pad to have an input and output impedance of 600 ohms may be calculated as follows:

(In view of the fact that common logarithms are used in calculating pads, the expression $\log_{10}$ in the formula means the base is 10 and differentiates it from the Naperian system of logarithms.)

In computing attenuation networks, it is merely a question of obtaining the ratio of the voltage or the current to determine the gain or loss in decibels. In other words, if $\dfrac{E_1}{E_2}$ is the voltage ratio, then to find the result in decibels we write db $= 20 \log_{10} \dfrac{E_1}{E_2}$.

Simplifying, we say $\log \dfrac{E_1}{E_2} = K$. The ratio K, therefore, in this example is found as follows: $\dfrac{E_1 \ (10)}{E_2 \ (20)} = $ antilog 0.5 or

expressed mathematically $\log^{-1} 0.5$, meaning the number whose logarithm is (in this case) 0.5.

By referring to a common or Briggs logarithm table, we find that 0.5 under the log column will be equal to 3.16 which is found under the N column in the table.

Hence

$$K = 3.16$$

Thus

$$10 \text{ db} = 20 \log_{10} K$$

From this it can readily be seen that the actual working out of the resistance values in the following solution is relatively simple once the value K has been found.

Solution

Formula (1) $X = \dfrac{600}{2}\left(\dfrac{3.16 - 1}{3.16 + 1}\right) = \dfrac{648.00}{4.16} = 156$ ohms

(2) $Y = 1200\left(\dfrac{3.16}{9}\right) = \dfrac{3,792}{9} = 421$ ohms

Hence, a 10-db pad with a 600-ohm impedance will read as follows (values of R to the nearest 5 or 10 are used, Fig. 87g):

Example II.—Calculate a 20-db pad for an impedance of 600 ohms.

By following the same procedure as in the previous example we find

$$K = 10$$

Fig. 87g.—Attenuation network.

Hence

$$20 \text{ db} = 20 \log_{10} K$$

Here we find the ratio K by the same formula $\dfrac{E_1 (20)}{E_2 (20)} = $ antilog 1.0 or expressed mathematically $\log^{-1} 1.0$, meaning the number whose logarithm is (in this case) 1.0.

By again referring to the table, we find that 1.0 under the log column will be equal to 10 which is found under the N column in the table.

Solution (1) $X = \dfrac{600}{2}\left(\dfrac{9}{11}\right) = \dfrac{2,700}{11} = 245$ ohms

(2) $Y = 1,200\left(\dfrac{10}{100 - 1}\right) = 121$ ohms

Hence, a 20-db pad with a 600-ohm impedance will read as follows (see Fig. 87h):

FIG. 87h.—Attenuation network.

In this method of computing pad values, the denominator of the fraction is always 20, when E or I is given or 10 if P is used, while the numerator of this fraction becomes the value of the pad in dbs.

Ques. 394q.   What is the difference between   high-level   and   low-level modulation?

Ans. In high-level modulation systems the amplitude of the radiofrequency oscillations are varied in the last stage of the radiofrequency power-amplifier system by the modulator tubes, while in the case of a low-level modulation system the radiofrequency oscillations in one of the intermediate radiofrequency amplifier stages are varied by the modulator tubes. In this latter system the final power stage is functioning as a linear amplifier.

Ques. 394r.   How are the power input and output ratings of a broadcast transmitter determined?

Ans. The operating power of a broadcast station may be determined by either a direct or an indirect measurement of the plate input power to the last radiofrequency stage.

The indirect method of determining the input power of the last radiofrequency stage may be obtained from the formula

$$\text{Operating power} = E_p \times I_p \times F$$

where E_p is the plate voltage on the final power tube or tubes

I_p = the total plate current of the last radio stage

F = a factor dependent upon the level of modulation used

The factor F as determined by the Federal Radio Commission is as follows:

A. FACTOR TO BE USED FOR STATIONS USING HIGH-LEVEL MODULATION

Maximum rated carrier power of transmitter, watts	Factor (F) to be used in determining the operating power from the plate input power
100	0.50
250 to 1,000	0.60
2,500 to 50,000	0.65

B. Factor to Be Used for Stations of All Powers Using Low-level Modulation

Maximum percentage of modulation	Factor (F) to be used in determining the operating power from the plate input power
75 to 85	0.40
86 to 100	0.33

C. Factor to Be Used for Stations of All Powers Using Grid-bias Modulation in the Last Radio Stage

Maximum percentage of modulation	Factor (F) to be used in determining the operating power from the plate input power
75 to 85	0.27
86 to 100	0.22

The direct method of determining input power is to multiply the square of the antenna current by the resistance, I^2R.

When using this method, great care must be taken to obtain accurate resistance measurements to insure precision results. A detailed explanation for determining the antenna resistance to be used in figuring the power input by this method follows.

Figure 87i illustrates the circuit arrangements of the apparatus used for measuring antenna resistance.

The measurement is based on the formula

$$R = \frac{R_1}{\dfrac{I}{I_1} - 1}$$

Where R is the resistance of the antenna.

R_1 is the added resistance.

I is the current reading without added resistance.

I_1 is the current reading with added resistance.

Fig. 87i.—Resistance-variation method of measuring antenna resistance.

To make the measurement proceed as follows:

1. Antenna circuit should be adjusted for operating conditions. Radiation ammeter may be left in the circuit.

2. Take out all R_1 resistance by closing the short-circuiting switch.

3. Start driver and tune it to resonance with antenna circuit.

4. Record current reading on radiofrequency milliammeter. This becomes the I value in the formula.

5. Do not vary power in driver. Insert a value of R_1, say, 2 ohms.

6. Record current reading on radiofrequency milliameter. This becomes the I_1 value in the formula.

The above procedure may be repeated with four or five different values of R_1 and the value of R averaged. Accurate results are more likely to be obtained in this way.

The power in the driver must be constant throughout the entire measurement or the results will be inaccurate.

If a current squared galvanometer or wattmeter is used in place of the radiofrequency milliammeter, the "square roots" of the readings must be used for current readings.

The resistance of the radiofrequency milliammeter must be subtracted from the value of R computed as described in order to get the true R of the antenna system as it is under operating conditions.

A 50-watt tube operating at a reduced input power should be used to insure the greatest degree of accuracy when using loose coupling between the driver and the pick-up coil.

The above-described method is commonly known as the "resistance-variation system" for measuring the antenna resistance and is generally accepted as a very accurate and simple procedure.

The input power can thus be determined by multiplying the antenna current reading at the maximum current point by the resistance R using the formula I^2R.

The above method does not, however, determine the actual amount of radiated power from an antenna, since this can only be obtained by field strength measurements at various points at a distance from the radiating system.

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 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 at which the modulated variations are impressed upon the carrier wave without producing distortion. In modern broadcasting systems the percentage of modulation is generally between 90 and 100 per cent peak modulation. Transmitters of this type also increase the effective radiated field strength, owing to the complete modulation of the carrier frequency.

The percentage of modulation (M) can be calculated thus:

$$M = \frac{I \text{ modulated} - I \text{ carrier}}{I \text{ carrier}} \times 100.$$

where I modulated and I carrier are peak-current values.

Musical Tone.—A sound having such regularity of vibration as to impress the ear with its individual characteristics, 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 freqencies. 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

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.

HORN, C. W.: "Ten Years of Broadcasting," March, 1931.

HANSON and MORRIS: "Design and Construction of Broadcast Studios," January, 1931.

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.

NOTE.—Part I, Tube Transmitters, and the Addenda also contain questions and answers pertaining to broadcast transmitters.

Commercial and Broadcasting Operating are covered
in Parts I to IX, preceding

Amateur Operating is covered in Parts X to XII,
following

PART X

AMATEUR STATION OPERATION
(CW TELEGRAPH)

INTRODUCTION

The Government Regulations governing the issuance of Amateur Class Radio Operators' Licenses read as follows:

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 75 will constitute a passing mark. This license is valid for the operation of licensed amateur radio stations only.

Students of this book who contemplate taking the examination for an Amateur Class license as described above should study Part X and XI of this book and also Questions 9, 12, 27, 29, 42, 131, 146, 153, 167, 168, 184, 186, 350, 386a, 386b, 386c as they appear in this book.

Any applicant who thoroughly understands the theory and application of radio, as covered in the references above, may feel reasonably certain of passing the written part of the government examination. The only other requirement is the ability to read the code at a speed of at least ten words per minute.

Ques. 395. Draw a diagram of a modern amateur transmitter and receiver. Indicate the name and purpose of each part.

Ans. This question can be answered by learning to araw the diagram in Fig. 88 or one like it. The name and purpose of each part is given on the page facing the diagram.

Ques. 396. Explain the theoretical operation of the transmitter and receiver drawn in answer to the previous question.

269
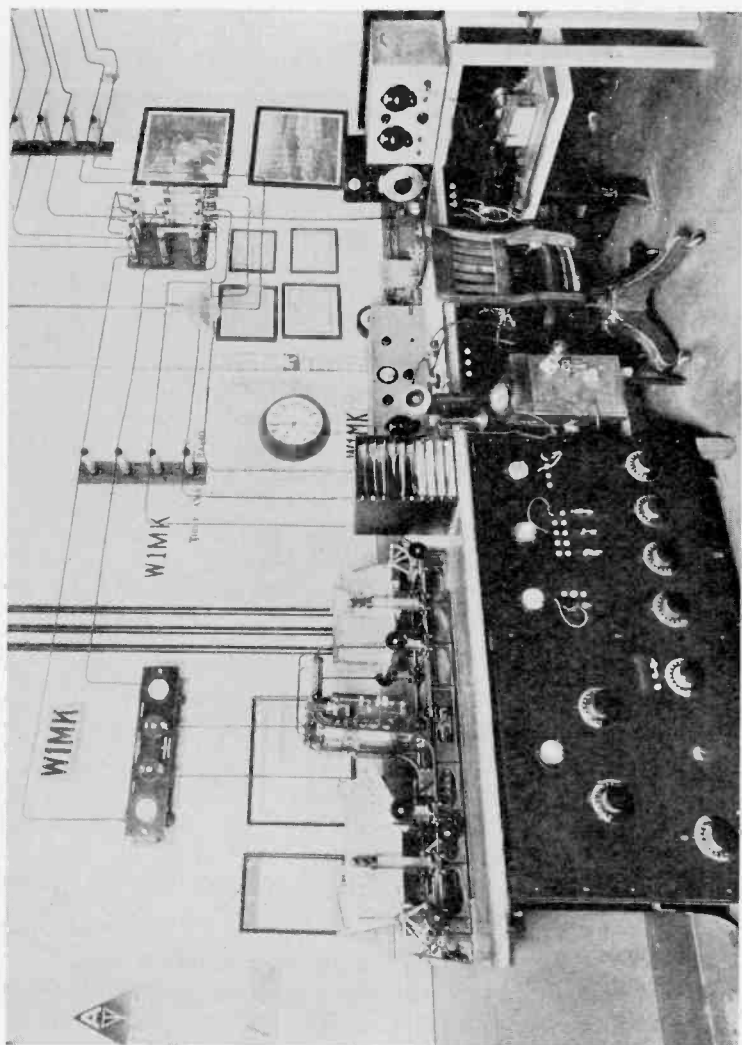
Fig. 87j.—W1MK. The station of the ARRL. at Hartford, Conn.

On the table is a 3,500 to 4,000-kc. transmitter using two Type '04-A tubes in a self-excited tuned-plate tuned-grid circuit. The panel transmitter below is for the 7-mc. and 14-mc. bands and is a controlled-temperature crystal-excited set terminating in a Type '61 tube. Modern amateur receivers and dynatron frequency meter are shown on the table. (Photograph and description, *courtesy*, American Radio Relay League.)
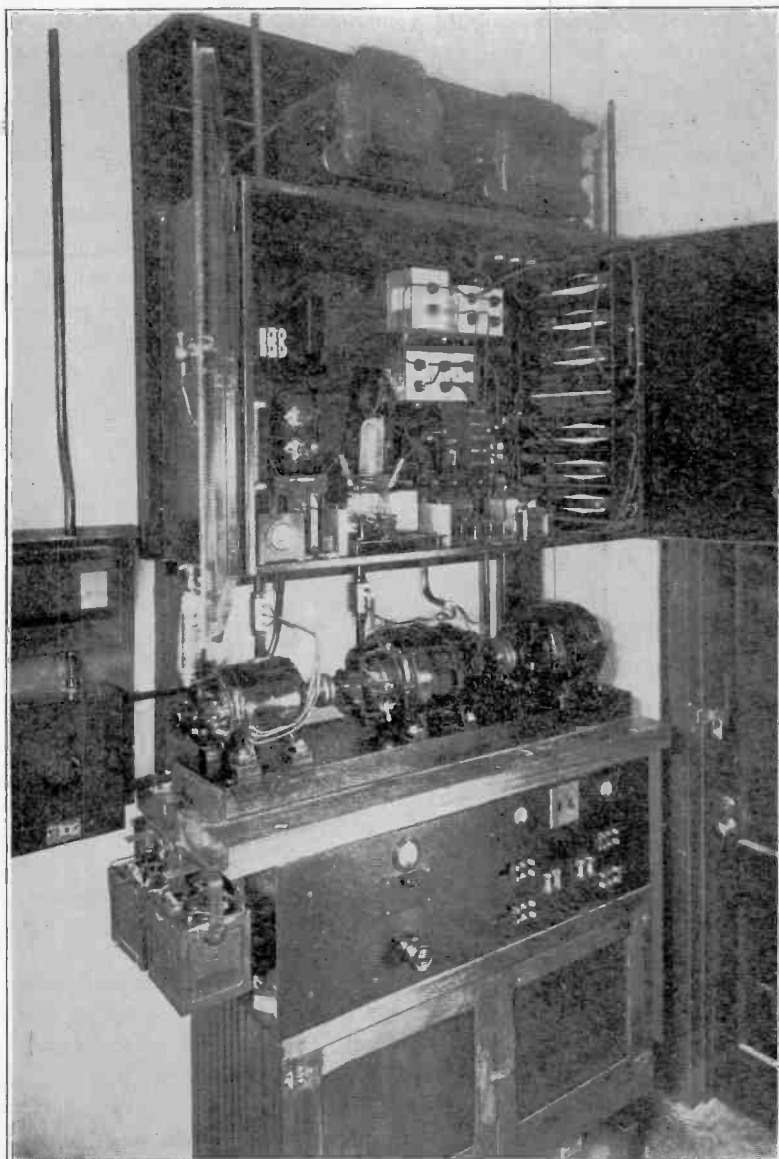
Fig. 87k.—Station W1MK power supply.

The power-supply equipment illustrated above is contained in a separate room and either motor-generator or mercury-arc supply is available by means of switches on the operating table. (*Courtesy*, American Radio Relay League.)

Ans. The filaments of the transmitting tubes are lighted by closing the main-line filament switch S_2. This line is protected against overload by the fuses F_1. The resistance R_7 is now adjusted until the voltmeter V_2 reads the proper value. Assuming that two UX 866 half-wave rectifier tubes are used, the filament voltage on the voltmeter V_2 should read 2.5 volts.

The power-line voltage is stepped down to the proper filament values by the filament transformer FT. Now the value of the filament current-controlling resistance R_2 may be adjusted until the filament voltage to the oscillator tube OT is of the proper value. Assuming a UX 852, 75-watt tube is used, the filament voltage is 10 volts and this value should be indicated on the voltmeter. V_1.
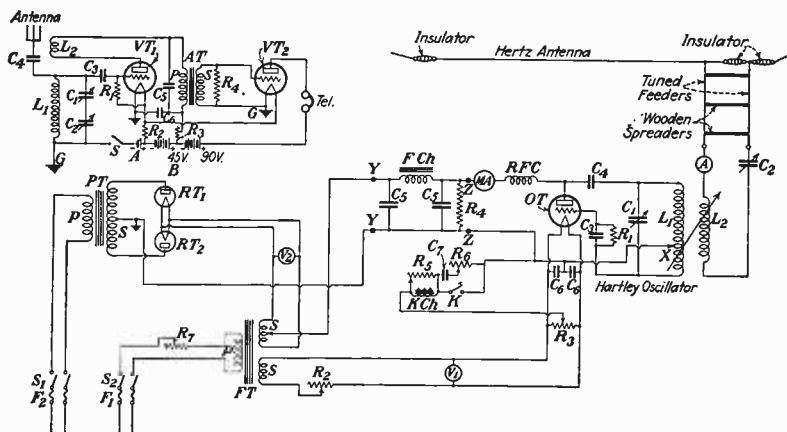
Fig. 88.—Amateur radio (CW) transmitter. See page 273 for key to drawing.

When the rectifier tubes are heated to operating temperature, the main power switch S_1 is closed. This causes a current flow of 110 volts alternating current in the primary P of the power transformer PT. This power line is protected by the fuses F_2.

When an alternating current flows in the primary of the power transformer, a rising and falling magnetic field is set up around the transformer windings and, as this transformer is of the step-up type, a high-voltage alternating current is induced in the secondary S of this transformer.

TRANSMITTER

L_1 Main inductance, closed oscillating circuit.
L_2 Antenna inductance, open oscillating circuit.
C_1 Variable tuning condenser, closed oscillating circuit.
C_2 Variable tuning condenser, antenna circuit.
C_3 Grid blocking condenser to keep filament direct current potential from grid.
C_4 Plate blocking condenser to block plate direct current from L_1.
C_5 Filter condenser to minimize plate voltage fluctuations.
C_6 Radio-frequency by-pass condensers.
C_7 Key click reducing condenser.
R_1 Grid leak to provide bias to grid of oscillator tube.
R_2 Variable filament current resistance for oscillator tube.
R_3 Center tap resistance to provide electrical center for negative plate and grid direct-current return to filament.
R_4 Load resistor on plate supply to prevent filter condensers from assuming a high peak charge.
R_5 Variable resistance to adjust for proper impedance effect in $K\ Ch$.
R_6 Variable resistance which with C_7 reduces key clicks.
R_7 Resistor for regulating filament current in rectifier tubes.
RFC Radio-frequency choke coil.
FCh Filter choke coil, may be 30 henries.
PT Power transformer.
FT Filament transformer.
RT Diodes, half-wave rectifier tubes.
OT Triode, oscillator tube.
MA Plate milliammeter.
A Antenna radiation ammeter.
V_1 Voltmeter for oscillator Tube.
V_2 Voltmeter for rectifier tubes.
YY Input to filter.
ZZ Output from filter.
$K\ Ch$ Choke, lag circuit to prevent oscillation thumps.
S_1 Main-line power switch.
S_2 Main-line filament switch.
F Fuses.
X Filament clip for adjusting feed-back.
K Key.

RECEIVER

L_1 Grid inductance.
L_2 Tickler coil (fixed) for regeneration feed-back.
C_1 Main tuning variable condenser.
C_2 Midget "band spread" variable condenser.
C_3 Grid condenser which with grid leak produces rectification.
C_4 Antenna coupling condenser.
C_5 Radio-frequency by-pass condenser.
C_6 Radio-frequency by-pass condenser.
R_1 Grid leak to prevent tube from blocking and to provide bias.
R_2 Filament current regulating "ballast" resistor.
R_3 Regeneration controlling resistor.
R_4 Resistor for eliminating audio-frequency howling.
$Ant.$ Antenna.
G Ground.
AT Audio-frequency transformer.
VT_1 Detector tube (triode).
VT_2 Amplifier tube (triode).
A Filament battery.
B Plate battery.
$Tel.$ Telephone receivers.
S Filament switch.

Key to Fig. 88.

The terminals of the secondary S of the high-voltage transformer are connected to the plates of the rectifier tubes. This secondary is also center-tapped and this tap becomes the negative side of the plate-voltage line. The rectifier filament transformer is also center-tapped and this becomes the positive side of the plate-voltage line. Owing to the rectifying qualities of the rectifier tubes and to the method of connection employed, the high-voltage alternating current from the secondary S is rectified and delivered to the input terminals of the filter YY as a pulsating direct current.

The method of connecting the rectifying tubes, before described, makes this a full-wave rectifier. The tube RT_1 works on one alternation while RT_2 is idle, and RT_2 works on the following alternation of the cycle while RT_1 is idle. Thus the full wave (one complete cycle) of alternative current is rectified. Full-wave rectification is desirable because of the increased ease with which it is possible to smooth out the plate-voltage supply with the filter.

The pulsating rectified current is passed into the input of the filter at YY and emerges at the output of the filter ZZ as a well-filtered direct-current plate voltage which will produce in the oscillator a pure direct-current note of a steady frequency. Most of the voltage variation due to the pulsating characteristic of the rectified plate voltage is eliminated by the filtering action of the condensers C_5 and power choke FCh (filter choke).

The high-value resistor R_4 provides a constant load across the filter and prevents the condensers C_5 from assuming a peak charge, thus improving voltage regulation in the plate supply line.

The milliammeter MA reads plate-current drain and the radiofrequency choke RFC prevents any radiofrequency currents from flowing back into the filter and power-supply lines.

The oscillator used in this transmitter is of the Hartley type. The oscillating circuit consists of the entire inductance L_1 and the capacity C_1. The grid circuit consists of all of the turns from the grid-connection end of the inductance L_1 to the filament tap X. The plate circuit of the tube consists of all the turns from the plate-connection end of the inductance L_1 to the filament tap X.

On account of the Hartley circuit used, which provides an inductive and magnetic feed-back from the plate to grid circuits, radiofrequency oscillations are generated when the filament- and plate-circuit voltages are applied. These radiofrequency oscillations flow in the tank circuit L_1C_1. The antenna circuit, consisting of the Hertz radiating system with tuned feeders, series condenser C_2, and antenna inductance L_2, is coupled to the oscillating circuit inductively through the inductances L_1 and L_2. The antenna is thus set into oscillation and a radiation field is set up which sends out the signal wave into space.

In order that the oscillations may be broken up into wave trains corresponding to the characters of the code, a telegraph key is inserted in the direct-current plate and grid to filament return lead. When the key is down, the tube oscillates; when the key is up, the tube ceases to oscillate.

In order to minimize key clicks, a condenser C_7 in series with a resistance R_6 is connected across the key. A lag circuit consisting of a choke coil KCh in parallel to a resistance R_5 is in series with the key in order to minimize thumping, owing to the tube's going into oscillation too quickly.

In order to telegraph, it is only necessary to manipulate the operator's key K.

To operate the receiver, close the filament switch S, which will light the filaments of both the detector and amplifier tubes. The plate voltage of the detector is then decreased by increasing the regeneration control resistor R_3 to below the oscillation point. Then gradually bring up the plate voltage until a thud or hiss is heard in the headphones, denoting that the tube is regenerating and in a condition to receive incoming CW signals.

The next step is to tune the receiver to the incoming signal. This is done by varying the condenser C_1 very close to the incoming wave and then making a finer adjustment by varying the condenser C_2. The capacity of C_2 is varied so little in value for each unit of condenser scale that the band is thus spread over a large portion of the scale on C_2. Let us assume that the receiver is tuned almost to 3,500 kilocycles per second.

Suppose now a 3,500 kilocycle per second signal cuts the antenna. A voltage is set up in the grid inductance L_1 which in turn causes an oscillatory current to be set up in the series

circuit L_1, C_1, C_2. A beat voltage is now applied to the grid and filament of the detector tube VT_1.

The next step is to adjust the regeneration control R_3 to the point just above where the tube stops oscillating. The receiver is now in condition to receive signals. For weak signals, simply refine the adjustments already made, being careful to bring the regeneration control down as far as possible without stopping regeneration.

The fixed tickler coil L_2 is in inductive relation to the grid inductance L_1. Therefore, when the signal voltage is detected and amplified by the tube, part of this amplified signal is fed back to the grid circuit of the tube, which further augments the grid voltage and causes a still greater voltage amplification in the plate circuit, a regenerative or self-heterodyning action.

The primary P of the audio transformer AT is in series with the detector plate circuit, and, as the alternating component of the plate voltage flows through it, a high voltage is induced in the secondary S of this transformer. A highly amplified signal voltage is thus impressed on the grid circuit of the first amplifier tube VT_2. This tube in turn amplifies the signal voltage still further and causes this amplified signal voltage to flow in its plate circuit where it is heard in the telephone receivers *Tel.*

Further adjustments of the tuning condensers C_1 and C_2 as well as careful adjustment of the regeneration control resistance R_3 may be made in order to get the signal, so that the note heard in the headphones is pleasing to the operator.

It is to be noted that although 45 volts of "B" battery is available for the detector only about $22\frac{1}{2}$ volts is actually used, the voltage being cut down by the resistance R_3.

In order to increase regeneration the plate voltage is increased by decreasing R_3 and *vice versa*. The detector is most sensitive to CW signals when the plate voltage is just above the point when regeneration ceases. Best reception of phone signals is just below the point where regeneration begins.

The condenser C_4 is the antenna-coupling condenser and is used to make regeneration over the entire dial more uniform and to eliminate "dead spots" where no regeneration takes place. It also shortens the fundamental wave length of the antenna.

The resistance R_4 is a high-value resistance which prevents audiofrequency fringe howling at the point of regeneration.

Ques. 397.   Draw a diagram of a simple filter system suitable for use on a modern amateur transmitter.

Ans.   This is shown in Fig. 88.   Draw the entire filter from the input terminals YY to the output terminals ZZ.

Ques. 398.   What is spark transmission?

Ans.   Spark transmission is accomplished with a spark transmitter which produces trains of damped oscillations by the oscillatory discharge of a condenser through a spark gap.   These damped oscillations are induced into an antenna circuit which acts as a radiating system.

Ques. 399.   Are amateurs permitted to use spark transmission?   Why?

Ans.   Amateurs are not permitted to use spark transmission because the damped oscillations produced by a spark transmitter occupy a wide spectrum of the frequency band used.   This causes widespread interference with all communications over the extended frequency band which the damped oscillations occupy.

Ques. 400.   What is the advantage of a direct-current over an alternating-current plate supply in a transmitter?

Ans.   A direct-current well-filtered plate supply results in an unmodulated pleasing musical note of constant power and frequency.   An alternating-current plate supply does not do this.   An alternating-current plate supply results in a wave modulated to a certain extent at the frequency of the alternating-current plate supply which produces strong side-band frequencies and a broad interfering wave.   This is true in all cases where an alternating-current plate supply is used (except crystal-controlled oscillations).

Ques. 401.   What do the regulations of the Federal Radio Commission require of amateur transmitters in respect to plate supply?

Ans.   Amateur stations must use adequately filtered direct-current power supply or arrangements that produce equivalent

effects to minimize frequency modulation and prevent the emission of broad signals.

Ques. 402. What are the restrictions upon methods of antenna coupling on amateur transmitters?

Ans. Amateur stations must use circuits loosely coupled to the radiating system or devices that will produce equivalent effects to minimize keying impacts and harmonics. Conductive coupling to the radiating antenna, even though loose, is not permitted, but this restriction does not apply against the employment of transmission-line feeder systems to Hertzian antennas.

Ques. 403. Explain how a regenerative receiver may be tuned to a weak CW signal.

Ans. Study the adjustment and operation of the receiver as given in the answer to Ques. 396.

Ques. 404. Draw a diagram of a frequency meter (wavemeter) using a thermogalvanometer.

Ans. See Fig. 89. Note how thermo-galvanometer is drawn.

Ques. 405. Explain briefly vacuum-tube detector action.

Ans. Vacuum-tube detector action is fully explained in the answer to Ques. 131. Briefly the action of the grid-leak and condenser method of detection is as follows:
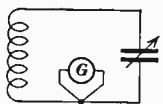
FIG. 89.—Frequency meter with thermo-galvanometer.

(1) Electrons are attracted to the grid from the filament during each positive swing of (signal) excitation voltage. (2) These electrons flow to the filament through the grid leak making the grid negative by the amount of IR drop across the grid leak. This action continues for the duration of a wave train. (3) This negative bias on the grid causes a decrease in the average plate current. This dip in plate current is proportional to the amount of negative bias on the grid. (4) When the excitation (signal wave train) is removed, the bias is removed and consequently the plate current returns to normal. (5) Every dip in the plate current results in a pulse of direct current through the headphones. (6) Therefore, if the incoming-signal wave trains, or detector grid-excitation voltage, is at the rate of 500

cycles per second, then 500 pulses of direct current will flow through the headphones and a 500-cycle note will be audible to the operator.

Ques. 406. Explain how you can determine if your transmitter is tuned within the legal amateur wave bands?

Ans. An amateur transmitter may be checked as to frequency by means of an accurate frequency meter or a calibrated monitor. The calibrated monitor should be a permanent part of the station equipment and every transmission should be checked to make certain the transmitter is properly tuned to an amateur wave.
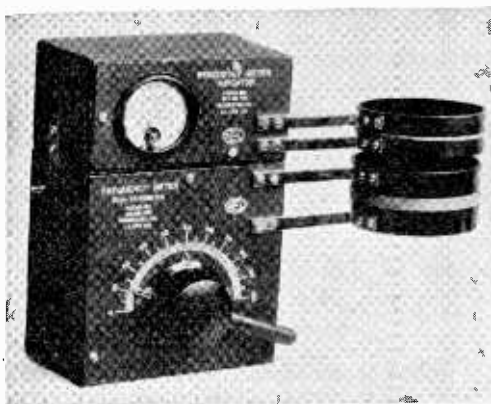
Fɪɢ. 89*a*.—Short-wave frequency meter with frequency meter indicator attached. (*Courtesy*, Radio Engineering Laboratories.)

Ques. 407. How would you determine if your transmitter causes interference to other services?

Ans. Make sure the transmitter is tuned to within the legal wave bands for amateurs. Listen on near-by broadcast receivers to see if forced oscillations, side-band frequencies, mush, or key clicks cause interference to broadcast reception. If interference is caused, either it must be eliminated or, if interference is only with broadcast reception and cannot be eliminated, quiet hours must be observed.

Ques. 408. What is the effect of excessive filament voltage; of a below-normal filament voltage?

Ans. The tube may burn out or its life greatly shortened if the filament voltage is too high.

If the filament voltage is too low, the tube will not function properly and, if the tube has a thoriated or oxide filament, the tube will soon become insensitive and finally inoperative. (See also Ques. 42 and 146).

Ques. 409.   How may a detector tube which oscillates too freely be controlled?

Ans.   If the detector tube oscillates too freely, the operator may decrease the coupling effect between the grid inductance and tickler coil. The necessary adjustment depends upon the type of regeneration control employed as shown in the tabulation below.

Type of Control	Necessary Action to Reduce Oscillation
Movable tickler	Turn tickler toward a right angle position with respect to grid inductance or separate tickler and grid inductance to a greater degree
Throttle condenser	Decrease capacity of condenser
Resistance in plate circuit	Increase resistance thereby decreasing plate current
Carbon-pile rheostat in filament circuit	Increase resistance, thereby decreasing filament current

Ques. 410.   What types of emission are permitted to amateur stations?

Ans.   All bands of frequencies allocated to amateur stations may be used as assigned for radiotelegraphy, type A-1 and also for type A-2 to the extent that they comply with the regulations pertaining to power supply, and for radiotelephony, type A-3. (See Ques. 22 and Fig. 7.)

Brief Bibliography

"The Radio Amateur's Handbook," published by The American Radio Relay League, Inc., West Hartford, Conn.

QST, published monthly by The American Radio Relay League, Inc., West Hartford, Conn.

PART XI

AMATEUR RADIO LAWS AND REGULATIONS

Ques. 411. What is an amateur?

Ans. The term "amateur" when used without further descriptive words means a person interested in radio technique solely with a personal aim and without pecuniary interest.

Ques. 412. Why are amateur stations subject to Federal regulation?

Ans. Because amateur stations radiate signals which extend beyond the borders of the state, and in some instances beyond the boundaries of the country, in which they are located. Therefore, supervision of these stations becomes a national matter which in the United States calls for Federal supervision.

Ques. 413. What is the regulation governing the location of amateur stations?

Ans. An amateur radio station shall not be located upon premises controlled by an alien.

Ques. 414. Define "mobile" and "portable" stations.

Ans. The term "mobile station" means a station that is capable of being moved and ordinarily does move.

The term "portable station" means a station so constructed that it may conveniently be moved about from place to place for communication and that is in fact so moved about from time to time, but not ordinarily used while in motion.

Ques. 415. May amateur-station licenses for mobile and portable stations be secured?

Ans. Licenses for amateur mobile stations will not be granted. Licenses for amateur portable stations will be granted. The licenses of a portable amateur station shall give to the supervisor of radio in the district where application was filed for said portable

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license advance notice of all locations in which the station will be operated.

Ques. 416. What is the regulation concerning amateur-station logs?

Ans. Each licensee of an amateur station shall keep an accurate log of station operation, in which shall be recorded:

a. The date and time of each transmission.

b. The name of the person manipulating the transmitting key of a radiotelegraph transmitter or the name of the person operating a transmitter of any other type with statement as to nature of transmission.

c. The station called.

d. The input power to the oscillator, or to the final amplifier stage where an oscillator-amplifier transmitter is employed.

e. The frequency band used.

This information shall be made available upon request by authorized Government representatives.

Ques. 417. Are amateurs subject to state or municipal regulations?

Ans. Amateur stations are not subject to state or municipal regulations from a communication standpoint. States and municipalities can make and enforce regulations affecting amateur stations in safeguarding health, enforcing electrical wiring codes, and abating nuisances.

Ques. 418. What are "quiet hours"? Under what conditions are they imposed?

Ans. In the event that the operation of an amateur radio station causes general interference to the reception of broadcast programs with receivers of modern design, that amateur station shall not operate during the hours from 8 P.M. to 10.30 P.M., local time, and on Sundays from 10.30 A.M. until 1 P.M., local time, upon such frequency or frequencies as cause such interference.

Ques. 419. What is the Washington Convention?

Ans. The Washington Convention is the general name given to the set of laws and regulations governing radio communication drawn up by delegates representing the principal nations

of the world who assembled for this purpose in Washington in 1927.

Ques. 420. Is the Washington Convention binding upon the United States?

Ans. Yes, the United States is one of the contracting governments and has agreed to apply the provisions of the Convention with the exception of the Supplementary Regulations.

Ques. 421. What is the Federal Radio Commission?

Ans. The Federal Radio Commission is a body of five members appointed by the President. This Commission was created by the Radio Act of 1927. Among its duties are the following: (a) classify radio stations; (b) prescribe the nature of the service to be rendered by each class of licensed stations; (c) assign bands of frequencies or wavelengths to the various classes of stations, and individual stations, and determine the power which each station shall use and the time during which it may operate; (d) determine the location of classes of stations or individual stations; (e) regulate the kind of apparatus to be used with respect to its external effects and the purity and sharpness of the emissions from each station and from the apparatus therein; (f) make such regulations not inconsistent with law as it may deem necessary to prevent interference between stations and in general to carry out the provisions of the Radio Act of 1927 and the Washington Convention.

Ques. 422. What are the rules and regulations regarding the secrecy of radiograms?

Ans. In general the law provides that it is unlawful for anyone intercepting or learning of the contents of a radiogram to divulge its contents or meaning to anyone except the addressee or his agent, or to another radio station for forwarding, or to a court of competent jurisdiction.

Ques. 423. As an amateur operator, what would you do if you heard an SOS call from a ship under various circumstances?

Ans. Immediately cease all transmission and copy all signals from the ship in distress. If no government or commercial station answers the distress call, the amateur operator should

do all in his power to notify a government or commercial station that a distress call has been sent, giving them complete particulars as received. It may be necessary to do this by telegraph or telephone. Perform any further communication service possible that is requested by the government or commercial-station operator. Continue to listen in and copy all distress signals until it is certain that a government or commercial station has received the call and effected communication. Do not use transmitter until distress traffic is finished or until regular broadcasting is resumed. These regulations may be modified in certain special instances.

Ques. 424. What are the International regulations relative to the maintenance of constant frequency and purity of signals?

Ans. The frequency of the waves emitted by amateur radio stations shall be constant and as free from harmonics as the state of the art permits. For this purpose, amateur transmitters shall employ circuits loosely coupled to the radiating system, or devices that will produce equivalent effects to minimize keying impacts and harmonics. Conductive coupling to the radiating antenna, even though loose, is not permitted, but this restriction does not prohibit the use of transmission-line feeder systems.

Licensees of amateur stations shall use adequately filtered direct-current power supply for the transmitting equipment or arrangements that produce equivalent effects to minimize frequency modulation and prevent the emission of broad signals. For example, the use of unrectified alternating-current power supply for the amplifier stages of oscillator-amplifier transmitters, so arranged that variations in plate voltage of this supply cannot affect the frequency of the oscillator, will be considered satisfactory.

Ques. 425. What are the International regulations relative to the exchange of communications between amateur stations of different countries?

Ans. The exchange of communications between private 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. 426. What penalties may be imposed for violation of radio laws and regulations?

Ans. For violation of any *rule, regulation, restriction,* or *condition made or imposed by the licensing authority* under the Radio Act of 1927 or any International Radio Convention or treaty ratified or adhered to by the United States, in addition to any other penalty provided by law, shall be punishable by a fine of not more than $500 for each and every offense.

For violation of any *provision* of the Radio Act of 1927 the penalty may be a fine not to exceed $5,000 or imprisonment for a term of not more than five years, or both, for each and every such offense.

Also an operator's license may be suspended for a period not to exceed two years as explained in the answer to Ques. 347e in this book.

Ques. 427. What class of radiograms hold precedence over all others?

Ans. Distress calls, distress messages, and distress traffic. In principle any radiogram having to do with the safety of human life holds precedence over all other signals.

Ques. 428. What is the law regarding the transmission of fraudulent communications?

Ans. See Ques. 297.

Ques. 429. Give the meaning of the following signals: SOS, CQ, QRT.

Ans. SOS is the International distress call; CQ is the general call to all stations. CQ in place of the call signal of the station called in the calling formula, this formula being followed by the letter K, is used as a general call to all stations with a request for reply; QRT means stop sending.

Ques. 430.　What is the law regarding the amount of power to be used to communicate over a given distance?

Ans.　See Ques. 295.

Ques. 431.　What is the distress signal for radio telephone?

Ans.　"May day." This is the English phonetic word for the French *m'aidez* meaning "help me."

Ques. 432.　What signal denotes the end of a message?

Ans.　The end of a message is indicated by ·–·– (end of transmission) followed by the call signal of the sending station and the letter K.

Ques. 433.　What signal denotes the conclusion of correspondence between two stations?

Ans.　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. 434.　What persons may operate an amateur station?

Ans.　The person manipulating the transmitting key of a manually operated radiotelegraph amateur transmitting station shall be a regularly licensed amateur operator. The licensees of other stations operated under the constant supervision of duly licensed operators may permit any person or persons, whether licensed or not, to transmit by voice or otherwise, in accordance with the types of emission specified by the respective licenses.

Ques. 435.　What are the restrictions placed upon amateur stations regarding the transmission of news, music, lectures, or any form of entertainment?

Ans.　Amateur stations shall not be used for broadcasting any form of entertainment nor for the transmission of news or lectures.

Amateur stations may be used for the transmission of music for test purposes of short duration in connection with the development of experimental radiotelephone equipment.

Ques. 436.　What are the regulations concerning communication between amateur stations and government or commercial stations?

Ans. Amateur stations shall be used only for amateur service except that in emergencies or for testing purposes they may be used also for communication with commercial government radio stations and for communication with mobile stations and stations of expeditions which do not have general public-service licenses and which may have difficulty in communicating with commercial or government stations.

Ques. 437. What frequencies are assigned to amateurs?

Ans. The following bands of frequencies in kilocycles per second are allocated for use by amateur stations:

1,715 to 2,000	28,000 to 30,000
3,500 to 4,000	56,000 to 60,000
7,000 to 7,300	400,000 to 401,000
14,000 to 14,400	

Ques. 438. What frequencies may the amateur station use for radiotelephony?

Ans. Effective April 1, 1932, an amateur may use a radio-telephone transmitter on the following frequencies: 1;875 to 2,000 kilocycles per second and 56,000 to 60,000 kilocycles per second.

In addition to the above frequencies which may be used by any amateur, operation on the bands 3,900 to 4,000 kilocycles per second and 14,150 to 14,250 kilocycles per second is allowed to amateur stations operated by a person who holds an operator's license of a grade approved · by the licensing authority for unlimited amateur radiotelephone operation.

Ques. 439. What frequencies may the amateur station use for television, facsimile, and picture transmission?

Ans. 1,715 to 2,000 kilocycles per second and 56,000 to 60,000 kilocycles per second.

Ques. 440. What frequency bands are assigned exclusively to amateur stations?

Ans. 7,000 to 7,300 kilocycles per second and 14,000 to 14,400 kilocycles per second.

Ques. 441. What amateur bands are shared, and by whom?

Ans. In the United States all of the amateur frequencies are assigned exclusively to amateurs with the exception of a

limited use of the 3,500 to 4,000 kilocycles per second band by off-shore naval aircraft.

According to the International Wavelength allocations certain amateur frequency bands are shared as indicated below:

1,715 to 2,000 kilocycles per second........ $\begin{cases} \text{Mobile services} \\ \text{Fixed services} \\ \text{Amateurs} \end{cases}$

3,500 to 4,000 kilocycles per second........ $\begin{cases} \text{Mobile services} \\ \text{Fixed services} \\ \text{Amateurs} \end{cases}$

Ques. 442. What is the maximum power allowed to amateur stations?

Ans. Licensees of amateur stations are authorized to use a maximum power input of 1 kilowatt to the plate circuit of the final amplifier stage of an oscillator-amplifier transmitter or to the plate circuit of an oscillator transmitter.

Ques. 443. How often must the call letters of an amateur station be transmitted during each transmission?

Ans. An operator of an amateur station shall transmit its assigned call at least once during each 15 minutes of operation and at the end of each transmission.

Ques. 444. What vessels are required by law to carry radio equipment?

Ans. See Ques. 347*f*.

Ques. 445. What is the distress-call frequency?

Ans. 500 kilocycles per second (600 meters).[1] See Ques. 311.

Ques. 446. What is the priority of various classes of radio communication?

Ans. See Ques. 330.

·Ques. 447. What is meant by "superfluous signals"?

Ans. Superfluous signals are signals unnecessary to the carrying out of communication or of normal testing. The latter is permitted by law under certain conditions but superfluous signals are forbidden.

[1] 410 kilocycles on the Great Lakes.

PART XII

AMATEUR RADIOPHONE OPERATION

INTRODUCTION

Students of this book preparing to take the government examination for an unlimited amateur radiotelephone operator's license should study the entire Part I of this book with the exception of those questions which obviously do not apply to amateur-station operation. In addition study the section on Broadcast Transmitters, Part IX of this book.

The applicant should have a fairly complete knowledge of modern practice as it affects the following: (a) microphones; (b) speech amplifiers; (c) modulation; (d) characteristics and uses of class A, B, and C amplifiers; (e) causes and prevention of interference (not by wave traps on receivers); (f) prevention of frequency fluttering; (g) diagram and description of a crystal oscillator; (h) method of keeping transmitter on assigned band.

The applicant should study and be able to draw a complete amateur 'phone transmitter, as explained in this section, or its equivalent. Particular attention should be paid to the circuits of the crystal oscillator with automatic temperature control.

No additional code test is required for this license.

The information given in this section is not required of the ordinary amateur operator but covers some of the more difficult theory which the operator of an amateur station licensed for unlimited 'phone operation should be acquainted with.

Ques. 448. Draw a diagram of high-quality amateur telephone transmitter using 100 per cent modulation and a crystal oscillator for frequency stabilization. Explain its operation.

Ans. Figure 90 illustrates a complete diagram of an amateur low-powered 'phone transmitter using class B modulation and crystal-controlled class C radiofrequency amplification.
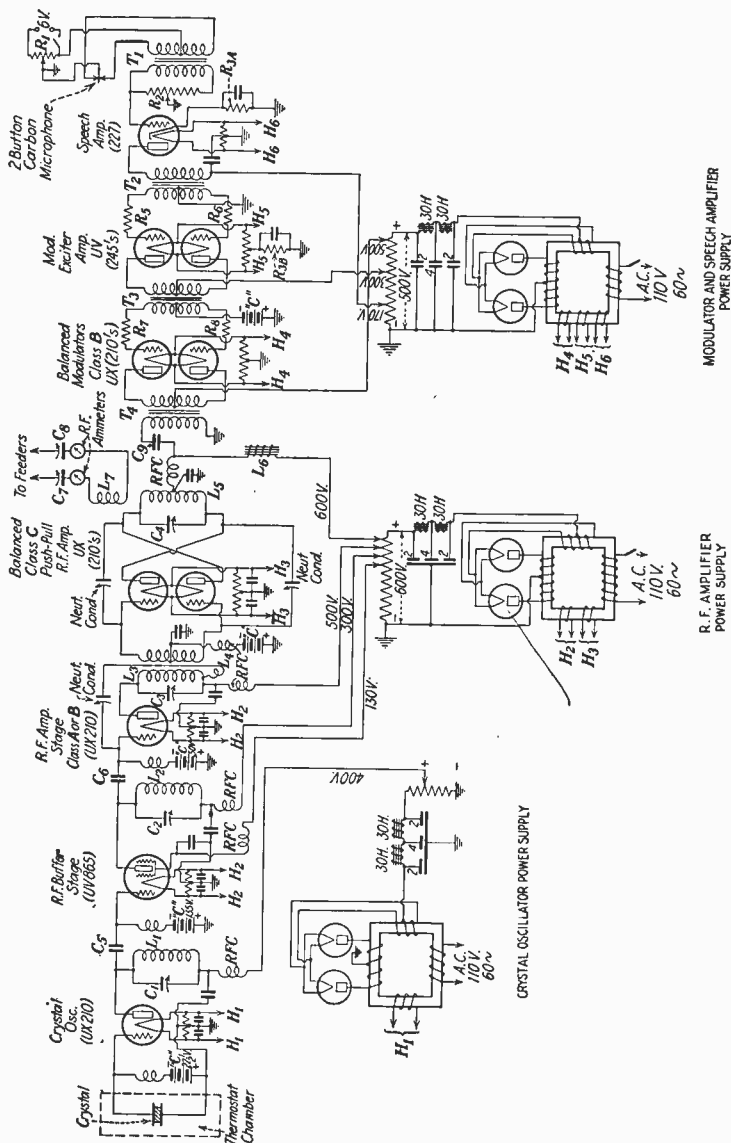
Fig. 90.—Amateur radiophone transmitter.

Name and Purpose of Parts

Crystal = Piezo electric plate for frequency stability.

C_1 — Plate tuning condenser for crystal oscillator circuit.

L_1 — Plate tuning inductance for crystal oscillator. $C_1 L_1$ forms the plate radio-frequency mesh circuit for adjusting the crystal oscillator to the point of oscillation.

C_2 — Buffer stage plate tuning condenser.

L_2 — Buffer stage plate tuning inductance.

C_3 — Second radio-frequency amplifier stage tuning condenser.

L_3 — Second radio-frequency amplifier stage tuning inductance.

L_4 — Neutralizing inductance. In conjunction with a series condenser forms the tube capacity neutralizing circuit of the second radio-frequency amplifier tube.

C_4 — Tuning condenser of the push-pull radio-frequency amplifier plate circuit.

L_5 — Plate tuning inductance of the push-pull radio-frequency amplifier plate circuit.

$C_4 L_5$ — Forms the final power radio-frequency amplifier mesh circuit for exciting the radiating system L_7.

L_7 — Radiating circuit coupling inductance.

L_6 — Modulator output coupling reactor or modulation choke.

$C_5 C_6$ — Interstage radio-frequency feed or coupling condensers.

$C_7 C_8$ — Radiation circuit tuning condensers.

C_9 — Audio-frequency coupling condenser, 2mfd.

R_1 — Microphone circuit potentiometer, 200 ohms.

R_2 — Gain control potentiometer, 500,000 ohms.

R_{3A} — Speech amplifier biasing resistor.

R_{3B} — Modulator exciter amplifier biasing resistor.

R_5, R_6, R_7, R_8 — Parasitic suppressor resistances, 100 ohms.

T_1 — Microphone transformer.

T_2 — Push-pull input transformer to exciter amplifier.

T_3 — Specially designed modulator input transformer.

T_4 — Specially designed modulator output transformer.

RFC — Radio-frequency choke coils.

All other condensers are radio-frequency by-passing units with the exception of the filter condensers in the power-supply system. See Ques. 396 for the theoretical operation of the power-supply systems.

The crystal oscillator is operated as a power crystal using a 210 tube receiving its plate supply from a separate B supply to insure a minimum of frequency deviation and frequency fluttering during modulation. A UV 865 screen-grid buffer stage follows the crystal oscillator to further insure a minimum of frequency fluttering during the process of modulation.

The combination of a crystal-controlled oscillator and at least one "buffer" stage is highly essential if fine-quality speech transmission is to be obtained.

The tube operating as buffer amplifier must be biased to operate without any grid current, thus preventing any possibility of grid-current modulation due to load reactions. In this way the oscillator will be practically isolated from any load variations due to the modulation process in the radio-frequency stages during speech transmission.

The radiofrequency variations are then fed into the third tube which operates as either a class A or B radiofrequency amplifier. From here the radiofrequency variations are fed into a class C pushpull amplifier and then into the radiation system.

The class C amplifier is modulated by a class B modulator system through the medium of two balanced modulator tubes operating into a specially designed modulation transformer.

A "modulation choke" in the plate-supply lead of the class C amplifier tubes is also provided to properly vary the amplitude of the radiofrequency oscillations during modulation.

The class B modulator tubes receive their speech impulses from a two-button carbon microphone feeding into a microphone transformer and a single-stage speech-amplifier tube of the −27 variety. The plate output of this tube is then fed into an ordinary input pushpull transformer which feeds two UV 245 exciter tubes in pushpull arrangement.

The output of these tubes then functions into another specially designed modulator input transformer in which the speech-signal variations are properly fed to the two grids of two 210 modulator tubes in pushpull.

Three separate B power-supply units are provided to operate the various units at maximum efficiency, particularly the crystal oscillator to maintain a maximum degree of frequency stability.

Load variations during modulation may seriously affect the stability of crystal oscillators when single power-supply units are used for the entire installation.

Radiofrequency chokes and radiofrequency bypass condensers are freely provided to keep the high frequencies out of the connecting leads and the power-supply units.

C batteries are used throughout the entire installation to reduce the possibility of grid modulation due to voltage changes in the power supply. B-power supplies connected to the A.C. power lines should not be used for bias regulation unless they are correctly designed electrically and mechanically by reliable engineering manufacturers.
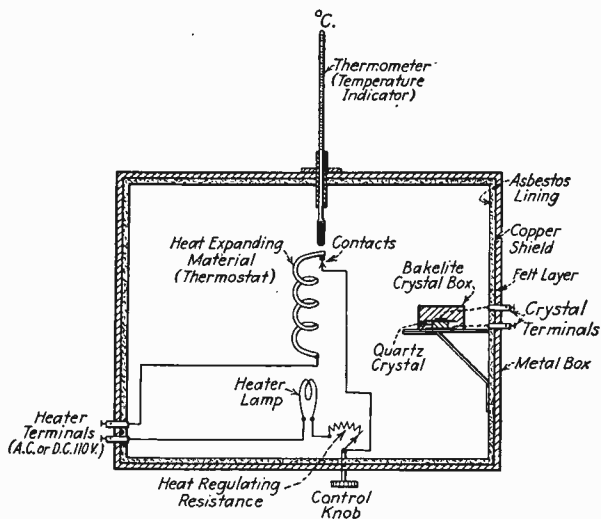
FIG. 91.—Automatic constant-temperature control-box for piezo-electric crystal suitable for an amateur station.   (Control knob may be located on side of box.)

The double-choke system of filtering is used throughout to obtain a continuously smooth output voltage. A single choke may be used with equally satisfactory results, provided the final filter condenser capacity is increased to approximate 10 or more microfarads.

The operating voltages for the 210 class B modulator and the class C amplifier tubes must be carefully adjusted to obtain

maximum efficiency. The approximate plate and grid voltages are as follows:

$$210 \text{ modulators, } E_B = 500 \text{ volts}$$
$$E_C = -57 \text{ volts}$$
$$210 \text{ class C amplifiers, } E_B = 300 \text{ to } 500 \text{ volts}$$
$$E_C = -90 \text{ to } -130 \text{ volts}$$

Ques. 449. Draw a diagram of an automatic temperature-control box for an amateur 'phone transmitter. Explain its operation.

Ans. Figure 91 illustrates a simple automatic temperature-control circuit which may be used to maintain the proper degree of crystal temperature in an amateur crystal-controlled 'phone or CW transmitter.

The entire unit should be enclosed in a double- or triple-layered box of alternate layers of asbestos, copper, and felt to insure a constant degree of temperature in the inner chamber.

The theoretical operation is as follows. When the heater terminals are connected to an a-c or d-c supply, the lamp generates a certain amount of heat determined by the value of the regulating resistance and the efficiency of the chamber. A spiral of antimony, or other material with a temperature coefficient is, located in the chamber and will expand and contract with the heat, which causes the contacts to be opened and closed with the change in temperature. Thus by the proper adjustment of the regulating resistance a fixed temperature may be obtained to keep the crystal at its proper operating frequency.

Ques. 450. Name the associated apparatus necessary to operate and maintain a transmitter on its assigned frequency.

Ans. A piezo-electric oscillator housed in an automatic temperature-controlled chamber, thermometer temperature indicator, precision frequency meter, and a monitor using a crystal-controlled or dynatron oscillator.

Ques. 451. Explain the theory of the dynatron oscillator.

Ans. Figure 92 illustrates the wiring diagram of a dynatron oscillator.

The dynatron oscillator presents a characteristic called negative resistance which is so well-known in the theory of regeneration

and which may also be used for other purposes requiring similar characteristics.

The theoretical operation of the dynatron oscillator may be described briefly as follows:

When the filament is lighted to incandescence and a plate potential is applied between the plate and the filament, an electron flow from the filament to the plate will result in accordance with the elementary theory of vacuum-tube operation.
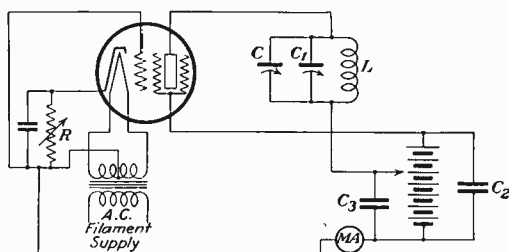
Fig. 92.—Schematic diagram of pliodynatron oscillator.

If the grid potential is operated at a higher potential than the plate, the electrons arriving at the grid will cause an electron flow in the grid circuit of fairly large amplitude, which is, of course, true in ordinary cases when large signal potentials are applied to the grid. The important function, however, remains in the electrons that have passed through the grid laterals towards the plate. These electrons on arriving at the plate cause a breakdown of the surface tension, due to the collision impact, which results in an emission of electrons from the plate surface. This phenomenon is known as *secondary emission*. Now since the grid is at a higher potential than the plate, the electrons due to secondary emission will be attracted to the grid. This presents a condition in which both the electrons from the filament and from the plate (the latter due to secondary emission) will be attracted to the grid. Now let us assume the plate voltage to be gradually increased. In ordinary tube circuits an increase in plate voltage would result in an increase in the plate current but in this case the gradual increase in plate voltage reduces the plate to filament current flow because of the neutralizing effect at some critical point between the normal electron emission from the filament circuit and the secondary electron emission from the

plate. When this particular point is reached, the plate to filament circuit resistance would indicate a negative resistance characteristic if an alternating-current potential is applied to the circuit. It is this peculiarity which is the basis of the action of a dynatron oscillator.

The dynatron oscillator illustrated in Fig. 92 uses a screen-grid tube and functions in accordance with the elementary theory of a three-electrode vacuum-tube oscillator, with the exception that the fourth electrode introduces the additional effect of secondary emission.

The important consideration in the practical operation of the dynatron oscillator is that the ratio of L/CR is at all times greater than the negative resistance of the tube. If at any time the negative resistance of the tube is greater than the impedance of the parallel resonant circuit L, C, the tube will cease to oscillate. All leads should be made as short as possible, particularly when the dynatron is used at very high radio-frequencies, to keep the ratio L/CR as low as possible.

It is a simple matter to determine if the tube is oscillating by touching the tube plate or stator plates of the condenser until a deflection is obtained at the milliammeter in the plate circuit.

The high degree of frequency stability is one of the outstanding features of the dynatron oscillator when using low power excitation. It is highly desirable for use as a heterodyne frequency meter and is capable of a frequency stability to within one-tenth of 1 per cent.

NOTE.—When a fourth element is used, such as in screen-grid tubes, the tube is called a *pliodynatron*.

Ques. 452. What is the meaning of shock excitation?

Ans. Shock or impulse excitation is a term generally applied to oscillatory circuits which have been set into oscillation by a highly damped impulse or an aperiodic surge or pulse.

This term has been originally used in conjunction with spark transmitters where the primary circuit is of a highly damped character, such as in the case of quenched or impact excitation transmitters.

It is, nevertheless, appropriate that the term shock excitation may be applied to modern circuits in which there is any possibility of the voltage's rising suddenly to a certain value and then

Aeronautical and Police Radio, Beacons, Airways,
Meteorology, and Teletype are covered in Part
XIII which follows

holding the value for a brief period of time and again rapidly falling to zero.

Hence, any aperiodic pulse in the vicinity of an oscillator may be capable of setting the circuit into oscillation not in accordance with the general law of resonance but merely by a sequence of shocks or impulses.

Static electricity, buzzer excitation, and key arcing (key clicks) in tube transmitter circuits are good examples of shock excitation.

It can readily be seen that shock excitation produces objectionable characteristics and should be eleminated wherever possible. See also Ques. 121.

Ques. 453.   What is the meaning of modulation?

Ans.   See definitions relating to broadcasting, page 265.

Ques. 454.   What is the advantage of a 100 per cent modulation system?

Ans.   When a carrier wave is fully modulated to 100 per cent, the instantaneous peak power is four times the carrier power. This is because the antenna resistance is constant for a fixed frequency and the power is therefore proportional to the square of the current.   Thus, systems employing 100 per cent modulation reduce the possibility of heterodyne interference at remote points by a relative decrease in the ratio of carrier frequency power to modulated power.

Ques. 455.   What is the disadvantage of overmodulation?

Ans.   Overmodulation causes frequency distortion and high-damping characteristics.

The frequency distortion is due to a change in the average amplitude as compared with the unmodulated amplitudes thereby resulting in a periodic deviation of the carrier frequency during modulation.

The high-damping characteristics are due to the cut-off periods which result in broad tuning.

Ques. 456.   How can the radiofrequency ammeter be used to determine 100 per cent carrier modulation?

Ans.   A 22.5 per cent radiation increase (radiofrequency ammeter) indicates 100 per cent modulation if load impedances are proper and the feed signal a pure sine tone.

PART XIII

AERONAUTICAL AND POLICE RADIO, BEACONS, AIRWAYS, METEOROLOGY, AND TELETYPE

This chapter covers the various applications of radio (particularly radiotelephony) to airplanes, aeronautical ground stations, and police radio systems. In addition, allied information on radio laws, beacons, airway regulations, meteorology, and teletype operation is included.

RADIO TRANSMISSION AND RECEPTION

Ques. 457. Draw a neat schematic diagram of a complete modern low-power radiotelephone station, including input system, source of power, antenna, and receiving system. Usual symbols may be used to designate the various parts.

Ans. See diagrams Fig. 93.

Ques. 458. (*a*) Draw a neat diagram of a complete modern short-wave receiver suitable for use at an aeronautical ground station. (*b*) If this receiver suddenly became inoperative, describe in detail how you would go about finding the trouble. Start with the antenna, and come down through the receiver and power-pack.

Ans. (*a*) See diagram Fig. 93. (*b*) The sequence mentioned in the question would be logical only in case the detector could still be heard to come into oscillation but signals were much weaker than usual. In this case the antenna and ground connections should be checked at the binding-post strips. Then the antenna, lead-in, and connections should be investigated for an open circuit, or contact with other wires, or poor insulators. Note if the antenna changeover relay contacts are clean and are not sticking in a neutral or transmitting position. Then the antenna coil (slot winding) should be observed for an open circuit in the winding or at the coil prongs. Vary the trimmer

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condenser from maximum to minimum with the detector in oscillation. If there is no place where the background noises are much louder, or if, with the detector barely in oscillation, there is no change when the trimmer condenser is varied from maximum to minimum and back, check the trimmer coil and condenser for an open or a short circuit. If the trouble has not been located so far, try changing radiofrequency amplifier tubes.

If all sound has ceased in the headphones, the first thing to check is the phone plug. If the dial light went out at the same time that the receiver became inoperative, observe the tube filaments. It takes between 5 and 10 seconds for the heaters to cool below a red glow when the alternating-current supply is taken from them. If this has happened, trace the 100- to 110-volt alternating-current supply from the plug through the switch and the primary of the power transformer. If the rectifier tube remained lighted when the other tubes went out, the 2.5-volt secondary circuit should be traced through the power plug to the tube filaments, looking for an open or a short circuit.

If the set went completely dead but the tubes remained lighted, a test set should be used with its plug in the detector socket. The plate voltage of this stage should be about 130 volts, and the screen-grid voltage should go from 0 to about 30 volts positive when the volume control is varied from minimum to maximum. If no voltage is shown at all, check the rectifier tube, and look for an open filter choke or short-circuited filter condenser. A weak rectifier tube may be discovered by taking it out of the socket and holding it upside down. If an excess of the white oxide collects in the bottom of the bulb, the tube is weak in emission and should be replaced. The sudden weakening of the tube may have been due to a short-circuited filter condenser's taking an excessive load from the tube.

The above remedies having failed, the various circuits of the receiver should be tested with a continuity meter and battery to find the open or short circuit.

Ques. 459. What steps are necessary in changing the frequency of the transmitter drawn?

Ans. This means changing the output frequency from "day" (5,300 to 5,700 kilocycles) to "night" (3,100 to 3,500 kilocycles)

WESTERN ELECTRIC 9-B TRANSMITTER

RECEIVER

National SW-5 Thrill Box

Power Pack
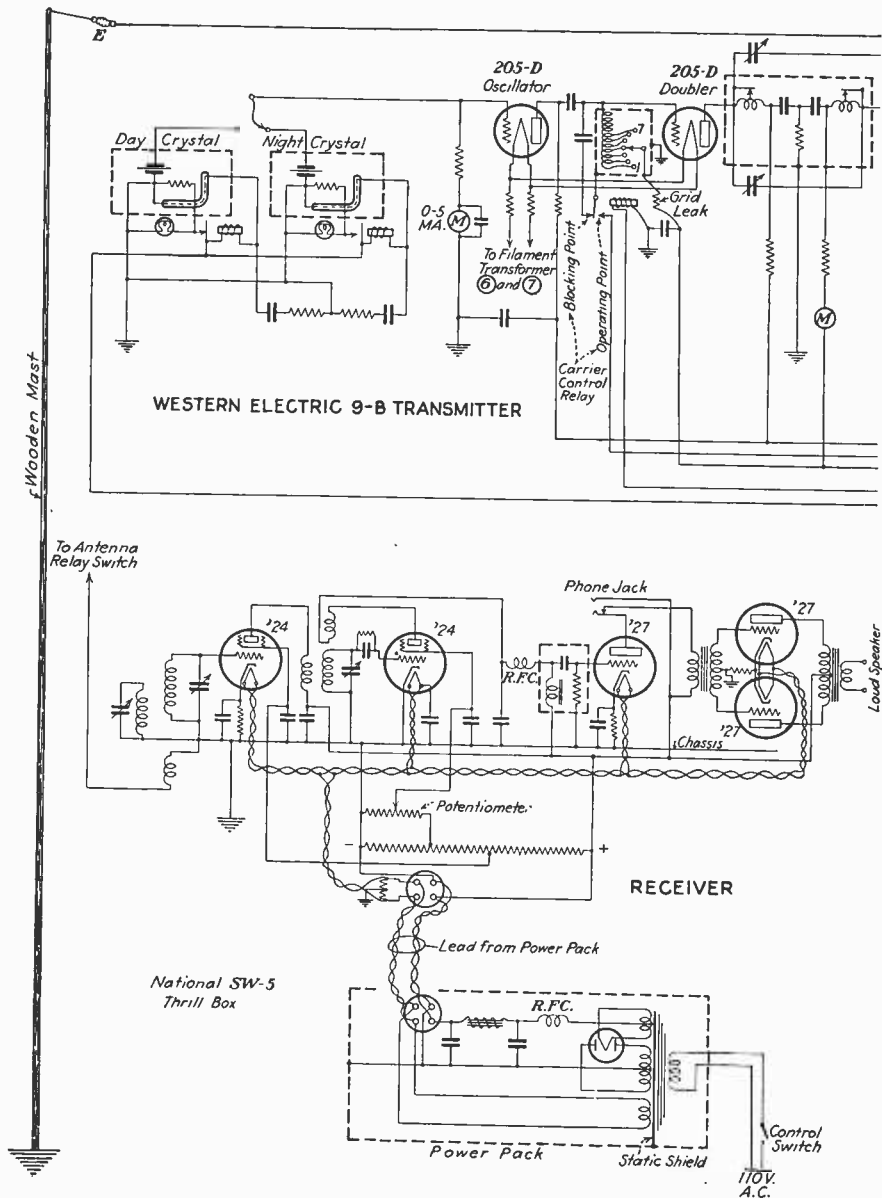
Fig. 93.—Complete low-power

WESTERN ELECTRIC 2-B RECTIFIER
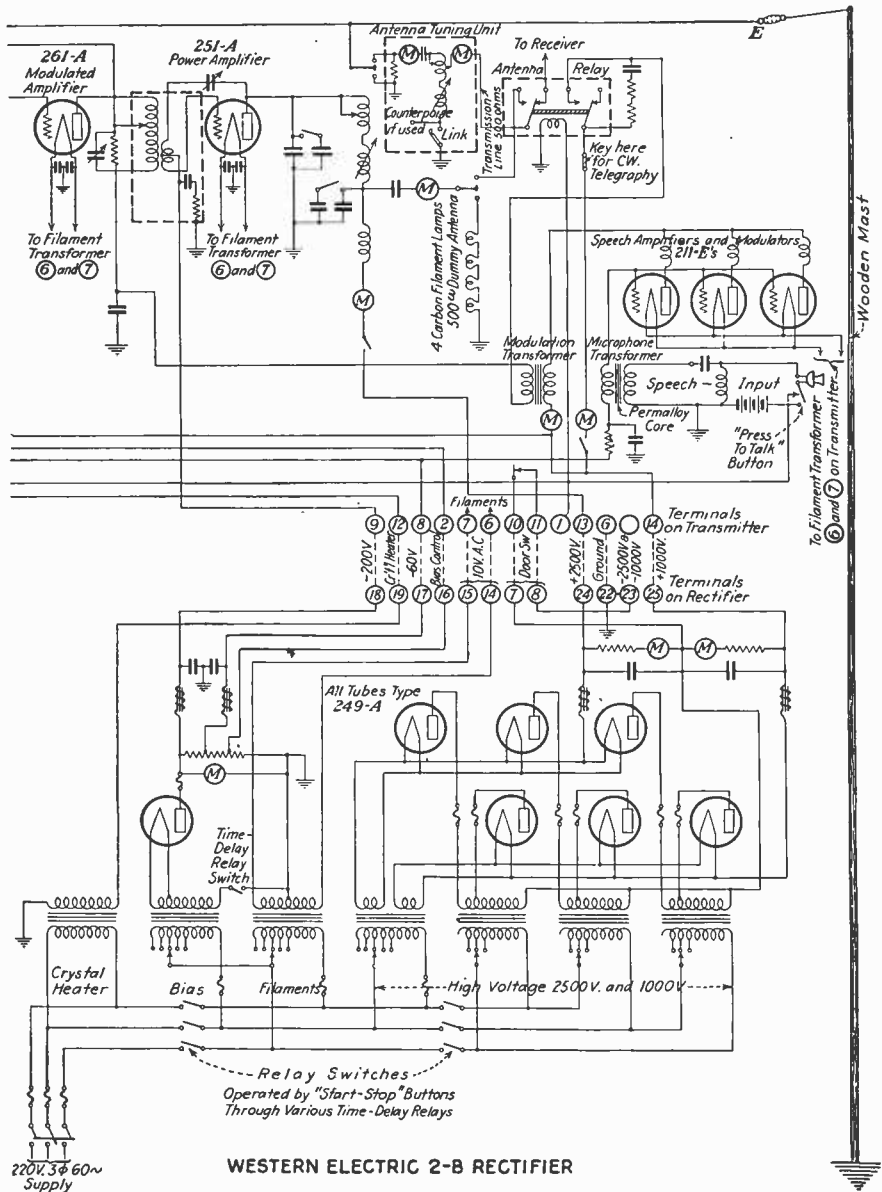
radiotelephone station, 400-watt transmitter.

or *vice versa;* airport transmitters do not change frequency in the ordinary sense. This question assumes that the tube capacities are already properly neutralized, and that changing of the neutralizing condensers is not necessary. The following are the necessary steps in changing the frequency of the Western Electric 9B transmitter:

1. Open the back of the transmitter.

2. Change D1T switch (osc.-plate impedance) to "day" 6, "night" 4.

3. Change D5T switch (power-amplifier inductance) to "day" 5, "night" 10.

4. Change D9T switch (modulating-amplifier inductance) to "day" 8, "night" 16.

5. Change crystal units by switching top clip to other unit. The "day" crystal unit is small and round, the "night" crystal large and square.

6. Close back of transmitter.

7. Switch antenna.

8. Push "start" button on front of 2B rectifier panel, and when time delay relay operates, close microphone stand "thumb switch" and make the following adjustments on tuning dials (approximate settings should be known).

9. Turn the doubler tuning dial until a maximum is obtained on the modulating-amplifier grid-current meter.

10. Turn the modulating-amplifier tuning dial until a minimum is obtained on the modulating-amplifier plate-current meter.   –

11. Turn the power-amplifier tuning dial until a maximum is obtained on the radiofrequency output meter.

12. Turn power-amplifier grid dial until 500 milliamperes is obtained on the power-amplifier plate-current meter.
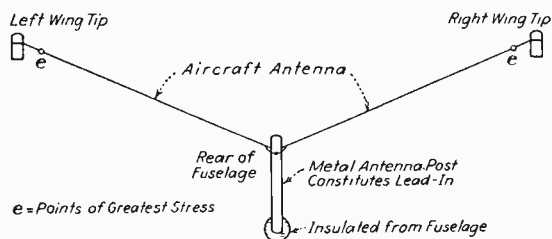
FIG. 94.—Schematic diagram of an aircraft antenna.

Ques. 460. Make a neat drawing of (a) an aircraft antenna, (b) a ground station antenna, showing point or points of greatest electrical stress.

Ans. (a) See Fig. 94. (b) See Fig. 93. *E* shows points of highest voltage.

Ques. 461. If the thermo-radiation meter of the transmitter moved backward upon modulation, explain how the trouble may be isolated.

Ans. First, the plate-current fluctuations of the audio-amplifier should be noted. It should be possible to increase this about 20 per cent with heavy modulation. A much greater increase indicates a faulty modulation transformer. The modulating-amplifier grid current must be at least 8 milliamperes in order to obtain proper modulation. The modulating-amplifier and audio-amplifier tubes should be watched for any defects in the tubes themselves. The speech-amplifier tubes may be checked by placing them one at a time in one of the speech-amplifier sockets and noting whether or not the plate current taken by each tube is approximately the same. Faulty tubes should be replaced as soon as discovered. If the trouble has not been located so far, the neutralization of the power amplifier should be checked. The power amplifier is properly neutralized when a maximum of output radiofrequency current and a minimum of power-amplifier input plate current occur at the same setting of the power-amplifier plate tuning dial. Another cause may be low modulating-amplifier or power-amplifier filament voltage. Still another cause may be open-circuited filter condensers in the 2B rectifier unit.

Ques. 462. How would you locate a faulty tube in a transmitter?

Ans. See Ques. 31.

Ques. 463. Explain briefly the action of a microphone.

Ans. Figure 93 includes a typical circuit arrangement of a single-button carbon microphone as used in aircraft telephone transmitters.

When sound vibrations are impinged upon the metallic diaphragm of the microphone, the entire diaphragm area will be set into vibratory motion at a definite rate depending upon the frequency of the impressed sound waves.

The diaphragm is attached to a small cup filled with carbon granules and is mechanically so arranged that when the diaphragm is in motion it will cause the carbon granules in the cup

to be either released or compressed depending upon the motional position of the diaphragm. The granules are connected in series with a battery and a winding to form an electrical circuit in which a definite amount of current will flow depending upon the circuit resistance and the voltage. If, therefore, the battery potential is kept constant, then the only variation in the current flow is that which can be obtained by the change in the carbon-granule resistance, by increasing or decreasing the compression. Hence, when the diaphragm is set in motion at a certain frequency by the sound impulses, the current flow in the circuit will be varied in direct accordance with the sound frequency, owing to the changing of the granule resistance by the compressing and releasing action. Thus, if the current is constantly changing in the circuit at the impressed sound frequency, magnetic variations will be set up around the primary winding of the microphone transformer which will then be transferred by induction into the secondary winding, resulting in alternating-current voltage changes across it which vary with the sound wave.

Ques. 464. What are the important transmitter failures? Explain the order in which to locate and remedy the same.

Ans. See Ques. 19, 30, and 37.

Ques. 465. Explain the function of an antenna circuit.

Ans. The antenna circuit as applied to transmission is an oscillatory circuit capable of radiating electric- and electro-magnetic-field energy into space in the form of electromagnetic waves or pulses.

The antenna circuit as applied to reception is an oscillatory circuit capable of absorbing electric and electromagnetic disturbances in the vicinity surrounding it, thereby setting it into oscillation. The oscillating energy may then be transferred into a receiving system by some suitable means of magnetic or capacitive coupling.

See also Ques. 362 and 386g.

Ques. 466. Describe two methods of checking the modulation on a transmitter.

Ans. By use of an oscillograph. See Ques. 390 and 456.

Another simple method would be to connect a peak voltmeter across the radiofrequency circuit in which the modulated radiofrequency variations are taking place and note the degree with which the modulated peaks swing during modulation. Then by the ratio

$$M = \frac{D_1}{I_o} \times 100$$

where I_o = amplitude of antenna or mesh circuit current (unmodulated)

D_1 = difference between I_o and the minimum antenna or mesh circuit current amplitudes

M = percentage of modulation

the exact percentage of modulation may thus be determined.

Another simple method for checking modulation is to apply a constant modulating frequency to the carrier and note the increase in the antenna current. If the carrier is modulated 100 per cent, the antenna current will rise to approximately 1.23 times the carrier value.

Ques. 467. Is the frequency of a modulated carrier wave constant?

Ans. See *Side Bands* page 267.

Ques. 468. What are the antenna condenser and loading coil used for?

Ans. An antenna condenser or a loading coil is generally used for adjusting the antenna oscillatory system to frequencies above or below the fundamental period of the antenna itself so that the entire system may be adjusted critically to a wide band of frequencies. For example, when a condenser is connected in series with the antenna, it reduces the effective capacity of the system, thereby increasing the frequency, and when an inductance is added in series with the antenna, the total circuit inductance is increased, thereby reducing the frequency.

Ques. 469. How is resonance generally indicated in a transmitter?

Ans. Resonance is generally indicated by a radiofrequency ammeter connected in the antenna radiating system.

When the exciting circuit has been properly adjusted with a wavemeter, the secondary circuit can be adjusted to resonance with it by varying the constants L and C until a maximum indication is obtained on the radiofrequency ammeter.
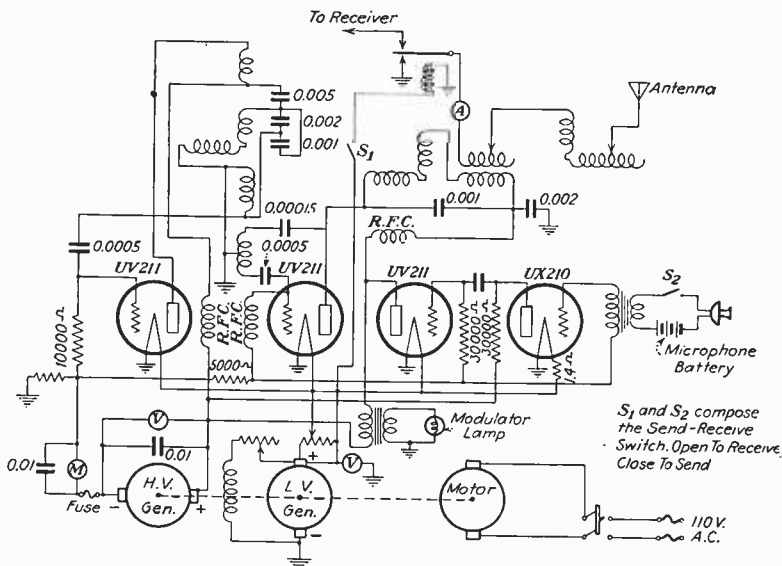
Fig. 95.—Schematic diagram of R.C.A. airport transmitter Type 3653-A.

Ques. 470.   State the difference between high-level and low-level modulation.

Ans.   The term "high-level modulation" means that the plate circuit of the last radiofrequency stage is modulated. The term "low-level" modulation means that a radiofrequency stage before the last one is modulated, and that the last one operates only as a linear power amplifier.

Neither term should be confused with "grid modulation" of the last stage, which means that the grid bias of the last radio stage is varied by the audiofrequency power supplied by the modulator.   If grid-bias modulation is employed in any other than the last stage, it is low-level modulation.   See also Ques. 394*q*.

Ques. 471.   Explain the action of the triode (a) as an amplifier, (b) as a detector (use either grid or plate rectification).

Ans.   (a) In a triode used as an amplifier, the voltage impressed by incoming oscillations on the grid circuit produces oscillations of much greater power in the plate circuit than the same voltage would produce if impressed directly on the plate circuit.   This occurs because the small voltage coming into the grid circuit is used to release a relatively larger current from the "B" supply to the plate circuit.   The advantage of this amplification process is obvious in the headphones, where the signals sound much louder.   Amplification can be accomplished before rectification of the incoming radiofrequency oscillations, when it is called radiofrequency amplification, or after the rectification, when it is called audiofrequency amplification.

When using the triode as an amplifier, the voltage used to bias the grid should be of such value that, on the positive alternation of the radiofrequency oscillations, the plate current is increased as much as it is decreased during the negative alternation, otherwise distorted amplification will occur.   This means that the tube should be operated on the straight portion of its grid-voltage plate-current curve.

(b) Grid rectification is explained in the answer to Ques. 131.

Ques. 472.   What are some of the receivers failures and in what order would you remedy the same?

Ans.   See Ques. 176.

Ques. 473.   (a) Explain briefly a method of regulating regeneration on a receiver.   (b) How are CW signals received?

Ans.   (a) See Ques. 177, 409.   (b) See Ques. 140.

Ques. 474.   Explain two ways in which a vacuum tube can be used as a detector.   Give the advantages and disadvantages of each.

Ans.   There are two general means of detection used in vacuum-tube receivers, the grid-rectification method and the plate-rectification method.

Grid rectification uses a grid condenser and grid leak in series with the grid of a vacuum tube and produces rectification by the

accumulating action of the electrons on the grid due to the blocking action of the grid condenser and grid leak. See Ques. 131 for a detailed theoretical operation of this method.

Plate rectification uses a permanent negative bias potential applied to the grid of the tube by a "C" battery or a drop resistance in the plate circuit. This bias must be of such value that the tube operates at the lower portion of the $I_p - E_g$ characteristic curve, so that when a modulated signal is applied to the grid of the tube the resultant plate-current variations will be asymmetrical in nature. This will enable the signal voltages to be built up on the telephone bypass condenser more on one condenser plate than on the other, which consequently allows group pulses to pass through the telephone winding during the intervals in which the modulated groups are either decreasing or stopping. Grid rectification has an advantage over plate rectification in that it follows a square law and consequently is a much more sensitive method of detection for weak signal voltages.

Plate rectification, on the other hand, is much more desirable where fidelity in reproduction is desired but requires heavier grid-signal voltages to produce the desired rectifying effect.

In high-quality receivers the latter method is highly desirable especially in view of the fact that the lack of relative sensitivity is overcome by the use of modern high gain radiofrequency amplifiers.

Ques. 475. What is an R.F. choke used for? What is an A.F. choke used for?

Ans. See Ques. 386*d*.

Audio- and radiofrequency choke coils are also used to reduce coupling between amplifier and power-supply circuits to insure maximum efficiency and circuit stability.

Audiofrequency choke coils are also used in parallel feed systems to keep the direct-current component out of the primary windings of audiofrequency transformers to prevent core saturation. This is particularly true where high-grade steel cores such as permalloy are used.

In general R.F. and A.F. chokes are considered effective isolation devices for insuring maximum circuit efficiency and stability.

Ques. 476. Why is a rheostat usually used in a filament supply?

Ans. See Ques. 5.

Ques. 477. What effect would a reversed "A" or "B" battery have on a receiver?

Ans. See Ques. 167.

Ques. 478. What is the purpose and method of bonding an airplane?

Ans. By bonding is meant the interconnection of all metal parts of the airplane by means of good electrical conductors. This decreases the fire hazard and eliminates certain causes of noises in the aircraft radio receiver. Bonding is also necessary in order that the metal parts of the plane may collectively constitute a counterpoise of sufficient capacity value to make it a proper substitute for the "ground" in the antenna circuit.

Ques. 479. How should all electrical connections be made to insure their effectiveness?

Ans. First a good mechanical connection should be made, then soldered.

Ques. 480. What precautions are always taken to insure the mechanical security of the components of an airplane?

Ans. Everything is safety-wired, cotter-keyed, or secured equally safely.

Ques. 481. What precautions should be taken when using shielded conductors in a plane?

Ans. Care should be taken that the shielding does not come in contact with the shielded wires or their connections. The shielding should be grounded at frequent intervals. High- and low-tension wires should not be installed in the same shield.

Ques. 482. What effect, if any would there be, and where would it be observed, if high- and low-tension wires were installed in the same shielding?

Ans. There would be undue pick-up in the low-tension circuit, which would result in objectionable noises in the radio receivers.

Ques. 483.   Discuss the care and servicing of an aircraft dynamotor.

Ans.   High-voltage brushes must be examined for wear every hundred hours of operation, and low-voltage brushes every two hundred hours.   Brushes should be properly lubricated with an approved grease of light consistency, such as the Bosch U.S. No. 501 Special High Temperature grease.   Window covers must be kept tight.   Brushes and brush boards must be kept clean. Commutators must be smooth, and free from dirt and grease. Brushes must make as full contact as possible with the commutator surface.   Brushes must move freely in their respective holders.

Brush-spring pressure on low-voltage brushes should be 16 to 18 ounces.   The high-voltage springs require not less than two nor more than three ounces to just lift the brush follower from the top of the brush box.   This is done with the brush removed. Neither high-voltage nor low-voltage commutator mica should be undercut.

If dirt, grease, or oil collects on the commutator, it should be removed and cleaned with a clean cloth.   The commutators should not be sandpapered unless absolutely necessary to remove roughness.   In time, the commutators should become covered with a dark semitransparent film which would be preserved thereon.

The natural wear of the brushes causes carbon dust to collect on the interior of the generator and this accumulation mixes with oil vapor, forming a gummy paste, which may adhere to the brushes, causing them to stick.   The brushes should be kept free in their respective boxes and when necessary may be washed in gasoline and thoroughly dried before reassembling. New brushes may be quickly seated by inserting a strip of No. 00 sandpaper (sanding side against brush) between the brushes and the commutator, then withdrawing the sandpaper with the rotation of the armature.   Sand particles should be blown out of the dynamotor after this operation.   The brushes should be given a final finish with No. 0000 sandpaper.   This should be carefully and thoroughly done by personnel with experience in sanding brushes.

Note.—See Addenda for additional questions and answers.

Ques. 484. Give the causes of a sparking commutator on a direct-current generator and the remedies.

Ans. See Ques. 275.

Ques. 485. State fully the care necessary properly to maintain lead-acid storage batteries.

Ans. See answer to Ques. 225, which also applies here.

Ques. 486. What causes sulphation in a lead-acid storage battery?

Ans. See Ques. 211.

Ques. 487. Give the composition of the positive and negative plates in a lead-cell storage battery and the composition of the liquid used.

Ans. See Ques. 204.

Ques. 488. What happens when a battery is charged at too high a rate?

Ans. This will cause excessive evaporation of the water in the electrolyte owing to the internal heat produced and may also result in the destruction of the active materials on the plate areas.

Batteries which are charged at too high a rate may also lose the acid content of the electrolyte, owing to the flooding or boiling condition produced by the excessive internal heat.

Ques. 489. How would you treat a lead-acid cell which shows signs of sulphation?

Ans. If a long charge at a high rate fails to raise the specific gravity above 1.200, new electrolyte should be mixed to replace the old. The new electrolyte should read between 1.275 and 1.300. See also answer to Ques. 221.

Ques. 490. What is the unit of capacity of a storage cell? The normal voltage per cell?

Ans. The ampere-hour is the unit of capacity. The normal voltage of the lead-acid cell is 2.1 volts when charged, 1.7 volts when discharged. See also Ques. 217.

NOTE.—Attention is invited to Part V of this book which discusses storage batteries thoroughly.

RADIO LAWS

Ques. 491. What class of radio communication holds precedence over all others?

Ans. Distress signals or messages relating to ships in distress.

Ques. 492. What is necessary if an aircraft is flying over maritime lanes?

Ans. It must be equipped for transmission and reception on 500 kc./600 meters.

Ques. 493. What is the regulation for standing by on the distress wave in the Maritime Service?

Ans. See Ques. 312.

Ques. 494. What are the provisions of the law regarding secrecy of messages?   The penalty for violation?

Ans. No one receiving a message shall divulge it to anyone excepting the addressee or authorized agent, and no one not entitled to it shall receive any radio communication and use it for his own benefit.   The penalty is a fine not exceeding $5,000 and imprisonment for 5 years or both.

Ques. 495. What penalties may be imposed upon a radio operator wilfully damaging radio apparatus?

Ans. His license may be revoked for not more than two years.

Ques. 496. (*a*) **What is the radiotelephone distress signal?** (*b*) **The emergency (urgent) signal?**

Ans. (*a*) "MAYDAY" (m'aidez).   (*b*) "Pan" (panne).

Ques. 497. Give complete correct procedure in calling a station; in answering a call.

Ans. In the radiotelephone service the calling station mentions its own call first, using the name of the town with which it is identified, followed by the word "to" or "calling," or no intermediate at all, followed by the call of the station called: for example, "Newark to Cleveland," or "Newark calling Cleveland."   Cleveland would answer, "Cleveland answering Newark, go ahead."   If there are more than one airline operating

at the same city, it is sometimes desirable to precede the call by the company identification· for instance, "American Airways Newark to Cleveland" or "TWA Columbus to Pittsburgh." See also Ques. 302 and 304.

Ques. 498. What is the penalty for violating any United States or International Radio Law?

Ans. The violator, upon conviction thereof by a court of competent jurisdiction, shall be punishable by a fine of not more than $500 for each and every offense.

Ques. 499. What is the penalty for violating a provision of the Radio Act of 1927?

Ans. Any person, firm, company, or corporation who shall violate any provision of this act, upon conviction thereof by any court of competent jurisdiction, shall be punishable by a fine of not more than $5,000, or by imprisonment for a term of not more than 5 years, or both, such fine and imprisonment for each and every offense.

Ques. 500. What is the penalty for infraction of rules?

Ans. Suspension of license for two years at the discretion of the radio authorities. See also Ques. 347e.

Ques. 501. What is the law regarding unnecessary signals?

Ans. See Ques. 310.

Ques. 502. What does QAA mean? QAH? QAF? QAO?

Ans. See Table II (Appendix II).

NOTE.—Attention is invited to Part VII of this book which discusses radio laws thoroughly.

BEACONS

Ques. 503.   Describe briefly the operation of aural beacons.

Ans.   The aural-type radio range beacon transmits characteristic signals alternately from equivalent loops, which interlock, marking the course along the line of equal signal strength.   Each radio range provides four courses.   The standard "off-course" signals, "dash dot" (Morse N) and "dot dash" (Morse A), are transmitted at the rate of 22 signals per minute in groups of four, separated by the station identifying signal.   "On course" is indicated when the "off-course" signals interlock with equal signal strength, thus forming a series of long dashes, or continuous monotone signals of about 12 seconds duration, which signals are also broken up by the station identifying signal.   The latter is sent at a much higher rate of speed than the "off-course" signals.   This precludes confusion between the two purposes, one purpose being to mark the course and the other to identify the station transmitting the course-marking signals.

Ques. 504.   Draw a simple diagram showing the courses and relative positions of the "zones" transmitted by an aural beacon station.

Ans.   See Fig. 96.

Ques. 505.   What is the meaning of equi-signal zone?

Ans.   It is the region in which two distinctive signals from an equi-signal radio range beacon are received with equal intensity, so as to sound like a long dash or monotone in the headphones. It is the shaded portion of the diagram Fig. 96, there being four shaded portions from a four-course radio range.

Ques. 506.   What is the rule for determining the positions of the zones with relation to the courses and true north?

Ans.   A uniform practice for designating aural radio range beacon signal zones has been adopted whereby "dash dot" (Morse N) and "dot dash" (Morse A) are assigned as follows:

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The "dash dot" (Morse N) zone is that zone through which the true north line, from the station, passes. If the true north line coincides with the center line of the equi-signal zone (or northerly radio-marked course), then the adjacent on the west shall be the "dash dot" (Morse N) zone.

OC = "On Course" Line.
(shaded areas are
equi-signal zones)

LL = Direction of Loop
Antenna

N = (Morse N)
"dash dot" zones

A = (Morse A)
"dot dash" zones
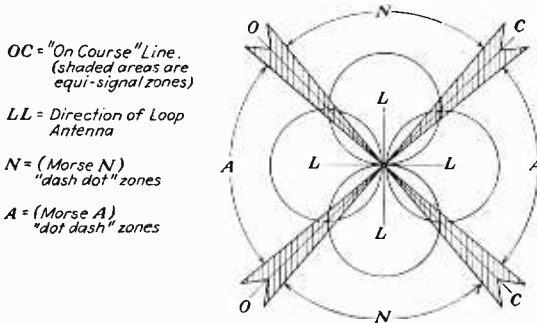
FIG. 96.—Field pattern of aural-beacon radio transmitter.

Ques. 507. Describe briefly the method of operation of visual beacons.

Ans. The fundamental of this system is to send the carrier wave simultaneously into each loop, and to modulate each one separately to a different frequency. The indicator consists of two reeds that vibrate vertically between electromagnets which are connected electrically to the output of the long-wave receiver. One of the reeds is mechanically tuned to the modulated frequency of one loop, while the other reed resonates to that of the other loop. The tips of the reeds are white and have a dark background. When the plane is flown on the course, the reeds vibrate with equal amplitude. When the plane is off course, the reed that is nearest its corresponding loop has the larger amplitude, so that the pilot always turns in the direction of the reed that is vibrating least to find the course.

AIRWAYS

Ques. 508.   Define the term "aircraft."

Ans.   An aircraft is any weight-carrying device designed to be supported by the air, either by buoyancy or by dynamic action, excepting those devices designed for use as emergency equipment, such as parachutes.

Ques. 509.   What is an airport?

Ans.   An airport is a locality, either water or land, which is adapted for the landing and taking-off of aircraft and which provides facilities for the shelter, supply, and repair of aircraft; or a place used regularly for receiving passengers or cargo by air.

Ques. 510.   What is an intermediate or emergency field?

Ans.   It is a field, along an established airway, which is adapted for the landing and taking-off of aircraft, but which is not equipped for facilities for the shelter, supply, and repair of aircraft and is not regularly used for the receipt or discharge of passengers or cargo by air.

Ques. 511.   Describe the equipment of an intermediate field suitable for night flying.

Ans.   An intermediate field is marked by a 50-foot white circle located at the intersection of the runway center lines. White panels 20 feet long and 2 feet wide extend from the outside of the circle along the runway center lines to indicate the landing directions.   The boundaries of the field are marked by chrome-yellow sheet metal cones 30 inches in diameter and 24 inches in height.   They are attached on the boundary-light standards immediately below the boundary lights.   A concrete arrow course marker about 70 feet long points to the next higher numbered beacon.   The beacon tower rises from the center of the arrow.

The lighting of an intermediate field comprises a beacon, boundary lights, approach lights, obstruction lights, and an

illuminated wind indicator. A standard 24-inch revolving beacon is provided at each field. Boundary lights are installed at intervals of approximately 300 feet around the perimeter of the field. They consist of clear electric bulbs of 10 or 15 watts placed in water-proof prismatic globes. These are mounted on iron-pipe standards 30 inches or more above the ground.

Approach lights are installed in the boundary system. They are similar in all respects to boundary lights, except that the wattage of the bulbs is from 20 to 25 watts, and the clear prismatic globes are replaced by green globes.

Two such approach lights are placed at the principal or "prevailing-wind" runway, and single lights mark the center of the other runway.

Obstructions at the end of landing strips or runways over which approaches or take-offs must be made are marked in all cases by red lights at the height of the obstructions. These consist of 25-watt electric bulbs in lighthouse red globes.

Illuminated wind cones are supported on brackets attached to the beacon towers. A conventional wind cone or sock 8 feet long, 18 inches in diameter at the mouth, and 8 inches in diameter at the end, of porous weave, is colored chrome yellow. A 75-watt electric lamp is located at the mouth and has a reflector which directs the entire output of the light into the sock. This indicator shows wind direction at velocities as low as 5 miles per hour. At greater velocities the sock inflates and rises proportionately, reaching an angle of about 7 degrees below the horizontal at a wind speed of 30 miles per hour.

Ques. 512. What is the average distance between these intermediate fields?

Ans. Thirty to fifty miles.

Ques. 513. What is the usual distance between beacon lights along an airway?

Ans. Ten to fifteen miles.

Ques. 514. What are course lights?

Ans. These are colored lights installed on beacon towers below the revolving beacon and visible only in the direction of the course. Course lights are red where there is no intermediate field, and green where there is one.

Ques. 515.   What are the right-of-way rules over an airport?

Ans.   Ships in distress have the right of way over all others. Ships landing have right of way over ships taking off.   Air-mail and scheduled passenger ships have right of way over others. Aircraft at greater heights must avoid the one at lower altitudes. Right of way does not relieve the pilot from keeping clear of other aircraft.

Ques. 516.   What lights must a plane show?   And when?

Ans.   Airplanes must show a red light on the left wing tip, green on the right, and white on the tail, from one-half hour after sunset to one-half hour before sunrise.

Ques. 517.   On which side of the airway should an aircraft fly?

Ans.   On the right of the course, with the airway on the pilot's left.

Ques. 518.   When is it proper to commence take-off?

Ans.   A pilot should first make sure that he has the right of way, then clear his motor (by "revving up"), turn the ship in the direction from which the wind is blowing, make sure that no obstructions will be encountered, then take off.

Ques. 519.   What is the penalty for exhibiting false lights?

Ans.   Any person (1) who, with intent to interfere with air navigation in the navigable air space or waters of the United States, exhibits within the United States any false light or signal at such place or in such manner that it is likely to be mistaken for a true light or signal required by regulations, or for a true light or signal in connection with any airport or other navigation facility, or (2) who, after due warning from the Secretary of Commerce, continues to maintain any false light or signal, shall be guilty of an offense punishable by a fine not exceeding $5,000, or by imprisonment not exceeding 5 years, or by both such fine and imprisonment.

Ques. 520.   Discuss the Regulations Governing Scheduled Operations of Interstate Passenger Air Transport Services.

Ans. Generally speaking, airplanes are not allowed to fly over top of fog or clouds, or carry passengers at altitudes less than 500 feet, except as outlined below.

Over Top of Fog or Cloud Flying.—No airplane shall be operated over the top or through solid fog or clouds, except when directional radio is in operation over the route to be flown, the airplane is equipped properly (instruments and accessories), and weather conditions are equal to or better than outlined below:

1. When equipped with directional radio and weather-broadcasting receivers, airplanes are permitted to proceed over the top of solid fog and clouds, provided the point of take-off and intended place of landing are clear (for the purpose of this regulation "clear" is interpreted as meaning not less than 1,500-foot ceiling and 2 miles visibility).

2. When equipped with directional radio and weather-broadcasting receivers, and while maintaining two-way radio communication with stations operating under the control of the company involved, airplanes may be operated over the top or through solid fog or clouds when terrain and weather conditions make it necessary, provided there is, at the time of take-off, sufficient ceiling and visibility at the intended point of landing to permit the airplane to be safely maneuvered and landed without danger of striking any object or objects on the ground, and further provided that, within fuel range of the plane, there is an airport or intermediate field where weather conditions are favorable to which the pilot may be directed.

Waiver of Prescribed Altitudes of Flight.—Waiver of the 500-foot minimum altitude requirements of the Air Traffic Rules is granted to air lines operating under Certificate of Authority, when terrain and local weather conditions make it necessary, provided:

1. There is a definite indication of more favorable weather conditions ahead.

2. There is sufficient ceiling to permit safe maneuvering of the airplane without danger of striking any object or objects on the ground, and there is at least a visibility of 2 miles in the daytime, and from beacon to beacon at night.

3. In hours of darkness, directional radio is in operation over the route and the plane is equipped for the reception of same.

4. The pilot in his own judgment believes the flight can be accomplished with safety.

METEOROLOGY

Ques. 521. What is the greatest single handicap to air navigation?

Ans. Fog.

Ques. 522. What is the minimum ceiling height at which passengers may be carried?

Ans. Five hundred feet.

Ques. 523. Why is the dewpoint important for the pilot to know?

Ans. Because by the observation of the difference between the temperature and the dewpoint the pilot may predetermine the possibility of fog formation. If the temperature is greater than the dewpoint by 7 degrees or *less*, there is danger of fog.

Ques. 524. What is meant by a line squall, and how may it be detected on the weather map?

Ans. A line squall is a very rapid air movement, or high wind, accompanied by a long line of very dark clouds. It brings violent rain or hail, a change of wind directions, and a drop of temperature. It is sometimes as much as 200 miles in width. It can be detected on the weather map by the V-shaped isobars. A line drawn through the points of the V-shaped isobars is the line of the squall, which usually runs in a west-east direction.

Ques. 525. What is meant by ceiling? Visibility? Dewpoint? Barometer?

Ans. Ceiling is defined as the greatest altitude vertically above the ground at which the ground may still be seen (usually expressed in feet). This will include all cases. For instance, if there is a bank of clouds at 1,000 feet from which a moderate snow is falling, and the ground cannot be seen at more than 500 feet in the air (this may be calculated from the ground), then the ceiling at that place is 500 feet. When the snow stops

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falling it will be possible to see the ground from up to a short distance in the cloud bank, and the ceiling will be 1,000 feet. Then if a fog formation comes over the ground and extends up to 500 feet, and the ground cannot be seen above 100 feet, the ceiling is 100 feet instead of 1,000 feet.   Ceilings less than 100 feet are recorded as zero.   Visibility is the greatest distance that can be seen horizontally.   The dewpoint is the temperature at which the air is saturated with moisture.   A barometer is a device for determining the pressure of the atmosphere.

Ques. 526.   Describe "high" and "low," and in what direction the winds travel.

Ans. A "high" is an area of high barometric pressure.   The winds follow the isobars outward in a clockwise direction and move toward the nearest or strongest "low."   "Highs" cover much larger areas than "lows" and have been known to cover the entire United States.   They move at the rate of about 25 miles per hour.

A "low" is an area of low barometric pressure, with more or less circular isobars, though in some cases they may assume V or wedge shapes.   The winds follow the isobars inward in an anti-clockwise direction.   The diameters of "lows" vary from 300 to 2,000 miles, the average in the United States being 1,000 to 1,500 miles.   "Lows" will be seen to follow the general trend of surface isotherms moving at the rate of 27 to 28 miles per hour.

Ques. 527.   Name and describe the principal forms of clouds

Ans.   *Cirrus* are white clouds, generally detached in the form of tufts, although they may appear as long stretches across the sky.   Their normal altitude is 25,000 feet.

Cumulus are the well-known billowy wool-pack clouds.   They have the thickest known dimensions of any cloud formation, estimated to average about 2,400 feet in thickness.   They appear in large patches but in high winds become broken into small portions and are called fracto-cumulus.   Their normal altitude is 5,000 feet.

Nimbus (rain clouds) are thick layers of dark clouds without shape and with ragged edges, from which rain or snow is generally

falling. If nimbus clouds separate into shreds, or if small loose clouds are visible floating underneath large nimbus, they are commonly called "scud"; height 6,000 ft. or less, thickness 1,000 ft.

Stratus is the lowest cloud formation of all, often reaching almost down to the ground and never higher than 3,000 feet. The sky is generally completely overcast and the visibility poor.

TELETYPE

Ques. 528. Decode the following into plain language: BF BRKN 4 THSD 9 NW 12 65 41 3015.

Ans. The above sequence is used in all weather reports on the Department of Commerce Teletype Circuit, generally abbreviated D.O.C.

1. Name of town (abbreviation) BF, Bellefonte.

2. General conditions, BKN—broken clouds.

3. Ceiling height, 4 THSD—4,000 feet.

4. Visibility, 9—9 miles.

5. Wind direction and velocity, NW 12—wind from NW, 12 m.p.h.

6. Temperature, 65—65 degrees.

7. Dewpoint, 41—41 degrees.

8. Barometer, 3015—barometric pressure 30.15 inches of mercury.

The complete message decoded would read: Bellefonte, broken clouds, ceiling 4,000 feet, visibility 9 miles, surface wind northwest 12 miles per hour, temperature 65 degrees, dewpoint 41 degrees, barometer 30.15 inches.

Ques. 529. Code the following message for dispatch as a PX over the "D.O.C." teletype circuit: American Airways plane NC 9790, pilot Smith, departed from Cleveland for Albany at 1:40 P.M., PX put on circuit at 1:43 P.M.:

Ans. The following sequence is used in sending PX reports:

1. 6 bells (preceding PX reports).

2. Company initials.

3. Number of PX.

4. Time put on circuit (24-hour system).

5. Name of pilot.

6. Destination (D.O.C. abbreviation).

7. The letter "D" for "departed."

8. Departure time (24 hours notation).

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9. City departed from (D.O.C. abbreviation).

10. 1 bell (end of PX).

The above message would read: AA3PX 1343 NC 9790 SMITH AH D 1340 CV.

Ques. 530. What do the following calls on the teletype circuit signify: 1 bell, 5 bells, 6 bells, 10 bells?

Ans. 1 bell designates end of message or weather report, or PX. 5 bells precedes a rush message. 6 bells precedes a PX report. 10 bells precedes a weather sequence.

Ques. 531. Give an example of a teletype call-bell signal.

Ans. Besides the call bells used to designate end of message, etc., various combinations of bells are used as station calls. For example: Cleveland, 1 bell space 3 bells.

Ques. 532. What types of messages are accepted on teletype circuits?

Ans. PX reports (arrivals and departures of planes), weather reports and sequences, emergency messages pertaining to safety of flight, and some Post Office messages.

Ques. 533. Can weather reports be obtained between sequences? If so, how?

Ans. Where the regular hourly sequences are received, special reports should not be requested, since any drastic change in weather for better or worse is immediately placed on the circuit. However, where reports have been garbled, or the machine has been out of operation, a repeat may be requested.

Ques. 534. When emergencies involving life and property make it necessary to stop all operations on the teletype circuit, what call-bell signal should be used?

Ans. 3 bells space 3 bells space 3 bells: SSS.

ADDENDA

As the heading explains, this section will include questions and answers of value prepared too late to be placed in their proper section in the book. These questions may be on any division of radio previously covered in the book. All questions will be grouped under a title indicating their proper classification. The reader should inspect this section carefully as it may contain questions in which he is interested.

BROADCASTING

Ques. 535. Describe the operation of a precision frequency-monitoring unit.

Ans. The following is a brief description of the Western Electric 1A frequency-monitoring unit and its theoretical operation.

The unit comprises a crystal-controlled oscillator, two screen-grid radiofrequency amplifiers, a detector, a visual frequency-difference indicator, temperature-control equipment for the oscillator, and a complete alternating-current power supply for 110-volt operation. The temperature of the crystal and chamber is maintained constant by a resistance controlled through the plate circuit of an argon-tube regulator previously described in Ques. 394*i*.

The oscillator in the monitor compartment is a quartz crystal-controlled unit which is critically calibrated to the assigned frequency of the station. The variation of frequency in this precision monitor may be kept to within 5 or 6 cycles of the assigned frequency by maintaining the crystal temperature constant by day and night.

The theoretical operation is briefly as follows: The carrier frequency from the transmitter which is to be monitored is picked up by a small antenna or transmission line coupled to the output mesh of the power-amplifier circuits. The carrier frequency is then fed through the two tubes functioning as radiofrequency amplifiers and then to the grid of the detector tube. In the plate circuit of the detector tube is a small relay energized through a small series condenser. When the radio-

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frequency-voltage changes from the transmitter and the crystal oscillator are fed to the grid of the detector tube, a resultant beat frequency is produced which is the difference between the monitoring-unit oscillator and the transmitter carrier frequencies. This causes the armature of the relay to vibrate at the beat frequency which in turn operates between two contacts. In one position of the armature and contact a small condenser is charged, and when the position of the armature is changed to the other contact the condenser discharges through a direct-current meter which is calibrated in cycles per second. This meter then indicates directly the difference in cycles between the two frequencies or the deviation of the transmitter from its assigned frequency. A small capacity is also applied in shunt to the monitoring crystal to allow for the direction of the frequency shift. That is to say, if the meter indicates a deviation of 10 cycles from the assigned frequency it will be necessary to determine in which direction the frequency has shifted, $+$ or $-$.

This is accomplished by pressing a small button which operates the crystal load capacity. If the meter reading drops when the load capacity is inserted, it shows that the frequency of the crystal has been decreased, since increasing the capacity of an oscillatory circuit decreases the frequency. Hence, if the frequency difference is assumed to be 10 cycles and inserting the load capacity lowers the frequency of the oscillator, the frequency of the carrier frequency will obviously be 10 cycles low or -10 cycles from the assigned frequency.

A telephone jack is also provided in the plate circuit for audible indication of the frequency difference. If the carrier frequency is exactly the same as the monitor crystal frequency, clear reproduction of the musical program will result. This is known as zero beat adjustment.

Ques. 536. What causes audio distortion? Name three or more reasons for distortion.

Ans. Audiofrequency distortion in transmitters may be due to one or more of the following reasons.

1. Improper adjustments of microphone currents (button balance).
2. Core saturation in modulator chokes or in speech-input-equipment transformers.

3. Improper bias-voltage adjustment.
4. Improper plate-voltage adjustment.
5. Overloading.
6. Overmodulation.
7. Improper impedance function between tube and load circuits.
8. Improper amplifier balance.
9. Poorly filtered plate power supply.
10. Load fluctuations during modulation.

Audiofrequency distortion in receivers may be due to one or more of the following reasons.

1. Improper adjustments of plate, grid, and filament voltages.
2. Overloading (excessive grid swings).
3. Improper type of power tube to accommodate heavy grid-voltage variations.
4. Common coupling between grid, plate, and power-supply circuits (poor isolating).
5. Improper impedance function between tube and load circuits.
6. Transformer core saturation.
7. Poorly filtered power supply.
8. Load fluctuations during reception due to poor filtering or insufficient bleeder current in power supply.
9. Extreme selectivity in radiofrequency circuits causing side-band cut-off distortion.
10. Defective telephones or loud speaker.

Ques. 537. State the care necessary to keep a broadcast transmitter in good condition.

Ans. The routine of care necessary to keep a broadcast transmitter in good operating condition is as follows:

1. Systematic cleaning of the entire transmitter by vacuum suction method to minimize leakage due to dust creepage. This is particularly necessary for all air-dielectric condensers which are subject to high oscillating voltages.

2. Tighten all bolts and lock nuts periodically to insure against high-resistance connections. High-resistance connections may seriously impair the electrical efficiency as well as the circuit balance.

3. Check all tubes, particularly mercury-vapor rectifiers, after 2,000 hours of continuous operation. Mercury-vapor tubes may be checked as to their condition by measurement of the IR drop across anode and cathode; the ionization of mercury vapor in the tube begins at 10.4 volts and the arc drop is approximately 15 volts. If the tube is in good condition, the arc drop is practically constant between 12 and 17 volts regardless of the current drawn under load.

4. High-vacuum tubes in the speech-input and transmitting circuits should be carefully checked as to plate-current and plate-voltage readings every half hour during operation.

5. Radio lines should be periodically checked for proper equalization and noise.

6. All movable contacts, particularly potentiometers on speech-input equipment, should be frequently checked to guard against oxidization and dust accumulation to insure quiet operation.

7. Microphonic tubes should be changed or cushioned.

8. All circuit plugs and patch cords should be highly polished with chamois to insure good contact connections into jacks.

9. Jacks should be kept clean and free from dust by vacuum-cleaner suction.

10. Jacks infrequently used should be operated each day by inserting patch cord and plug to reduce high-resistance formations on contacts. This must not be done while equipment is in operation.

11. All soldered connections on speech-input equipment and transmitter should be frequently inspected.

12. Neutralization of all radiofrequency· transmitting tubes should be checked frequently.

13. All meter connections and zero adjustments should be frequently inspected.

14. Careful adjustment of all variable filament voltages.

15. All relays and circuit breakers should be frequently tested and inspected.

16. Proper adjustment of overload relays to protect tubes against excessive peaks during modulation. See that proper fuses are used.

17. Occasional cleaning of antenna insulators and tightening of guy ropes.

Ques. 538. Why must a telephone line be equalized? What frequencies are attenuated most in telephone transmission lines?

Ans. For intelligible transmission of speech a telephone line must be capable of covering a frequency spectrum of from 200 to 3,000 cycles and for high-quality transmission of both speech and music from 50 to at least 5,000 cycles.

In view of the distributed capacity in a telephone line connecting the studio with the transmitter, most of the higher audio frequencies, particularly above 4,000 cycles, are attenuated. In order to improve the frequency characteristics of a line so that it may be used for high-quality transmission, some correcting network or attenuation equalizer must be used.

These equalizers generally consist of an anti-resonant network forming a series resonant or a parallel resonant circuit shunted

across the line at the beginning or end of the telephone line or perhaps at both ends. The equalizer is then tuned to the particular frequency it is desired to emphasize and thus consequently tends to raise the response at the higher frequencies and lower the response at the lower frequencies, resulting in a practically flat frequency characteristic from 50 to 5,000 cycles or more.

The equalizer generally consists of a parallel resonant circuit and a resistance in series in which the resistance merely regulates the effectiveness of the network. This combination is then shunted across the telephone line. Equalizers are generally tuned to 3,000, 5,000, or 8,000 cycles, depending upon the length of the telephone radio line.

Ques. 539. If your broadcast transmitter failed to operate, state the order in which you would look for the trouble.

Ans. The order of looking for trouble would depend entirely upon the type of transmitter and the symptoms evidenced. For a transmitter of the 1,000-watt variety such as is illustrated in Fig. 81 the order might generally be as follows, if the transmitter suddenly stopped during operation. The trouble might be due to any of the following causes.

1. Circuit breaker or fuses opened due to (*a*) excessive modulation peak; (*b*) short-circuited high-voltage filter condenser; (*c*) grounded *B* plus lead; (*d*) defective power tube, shorted or gaseous; (*e*) grounded filter choke; (*f*) broken antenna lead which causes increase in load through overload circuit breaker owing to disconnection of antenna load; (*g*) open in grid-bias circuit owing to a defect in a tube or voltage divider.

2. Defective contacts on door switches or doors may not be closed properly

3. Burned out circuit-breaker coil.

4. Burned out plate-circuit or grid-circuit relay coil.

5. Failure of power supply.

6. Grounded antenna.

7. Burned-out filament in transmitting tube.

8. Burned-out rectifier tube. This may or may not stop operation, depending upon the phase location of the defective tube. A burned-out rectifier tube is usually indicated by a drop in the plate-voltage reading.

9. Crystal oscillator stopped oscillating owing to, a defective tube, an open plate lead, a blown fuse, a shorted bypass condenser, an open grid leak, bad socket contacts, a defective crystal, defective contacts on crystal box, shorted output circuit, open biasing resistor, open radiofrequency choke, a frequency shift due to an open heater resistance, or a defective temperature-control tube as indicated by the heater-unit pilot light.

All troubles are located by a systematic routine, first eliminating all general possibilities such as open breakers, fuses, defective tubes, shorted condensers, shorted coils, open plate or grid circuits, grounded plate or grid circuits and then continuing on to other possible sources of trouble.

Plate milliammeter and voltmeter readings on all tubes will generally enable quick detection of open circuits or tube failures. Short circuits of high-potential circuits will not permit voltage or current readings, since each closing of the circuit breaker results in the blowing of certain fuses thereby preventing circuit readings. Such troubles are generally due to a shorted filter condenser and may be readily localized by a simple continuity test between plate and ground. A full-scale reading indicates either a shorted condenser or a grounded positive lead. However, this is not always the case, as a shorted condenser on the low side of a filter choke would give an IR drop if the reading is taken from the high side of the choke.

In modern transmitters the main troubles are usually easily remedied; but if certain situations arise which are not covered by the deductions stated above, then a systematic test of each circuit should be given with a good continuity tester or ohmmeter.

Ques. 540. Why must a radiofrequency amplifier be neutralized?

Ans. The internal grid-to-plate capacity of a three-element tube generally allows sufficient coupling between the input and output circuits to cause the tube to go into sustained oscillation.

Tubes adjusted as radiofrequency amplifiers in transmitting circuits may have a large plate current flowing in their output circuits at normal operating voltages; and under these conditions if a tube should suddenly go into self-oscillation, a large increase in plate current would result, which, if the circuit is not protected by overload relays or fuses, may ruin the tube or burn out the primary radiofrequency choke. In all probability the tube would be ruined.

It is necessary, therefore, that a system of neutralization be provided whereby the voltage feed-back through the tube capacity is opposed by an equal and opposite e.m.f. from the grid to

the plate. See Figs. 1 and 81 for typical radiofrequency neutralizing systems. In the latter diagram the neutralizing condenser is marked *NC*.

Ques. 541. What is meant by blocking a modulator tube?

Ans. Overloading of the grid circuit or "blocking" of the modulator tube will cause "singing" of the carrier wave, something which should be avoided under all circumstances. The modulator tube may be overloaded by too great an output from the speech amplifier or by radiofrequency pick-up. This latter must be guarded against by the use of radiofrequency chokes in the direct-current leads, proper shielding, and placement of modulating equipment away from radiofrequency fields.

Ques. 542. Explain the operation of two types of rectifier for high-voltage supply. / C

Ans. Two types of rectifier for high-voltage supply are the Kenetron high-vacuum type of rectifier and the hot-cathode mercury-vapor type of rectifier, both of which are two-element tubes having a cathode and a plate.

The Kenetron tube is a highly exhausted vacuum tube in which the gas content plays an unimportant part in the actual rectifying action of the tube. The plate current is entirely dependent upon the physical dimensions of the tube and is never greater than that actually emitted by the hot cathode. The high degree of vacuum used in the Kenetron rectifier prevents even the slightest amount of ionic current even at potentials as high as 75,000 volts. These tubes are generally made and used in large sizes, sufficiently large to rectify several kilowatts of power.

The mercury-vapor hot-cathode tube utilizes the principle of electronic bombardment of a mercury vapor by ionization due to collision and depends for its action entirely upon the electronic emission from a filament.

The operation of these types of rectifier is as follows:

The Kenetron operates on the elementary principle of plate-current flow by electronic emission from a hot cathode to a point of positive or anode potential. This flow of plate current is the electronic stream from cathode to anode through a high vacuum. This current flow is present only during the period when the plate

is charged positively.   If an alternating potential is applied to the plate, rectifying action takes place resulting in the conversion of the alternating to a direct current.

The mercury-vapor hot-cathode rectifier tube also operates on the theory of electronic emission from a hot cathode, with the exception that the tube is filled with a low pressure gas (mercury vapor) which enables operation at high voltages.   At low gas pressures the cathode evaporation is considered negligible and may be entirely avoided if the arc drop is maintained below a definite value.   The rectifying action of the tube is dependent upon an electronic emission from a cathode, which results in an ionized atmosphere between the cathode and the anode elements. The ionized atmosphere is the result of the collisions of emitted electrons with mercury-vapor atoms resulting in a disintegration of the gas atoms causing an ionic stream toward the cathode and a greatly increased electronic stream toward the anode (plate). The current is dependent upon the electronic emission from the cathode, which in turn is dependent upon the current passed through the tube.

The advantage of the mercury-vapor over the Kenetron tube is its better voltage regulation.   This is due to the mercury-vapor gas greatly reducing the space charge and the resultant constant arc-drop potential of approximately 15 volts.

In comparing the efficiency of the Kenetron with that of the mercury-vapor tube it has been found that the efficiency of the latter is approximately 99 per cent as compared to approximately 87 per cent for the former.

Ques. 543.   How would you know if your transmitter is on its assigned frequency?

Ans.   There are two accurate methods for checking the carrier frequency of a broadcasting transmitter as to its proper maintenance on its assigned frequency:

1. A direct check of the carrier frequency against a Government frequency standard receiving station or any other recognized receiving station having standard frequency measuring equipment.   (The R.C.A. Communications maintain frequency measuring stations at Riverhead, N. Y.; and at San Francisco, Calif. (Point Reyes), which will give an accurate frequency

check of any broadcasting transmitter in the United States at a nominal fee.)

2. A check against a precision frequency-monitoring unit as explained in Ques. 535. (A frequency-monitoring unit must be checked against a standard at least once a month to insure an accurate monitor maintenance on the assigned frequency.)

Ques. 544. Describe and explain the operation of some types of broadcasting antenna systems. State their advantages and disadvantages.

Ans. The most common types of broadcasting antenna used in the United States are the old type of horizontal radiators known as the flat top "T" or inverted " ⌐ " and the vertical or Hertzian radiator.

The flat-top variety generally consists of a horizontal network of wires varying in number anywhere from one to six parallel wires. These wires are properly insulated and supported by masts and guy wires. The earth is generally used as the ground system except in cases where the conductivity is very poor, in which instances special conductive networks or counterpoises are placed beneath the radiating system to complete the capacitive relationship to the antenna. The supporting guy wires must be broken up with insulators at strategic points to prevent harmonic radiation and resonance absorption.

The vertical or Hertzian radiator is a simple vertical wire or metal lattice-work insulated at the base and supported by guy wires. This is perhaps one of the most efficient broadcast radiators if properly designed, but one which requires extreme care in theoretical and mechanical design. The erection cost of this type of radiator at commercial broadcast frequencies makes its common use prohibitive.

The horizontal type of radiators as well as improperly designed vertical antennas have an electric field pattern which produces a high and low radiation-angle. This results in a wave disturbance toward both the sky and the ground simultaneously. Since the earth is a relatively poor conductor and as at night most of the energy toward the sky will be reflected by the Heaviside layer to the earth, heterodyne interference at distant points may be greatly increased. During the daylight periods this sky-wave

reflection is practically zero and all of the transmitted energy must take place along the earth. The objection to the common type of broadcast antennas, therefore, lies mainly in the interference caused by sky-wave (high-angle) radiation and ground-wave attenuation.

If the antenna system is so designed that the energy is decreased in the high-angle plane and concentrated into the low-angle plane, a considerable increase in ground-wave coverage will be obtained. This will increase the effective daylight transmission area and reduce the night interference at remote points due to sky-wave reflection. Fading conditions will also be greatly reduced by the adoption of low-angle radiators. In order to obtain this advantage of a gain in the low-angle or ground-wave at the expense of the sky-wave the physical dimensions of a vertical radiator must be increased above a quarter wave length, or to a $\frac{1}{2}$ wave radiator.

Another method for increasing low-angle radiation would be to use seven vertical antennas as $\frac{1}{4}$ wave antennas which are directive in a vertical plane, and by a careful adjustment of the amplitude and phase of the currents in the center and outside radiators the high-angle degree of radiation would be considerably reduced.

In the half-wave radiators such as are now used by several high-powered broadcasting stations the steel-metal lattice work is the actual radiating system. This tower may be 35 feet wide at its widest point, tapering uniformly to points at each end.

The tower rests, on end, on a hollow porcelain insulator, conical in shape, about 6 feet in height, weighing about 300 pounds.

Ques. 545. Describe the operation of the ribbon- or high-velocity-type microphone.

Ans. This type of microphone consists of a very light piece of aluminum foil corrugated and suspended between the poles of an electromagnet. The terminals of the aluminum ribbon are connected to a step-up transformer in which the secondary winding is connected to a resistance-coupled audiofrequency amplifier.

When a sound wave is set up in the vicinity of the aluminum foil diaphragm, two components are set up which are analogous to voltage and current. One of these is called the pressure point

and the other the air-particle velocity at the particular pressure point. The condenser type of microphone illustrated and explained in Ques. 394*f* records only the pressure of the air particles.

The essential theoretical difference in the performance of the two types is that the one type measures the sound pressure, which is non-directional, while the other measures the velocity of the air-particle disturbances or vibrations.

The main feature of this new type of microphone lies in its directional effect to particle vibration. That is to say, it will respond bilaterally only to waves to which it is in the position of maximum wave velocity. The response is zero when it is placed at right angles to this direction. This makes it a strictly velocity-responsive device and not a pressure device as is the case in most microphones.

Under similar conditions this type of microphone will generate voltages of approximately the same order as the dynamic-type microphone but very nearly twice the amount of that which a condenser microphone will deliver without its own voltage amplifier.

Ques. 546. Explain the operating procedure and how you would change the frequency of a broadcast transmitter. Give a detailed explanation.

Ans. The manner in which the frequency of the broadcast transmitter illustrated in Fig. 81 may be changed is as follows:

1. Change the crystal oscillator box to one corresponding to the newly assigned frequency. This box is adjusted to within 25 cycles of the assigned frequency by the Western Electric Co.

Care must be taken that the mercury column in the box is free to rise. This may be assured by slightly tapping the rear edge of the box on a desk or table.

2. Insert a new argon heater-regulator tube but leave the plate voltage disconnected until its filament has been heated for several minutes. Then close the plate-voltage supply.

A pilot light will show that the heater unit in the crystal box is being properly heated. It will take at least 2 hours before the box temperature is correct and the pilot light goes out. Read Ques. 394*i*.

3. During the two hours interim, calculate the radiation resistance of the antenna by the method illustrated in Fig. 87*i* (Ques. 394*r*).

4. Refer to the tuning-adjustment chart and connect coils, condensers, and links to correspond to the desired frequency.

5. Close all door switches by closing doors and place the master switch in starting position. Various time-delay relays will close in gradual succession but only after the bias rectifier tubes are in operation. This prevents any possibility of the plate voltage being applied before the bias potential is completed.

6. The first amplifier or buffer stage requires no tuning adjustments or neutralization because of its aperiodically tuned plate-circuit transformer. This transformer effectively covers the broadcast frequencies of from 500 to 1,200 kc/s.

A variable resistance controls the bias voltage on the grid of this tube and incidentally is the main radiofrequency drive control for the succeeding amplifier tubes.

7. Neutralize the second radiofrequency amplifier by opening the 3rd amplifier plate-supply switch and closing the 2nd amplifier plate-supply switch. (Switches are not shown on the diagram in Fig. 81 for simplification.)

Close the "high-voltage" supply switch on the 12A transmitter panel and note the plate-current reading of the milliammeter. Adjust the tuning condensers which are connected across L_4 until the plate milliammeter shows a maximum drop. This is a preliminary tuning adjustment before neutralizing; and should difficulty be encountered in the adjustment, then the neutralizing condenser should be shifted slightly. It was assumed that the neutralizing condenser was approximately one-fourth engaged.

The second stage is now prepared for neutralizing, but it is advisable in this case to proceed with the neutralization of the 3rd amplifier first to simplify matters.

8. Open the "high-voltage" supply switch and open doors.

Set the neutralizing condensers on the 3rd amplifier stage so that they are a little less than one-half engaged. Insert a thermo-galvanometer and thermo-couple into the plate mesh circuit C_7L_6. Close the panel doors and adjust the radiofrequency drive to a minimum position and loosen the magnetic coupling of L_6L_7. Close the "high-voltage" supply switch and begin to

vary the 3rd amplifier tuning condensers across L_6 until the radiofrequency ammeter in this mesh circuit reads maximum. If no reading is obtained, increase the radiofrequency drive. Also vary the mesh tuning condensers. An excessive reading will require an increase in the capacitance of the neutralizing condensers until the reading drops to a low value. Continue to increase the radiofrequency drive but keep adjusting the neutralizing condensers so that the mesh current does not exceed $\frac{3}{4}$ ampere.

Both the 2nd and 3rd amplifier tuning condensers must then be varied until a maximum current is indicated in the radio-frequency-mesh-circuit ammeter. Then vary the 3rd amplifier neutralizing condensers until the radiofrequency ammeter in the mesh circuit reads zero.

9. The 2nd amplifier may then be neutralized by opening the "high-voltage" switch and reducing the radiofrequency drive to a minimum.

Open the plate-supply switch to the 2nd amplifier and close the plate-supply switch to the 3rd amplifier. Close the "high-voltage" supply switch and vary the radiofrequency drive together with the neutralizing condenser until the radiofrequency ammeter in the 3rd amplifier mesh circuit reads about $\frac{3}{4}$ ampere. Adjust the 2nd and 3rd amplifier tuning condensers until the 3rd amplifier radiofrequency mesh meter reads a maximum. Then vary the 2nd amplifier neutralizing condenser until this meter reads minimum. The radiofrequency drive should then be increased to a maximum and the 2nd amplifier neutralizing condenser adjusted until no reading is obtained at the radio-frequency meter in the 3rd amplifier mesh circuit.

10. The power amplifier stage may now be neutralized by reducing the magnetic coupling between L_8 and L_9 and increasing the capacity of the power-stage neutralizing condensers to about one-fourth capacity.

Apply the plate voltage by closing the "high-voltage" switches on both the 12A and the 71A amplifier unit.

Increase the radiofrequency drive and vary the power-amplifier tuning condenser across L_8 until the radiofrequency ammeter in the plate mesh $C_T L_8$ reads about $1\frac{1}{2}$ to 2 amperes. Increase the capacity of the neutralizing condensers until the reading of the

power-amplifier radiofrequency ammeter in the $C_T L_8$ mesh reads at, or very nearly, zero.

The entire transmitter may now be tuned for maximum efficiency by adjusting the various amplifier stages to the proper load and resonant conditions. All stages with the exception of the 1st amplifier and antenna circuits indicate a resonant condition when a minimum plate current is obtained in the tube whose tuned circuit is being adjusted. Great care should be taken in tuning the 2nd and 3rd amplifier so that they will not be resonant to the second-harmonic frequency of the carrier.

11. No tuning adjustments are necessary in the first amplifier circuits, since all condensers and coils are of the fixed or untuned variety. The 2nd amplifier is tuned for a maximum dip in the plate current by varying the condensers C_T across L_4.

The 3rd amplifier output circuit is then adjusted for the desired input to the power-amplifier tubes.

12. Open the plate-supply voltage of the 71A unit (power-amplifier stage) and insert the full power-input resistance across the grids of the power-amplifier tubes. Close the plate-supply voltage of the 12A unit and tune condensers C_T across L_6 until the radiofrequency ammeter in this mesh reads a maximum value. Adjust the radiofrequency drive so that this meter does not exceed 1.5 amperes. Vary the coupling of $L_6 L_7$ and adjust the power-amplifier input-control condenser C_T across L_7 until the radiofrequency ammeter in the $C_T L_6$ circuit reads a minimum. Increase the coupling of $L_6 L_7$ and the radiofrequency drive until the radiofrequency ammeter in the $C_T L_7$ circuit reads about 1 ampere and the radiofrequency ammeter in the $C_T L_6$ circuit drops between 0.8 and 1.3 amperes. The plate current of the 3rd amplifier stage at this point should read between 125 and 160 milliamperes. Then adjust C_T across L_6 for a minimum plate-current reading in this stage.

13. Before proceeding with the output tuning of the power-amplifier stage it will be necessary to adjust the radiofrequency drive so that the grids of the power-amplifier tubes receive the proper excitation.

This is accomplished by inserting a radiofrequency ammeter in series with the resistances (2,400 ohms) which are across the power-amplifier grids.

Assuming 100-watt excitation, the radiofrequency drive is increased until the radiofrequency ammeter in the resistance circuit reads a little less than .22 amperes. Thus $W = I^2R$ or 100 watts. Accurate power-amplifier grid excitation may thus be obtained for any power up to 1,000 watts in this transmitter.

14. The output circuit of the power amplifier may then be tuned as follows: Adjust the harmonic suppression coil to the reactance value which will offer a minimum impedance to the desired carrier frequency and a maximum impedance to the second-harmonic frequency. This value is obtained by referring to the calibration chart accompanying the transmitter. Close the power-amplifier plate-supply circuit. The plate current in this circuit should read very nearly 0.3 ampere.

Vary the radiofrequency drive until the radiofrequency ammeter in the $C_T L_8$ mesh reads approximately 2 amperes. At this point recheck the 3rd amplifier plate current by varying C_T across L_6 until the plate current in this stage is of minimum value.

Vary C_T across L_8 for maximum current in the $C_T L_8$ radiofrequency mesh. Increase the output coupling slightly and vary the antenna tuning condenser in series with the harmonic suppression coil until the radiofrequency ammeter in the plate mesh reads a minimum.

15. Increase the coupling of $L_8 L_9$ and vary the radiofrequency drive until all meter readings in the power-amplifier output circuit correspond with the required manufacturer's ratings for a given power output.

16. If the antenna resistance was found to be 50 ohms, then the radiofrequency drive should be adjusted to cause the antenna ammeter to read 3.2 amperes, or an input power of a little over 500 watts. In accordance with the Federal Radio Commission regulations, the operating power of a transmitter may be calculated by the formula $E_P \times I_P \times F$ (see Ques. 394r). Since this transmitter employs the low-level system of modulation and is capable of modulating the carrier frequency between 86 and 100 per cent, the operating power is readily obtained by the product of $E_P \times I_P \times F$, which in this case is $3,000 \times 0.52 \times 0.33 = 512$ watts (approximately).

The correct plate-current values are obtained by careful adjustments of the plate voltages in the various stages and the critical

variations of the load constants due to the *LC* ratios and reflected impedances (load-impedance changes due to magnetic coupling reactions).

These values are correctly maintained if all adjustments are carried out to conform with the mechanical adjustments described and by careful reference to the manufacturer's instruction sheets.

Although the above procedure of tuning a transmitter is applicable only to the Western Electric unit illustrated in Fig. 81, the entire procedure would in general be applicable to any similar type of high-quality broadcasting transmitter.

Ques. 547. State the advantage of a class B modulating system over any other type at the present time.

Ans. The efficiency of this system is considerably greater than that of class A modulators, because the plate-current flow in the class B system is very little during the period in which no grid voltages are applied, thus greatly reducing input plate-power expenditure.

It has been found that with a class A modulator system feeding into a class C amplifier only 34 per cent of the total input power is obtained in the carrier wave, while in the class B system under similar amplifying conditions approximately double of the total input is obtained in the carrier wave.

Ques. 548. What type of amplifier is preferable in a final power stage?

Ans. Any final power stage operating as a class B or C amplifier may be used effectively, preferably a class C.

Ques. 549. What is meant by the term "linear amplifier"?

Ans. A linear amplifier is one in which the power output is proportional to the square of the excitation grid voltage. The class B amplifier is frequently classified as a *linear amplifier*.

Ques. 550. Why is it essential to use two tubes in a class B audiofrequency amplifier and why is this not necessary in a class B radiofrequency amplifier?

Ans. In the audiofrequency circuit the class B or "push-push" amplifier requires two tubes to accommodate both halves

of the cycle, while in a class B radiofrequency amplifier the tube takes care of one-half and the radiofrequency mesh (*LC*) circuit takes care of the other half of the cycle owing to the "fly-wheel effect" of the circuit. It is advisable, however, in radiofrequency circuits to use a push-pull arrangement to provide a better circuit balance and stability, particularly in broadcast class B radio-frequency amplifiers.

Ques. 551. What is the maximum percentage of second-harmonic content permitted in a broadcasting transmitter?

Ans. The second-harmonic content must be sufficiently suppressed by trap or suppressor circuits to within 0.05 per cent of the fundamental carrier frequency. In terms of field-strength measurements the absolute limit of the second harmonic must be 500 microvolts per meter, and, whenever possible, every effort should be made to keep well within this figure.

Ques. 552. State the operating voltages, plate currents, and power ratings of a standard high-quality broadcasting transmitter and speech-input equipment.

Ans. The following are the approximate operating voltages and currents of the Western Electric type 12A-71A (1-kilowatt) transmitter and 9A speech-input equipment. (Figs. 80 and 81.)

All readings represent the actual working voltages and currents of the transmitter when operating at 500 watts.

DESCRIPTION OF SPEECH-INPUT EQUIPMENT

The low-level 69A amplifier contains two type 262A amplifier tubes operating at a plate potential of 90 volts and a plate-current consumption of 2.5 milliamperes per tube.

The high-level 70A amplifier contains one 262A tube operating at a plate potential of 150 volts and a plate current of 4 milli-amperes. The output stage is a push-pull arrangement which modulates the 3rd amplifier (class C) in the transmitter. Two type 205E tubes having a maximum continuous power output rating of 15 watts each are operated at a plate potential of 350 volts and a plate current of 23 milliamperes each. The *undistorted* power output of these tubes is approximately 0.25 watt or +16 decibels.

The filaments of both amplifiers are alternating current heated; the 262A operating at 10 volts and the 205E at 4.5 volts.

The entire unit is biased to operate as a class A amplifier, the tubes in the 69A operating at $E_c - 6$ volts and the 205E in the 70A amplifier at $E_c - 25$ volts.

DESCRIPTION OF TRANSMITTER

The crystal oscillator uses a type 271A tube which operates at a plate potential of 130 volts and draws a plate current of 7 milliamperes. The 1st amplifier uses a type 271A tube which operates at a plate voltage of 300 volts and draws a plate current of 6 milliamperes. The 2nd amplifier uses a type 242A, 50-watt amplifier tube operating at a plate potential of 1,500 volts, a plate current of 34 milliamperes, and a grid bias of -100 volts.

The 242A tube in the 2nd amplifier stage has been changed in some installations to 2-271A cathode-heater tubes connected in parallel. These tubes operate at a plate potential of 350 volts, plate current of 12 milliamperes, and grid bias of -75 volts. The 3rd amplifier or modulated radiofrequency stage uses two 270A tubes (350 watts each) operating as a class C amplifier at a plate potential of 3,000 volts, a total plate current of 125 milliamperes, and a grid bias of -250 volts. These tubes are adjusted to a 100-watt output.

The final, or power-amplifier, stage uses two type 279A tubes (rated at 1,200 watts each) operating as a class B amplifier with a plate potential of 3,000 volts, a total plate current of 0.52 ampere, and a grid bias of -275 volts.

The filaments of the entire transmitter are alternating current operated through the medium of single-phase power transformers. The filament-operating voltage of the 271A tubes is 5 volts, and the 242A, 270A, and 279A are all operated at 10 volts.

Ques. 553.   Explain how the tubes are lighted in a given type of broadcast transmitter.

Ans. In the Western Electric broadcast transmitter type 12A (shown in Fig. 81) the oscillator and 1st amplifier tubes are of the cathode-heater types (Western Electric 271A) lighted by a filament transformer. The cathodes are connected directly to ground and the secondary of the filament transformer is

center-tapped and grounded. All the other tubes are filament-type tubes connected directly to the secondary of a filament transformer. A shunt resistance, the center of which is grounded, is connected across the filament. A bypass condenser is connected from the resistor center-tap to each leg of the filament. This method is shown in Fig. 90, in the radiofrequency circuits.

Ques. 554. What rectifier tubes are used in the transmitter referred to in the preceding answer?

Ans. Plate rectifier tubes are Western Electric type 258A having a maximum inverse-peak potential of 6,500 volts. Grid-bias rectifier tubes are Western Electric type 253A having a maximum inverse-peak potential of 3,500 volts. Both types are mercury-vapor tubes. Type 253A tubes are used in this transmitter in the rectifier unit 3, and type 258A tubes are used in the plate-supply rectifier units 1, 2, and 4. Filament voltage of both types is 2.5 volts. The peak plate current of type 253A is 500 mils; of type 258A 1.1 amperes.

Ques. 555. Explain how the Western Electric 12A and 71A transmitter units are protected by relays and fuses. How are the transformers connected?

Ans. The transmitter illustrated in Fig. 81 should include several overload relays and fuses in the proper circuits to insure maximum protection. These have been purposely omitted from the diagram in order to simplify studying procedure. For examination purposes they should be drawn in as explained below.

A three-pole single-throw switch should be inserted in the power-supply system at the point marked 3 Phase 220 V. 50-60 cycle A.C. Power Supply to illustrate an electrical starting arrangement of the transmitter. A fuse should be inserted in each leg of the three-pole single-throw switch blades. This three-pole single-throw switch is the main starting switch which controls the entire transmitter by operating several thermal time-delay and magnetic relays at the proper intervals. These relays may be inserted in the diagram as simple single-pole single-throw switches as illustrated in the power-supply unit of the 2-B rectifier unit (Fig. 93). Then place an iron-core coil beneath each switch

with the ends open to illustrate the exciting magnet for operating the relay.

Fuses and relays should be connected in Fig. 81 as follows: Connect a fuse link in series with the primary windings of all power transformers in the following circuits.

TRANSFORMERS

(some of which are not shown on diagram)

One transformer has its primary connected across the two outside wires of the three-phase system. The secondary of this transformer supplies the regulator-tube filament, bias, and plate voltages shown in Fig. 87c. This unit should be drawn as part of Fig. 81 for examination purposes.

Another transformer has its primary winding connected across the center and an outside phase of the supply line. This transformer has five secondary windings. One lights the two grid-bias rectifier tubes in unit 3, one lights the three lower rectifiers in unit 4, and the remaining three secondary windings each light one of the three upper rectifiers in unit 4.

Another transformer has its primary connected to the center and the other outside phase of the supply line. It has three secondaries. One lights the oscillator and the 1st amplifier tubes in parallel, one lights the 2nd amplifier tube, and the remaining secondary lights the rectifier filaments of unit 1.

Another transformer has its primary winding connected in parallel with the previous transformer and its secondary operates the filaments of the two 3rd-amplifier tubes.

Another transformer primary is also connected in parallel with the previous two and its secondary is made up of three separate windings, one winding lighting the two lower rectifier tubes in unit 2, and the other two windings each lighting one of the upper two rectifier tubes in this unit.

Another transformer has its primary winding in parallel with the center and other outside phase of the supply line and its secondary lights the two power-amplifier tubes.

The four high-potential transformers have their primary and secondary connections illustrated in Fig. 81. A fuse should also be connected in each of the plate-supply leads at the high side of

the filter choke and in the plate-return lead to ground. In other words, connect a fuse link in the number 2 and 4 rectifier units where the plates are connected together, and locate the fuse in series with the plates and the ground.

An overload relay must be inserted at the same points in series with the fuses, between the plates and the ground in the 2 and 4 units. Simply draw an iron-core coil and mark it "overload relay."

Ques. 555a. Draw an elementary diagram of a relay system such as is used in the power supply circuits in a modern broadcast transmitter.

Ans. Fig. 96(*a*) illustrates a schematic arrangement of the overload and time delay relays in the power amplifier unit of the Western Electric 1 KW transmitter.
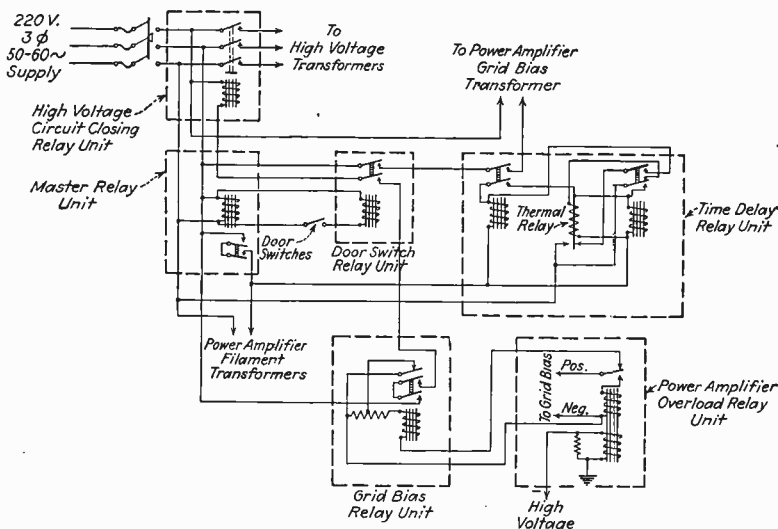
FIG. 96a.—Relay system, power supply of broadcast transmitter.

Ques. 556. Describe a monitoring output in a broadcast transmitter.

Ans. There are two methods of monitoring a program. They are described as follows: (1) a visible method using a vacuum-tube voltmeter or an oscillograph; (2) an audible method

using a rectifier and loud speaker, or a loud speaker operating without a separate rectifier.

The second method is the more commonly employed in broadcasting stations. In this method a loud-speaker unit is operated by a tube which is closely coupled to the transmitting circuit, and which, during modulation, picks up the voice frequencies, thereby indicating that the carrier is being modulated.

In the Western Electric transmitter type 12A shown in Fig. 81 a loud-speaker monitor which does not require a separate rectifier tube, is provided. The loud speaker is operated directly by the asymmetrical or rectified variations taking place in the power-amplifier stage during the period in which the modulations are taking place. This is accomplished by shunting an audio-frequency transformer primary in series with a condenser across a resistance which is connected in series with the filament center-tap and ground. As the audiofrequency modulations take place across the resistance, they pass through the condenser and transformer primary. They are then induced into the transformer secondary to which is connected a dynamic-type loud speaker. A double-pole double-throw switch is provided on the speech-input equipment, by means of which the loud speaker may be transferred from the output of the 9A speech-input equipment (Fig. 80) to the transmitter or *vice versa*.

Ques. 556a. How can you determine quickly when amplifiers are out of adjustment?

Ans. By carefully checking the various plate- and tank-current circuit readings and comparing them with their normal operating conditions. All stages should indicate a *minimum* plate-current dip when their respective tank circuits are properly adjusted. See also Ques. 546.

Ques. 556b. How are emission tests of vacuum tubes taken and what do these tests indicate?

Ans. Emission tests are taken by applying a steady voltage to the plate of the tube and connecting a milliammeter in the plate circuit. A normal operating grid bias is also applied, and the comparative reading of the ammeter is noted. If the proper emission is taking place, a definite change of plate current will

result. This relative reading must be within certain limits if the filament is emitting properly. Low variations indicate a deactivated filament. If the plate current at normal voltage readings is excessive, then the tube is apparently gaseous and should be discarded.

Ques. 556c. How do you adjust a transmitter circuit to change the percentage of modulation?

Ans. Assuming that the transmitter has been properly designed and is capable of 100 per cent modulation, the percentage of modulation may be changed by carefully adjusting the load impedance of the modulated radiofrequency amplifier stage. For example, if the load impedance is increased or decreased, the percentage of modulation may be either decreased or increased. The modulation percentage may also be very quickly increased by increasing the grid excitation of the modulated radiofrequency amplifier tube or tubes as the case may be. This, of course, assumes that the proper operating E_p and E_c characteristics are maintained for the desired modulation percentage and output power.

Ques. 556d. How are amplifiers adjusted?

Ans. Amplifiers are adjusted to maximum efficiency by operating them at their proper plate voltages, plate currents, and tank currents. Proper bias voltages are also necessary to govern the tube functions as Class A, B, or C amplifiers, to give the proper dip in plate currents when the tank circuits are adjusted to resonance, and the proper neutralization of interelectrode tube capacity.

Ques. 556e. Explain the effect when using an input filtercondenser in a mercury-vapor rectifier system.

Ans. Mercury-vapor rectifiers are rated according to their safe inverse-peak voltage and current-carrying capacity. For example, assume a full-wave rectifier system using two mercury-vapor tubes operating at a plate potential of 3,000 volts on each side of the center tap. Both filaments are operating in parallel at a potential of 2.5 volts.

When one tube is rectifying, the voltage drop across the cathode and plate will be about 15 volts since the arc drop for most loads is practically constant, varying only between 12 and 17 volts. Hence the effective voltage between the center tap and plate will be 3,000 minus 15 volts, or very nearly the full anode voltage. The other tube, however, will have its anode at a negative potential of 3,000 volts with respect to the filament. Thus when one tube is rectifying, the opposite one will be subjected to the entire transformer voltage of the secondary, or very nearly 6,000 volts effective.

Now if a condenser is used in the filter section, directly after the rectifier tube, the peak current will by necessity be extremely high, in order to maintain the load current on that portion of the cycle when the tube is not delivering current. Under this condition it is very probable that the output voltage of the filter will be quite high and the peak current may rise to a value greatly in excess of the load current. Consequently the current passing through the mercury-vapor tube may reach such an excessive value that the tube will be ruined. It is, therefore, advisable to eleminate an input filter-condenser in all rectifier systems using mercury-vapor tubes and use only a choke coil in the first section of the filter unit.

Ques. 556*f*. Explain the meaning of the standing-wave effect in a radio transmission line.

Ans. Standing waves are generally referred to as electrical or magnetic reflections from the point of termination in a line back to the source of excitation. This condition is prevalent in any transmission line in which the load or terminating impedance of the line is improperly matched. The impedance introduced into a line to prevent reflections or standing waves is generally known as the characteristic or surge impedance.

Ques. 556*g*. Draw diagrams of and explain the theory and operation of attenuation networks.

Ans. Figure 97 illustrates three different types of attenuating networks.

Figures (*a*) and (*c*) show the commonly known "pad" and impedance-matching systems generally used to introduce a

definite circuit loss or attenuation in the form of resistance from one circuit into another. The proper input and output impedance relationship may also be obtained by the use of these networks.

(a)	(b)	(c)
"H" Pad	Series Resonant	"T" Pad
Attenuator	Attenuator	Attenuator
	or	
	Equalizer	
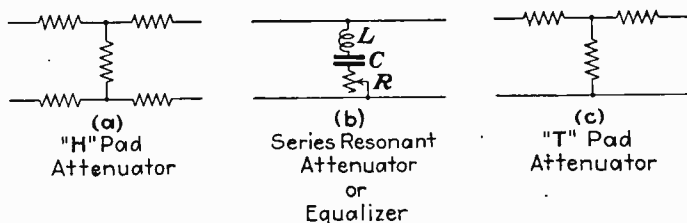
FIG. 97.—Attenuating Networks

For the calculation of losses to be introduced and the proper impedance matching, see Ques. 394*p*.

Figure (*b*) illustrates the series resonant circuit, or series equalizer, which is often used where it is desired to eliminate or attenuate certain frequencies or a small band of frequencies.

When a series resonant circuit is connected across a line it serves to by-pass the frequency to which it is resonant (tuned) because the inductive reactance X_L and the capacitive reactances X_c are equal and opposite at this particular frequency. Hence since the effective reactance will be zero the total effective impedance across the LC combination will also be practically zero and practically no voltage will be developed across the combination.

In other words, a series resonant circuit may be defined as a low-impedance resonant circuit.

RECEIVING APPARATUS

Ques. 557. Give three ways of connecting a wave trap in a receiver.

Ans. Three methods of connecting a wave trap in a receiver are:

1. A parallel resonant circuit of L and C in series with the antenna lead-in circuit.

2. A series resonant circuit of L and C shunted across the primary winding of the antenna radiofrequency transformer.

3. A parallel resonant circuit of L and C inductively coupled to the primary or secondary circuit of the radiofrequency transformer.

Wave traps should be completely shielded by a grounded shield to obtain maximum efficiency.

Ques. 558. In a resistance- or impedance-coupled amplifier what is the result of a leaky coupling condenser?

Ans. This would result in the application of a positive bias to the grid of the amplifier tube, causing a considerable increase in the plate current and totally changing the $I_p E_c$ operating curve. This would reduce the input grid impedance to the amplifier and might render the amplifier practically inoperative.

Ques. 559. Draw a diagram of a two-stage alternating-current audiofrequency amplifier, showing grid and plate filtering system.

Ans. For a high-quality two-stage audiofrequency amplifier using grid and plate filtering systems use the high-level speech amplifier 70A, as given in Fig. 80.

Ques. 560. What is the purpose of a C bias?

Ans. The C bias governs the operating characteristic of the tube when it is used as a power detector or an amplifier by regulat-

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ing the point on the I_pE_c curve at which the tube shall be worked. The C bias also serves to reduce the grid current in an amplifier tube, thereby maintaining a higher relative input impedance and raising the efficiency of the circuit as a whole.

Ques. 561. How are radio signals intercepted from an antenna?

Ans. Radio signals are intercepted from the antenna and delivered to the grid circuit of the first radiofrequency tube by a system of magnetic or electrostatic coupling. This coupling may be accomplished by any one of three methods, namely, direct-magnetic coupling, inductive-magnetic coupling, or capacitive coupling.

Ques. 562. In a condenser-grid leak detector why are signals of a high-percentage modulation generally distorted?

Ans. Detectors using the grid-condenser grid-leak method of detection are generally much more apt to produce signal distortion when receiving high-percentage modulated signals, because they follow a square-law output. This results in a second harmonic of the modulation frequency in the output or plate circuit which is equal to $\frac{1}{4}m^2$, where m is the percentage of modulation of the receiver carrier. In other words, a detector having this characteristic will produce considerable distortion when receiving high-percentage modulated signals due to the fact that the relation between the modulated radiofrequency input and the audio-frequency output is not a linear reproduction of the signal wave shape.

Even negatively biased detectors will follow the same square-law and result in distortion unless high plate and bias voltages are used. Under the latter conditions the input and output may become more approximately linear, but the ideal condition of perfect linearity cannot be expected.

Ques. 562*a*. Draw a diagram of a two-stage audio amplifier showing a wave filter.

Ans. See Fig. 80. Draw the high-level speech amplifier unit 70A and connect it to the plate and filament power-supply unit. Omit the low-level speech amplifier.

RADIO LAWS

Ques. 563. What must be done before a transmitting station is constructed?

Ans. With the exceptions hereinafter noted, no license will be granted by the commission for the operation of any station unless a permit for its construction has been granted previously by the commission upon written application therefor. The exceptions to the foregoing are: (*a*) amateur stations; (*b*) stations upon mobile vessels; (*c*) stations upon railroad rolling stock; (*d*) stations upon aircraft; and (*e*) stations the construction of which was completed prior to Feb. 23, 1927.

Ques. 564. What percentage of modulation of carrier frequency is required at broadcasting stations?

Ans. A licensee of a broadcasting station will not be authorized to operate a transmitter unless it is capable of delivering satisfactorily the authorized power with a modulation of at least 75 per cent. When the transmitter is operated with 75 per cent modulation, not over 10 per cent combined audio-frequency harmonics shall be generated by the transmitter.

Ques. 565. What is the law regarding equality of time on the air for political candidates?

Ans. Section 18 of the Radio Act of 1927 provides as follows:

If any licensee shall permit any person who is a legally qualified candidate for any office to use a broadcasting station, he shall afford equal opportunities to all other such candidates for that office in the use of such broadcasting station, and the licensing authority shall make rules and regulations to carry this provision into effect:

Provided, That such licensee shall have no power of censorship over the material broadcast under the provisions of this paragraph. No obligation is hereby imposed upon any licensee to allow the use of its station by any such candidate.

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Any violation of this section of the act shall be sufficient grounds for the revocation or denial of a broadcast license.

Ques. 566. What is the regulation regarding the keeping of log records at a broadcasting station?

Ans. The licensee of each broadcasting station shall maintain program and operating logs and shall require entries to be made as follows:

A. PROGRAM LOG

(*a*) An entry of the time each station and call announcement is made, with an indication of the type of announcement.

(*b*) An entry briefly describing each program broadcast, such as "music," "drama," "speech," etc., with the time of the beginning and ending. If a mechanical reproduction is used, that fact shall be noted, together with an indication whether or not announcement thereof was made. If a speech is made by a political candidate, the name and political affiliations of such speaker shall be entered.

B. OPERATING LOG

(*a*) An entry of the time the station begins to supply power to the antenna and of the time it stops.

(*b*) An entry of the time the program begins and ends.

(*c*) An entry of each interruption to the carrier wave, its cause and duration.

(*d*) An entry of the following each 30 minutes:

      (1) Operating constants of last radio stage (total plate current and voltage).

      (2) Antenna current.

      (3) Frequency check.

      (4) Temperature of crystal control chamber.

Each log shall be kept by the person or persons competent to do so, having actual knowledge of the facts required, and they shall sign the log when starting duty and again when going off duty. The logs shall be made available upon request by authorized Government representatives.

The exact form of the logs is not prescribed, but they shall be kept in an orderly manner and in such detail that the information required is readily available. Key letters or abbreviations may be used if the explanation of each is given plainly in the log.

Ques. 567. What is the law about announcing call letters every 30 minutes?

Ans. Each licensee of a broadcast station shall announce the call letters and location as frequently as practicable during the hours of operation and in any event before or after each program being broadcast. In no event shall more than 30 minutes elapse between such announcements, and in so far as is practicable such announcements shall be made on the hour and half hour. These requirements are waived when such announcements would interrupt a single consecutive speech; and in such cases the announcement of call letters and location shall be made as soon as possible.

Ques. 568. What is the law about the censoring of radio programs?

Ans. The licensee shall have no power of censorship over political broadcasts if given over its station.

Furthermore, the Radio Act of 1927 provides as follows:

Nothing in this act shall be understood or construed to give the licensing authority the power of censorship over the radio communications or signals transmitted by any radio station, and no regulation or condition shall be promulgated or fixed by the licensing authority which shall interfere with the right of free speech by means of radio communications. No person, within the jurisdiction of the United States shall utter any obscene, indecent, or profane language by means of radio communication.

Ques. 569. State the old and new regulations regarding the maintenance of a distress-signal watch at broadcasting stations.

Ans. The old regulations required that a licensed commercial operator listen in on the distress frequency (500 kc/s, 600 meters) during the entire time the broadcasting station was on the air. The new regulations are covered by Sec. 22 of the Radio Act of 1927, which read as follows:

The licensing authority is authorized to designate from time to time radio stations the communications or signals of which, in its opinion, are liable to interfere with the transmission or reception of distress signals of ships. Such stations are required to keep a licensed radio operator listening in on the wave lengths designated for signals of distress and radio communications relating thereto during the entire period the transmitter of such station is in operation.

Ques. 570. Give an outline of the Radio Act of 1927.

Ans. The act applies to the United States, its Territories and possessions. It regulates all radio communication, divides the United States into five zones, and establishes the Federal Radio Commission with certain duties and powers. It exempts certain Government stations from commission control and designates special call letters for certain Government-owned stations.

The act provides for compensation to owners of private stations taken over by the Government during a national emergency.

In the matter of station licenses and construction permits it provides for the granting of, renewal of, application for, restriction of, transfer of, refusal of, revocation of, and the right to appeal commission decisions regarding station licenses. It requires all stations to get a construction permit before granting it a license.

It furthur provides certain safeguards against restraint of trade and prohibits control by radio combinations of other electrical communication facilities.

The act guarantees free speech and equality of time on the air for all political broadcasts and prohibits censoring of political broadcast material by the licensee. It prevents the licensing authority from censoring any radio communications but prohibits the utterance of any obscene, indecent, or profane language by radio.

The act requires also that stations announce the names of program sponsors and their own call letters and location at least every 30 minutes unless such announcement interrupts a consecutive speech, when it may be made at the end of the speech.

It requires that a licensed operator do the actual operating of all radio transmitters and gives the radio commission power to designate certain stations which must maintain a listening watch on the marine-distress frequency.

It requires emergency apparatus on certain classes of vessels and requires all shore stations to communicate with all vessels at sea regardless of nationality or radio system employed.

The act further requires a silent period to be observed by private and commercial stations in the vicinity of government stations when the latter are subject to interference from the former. It requires that only the minimum power necessary be used to establish radio communication under all except distress conditions.

It requires all persons who may intercept a private message to keep it secret except that it may be delivered to the addressee. It prohibits the transmission of false or fraudulent distress signals and unauthorized rebroadcasting.

It provides for the use of naval stations for the transmission and reception of commercial paid radio traffic under certain conditions and defines the expression "radio communication(s)." It provides penalties for violating the act itself or the rules of the licensing authority. It eliminates the Philippine Islands and the Canal Zone from the provisions of the act.

It further provides for enforcement of the act by any designated Government employee and provides for a certain appropriation for the administration of the act. It declares all parts of the act effective except those declared invalid and repeals the old Act of August 13, 1913. It further declares the act effective when passed and approved and that it shall be referred to as the Radio Act of 1927.

GENERAL THEORY

Ques. 571. How is power computed in an alternating-current circuit? Why is the direct-current formula Watts = EI not applicable to alternating-current circuits?

Ans. Power dissipation in single-phase alternating-current circuits is computed by the formulas $W = I^2R$ or $W = EIpf$, where *pf* is the power factor.

The direct-current formula $W = EI$ is not applicable to alternating-current circuits containing inductance and capacity because of the individual reacting effects of these properties which change the phase relationship between the current and the voltage in the circuit—that is to say, the current and voltage do not reach their peaks at the same instant but are either leading or lagging with respect to one another. In the alternating-current circuit containing capacity only, the current leads the voltage by a certain number of degrees depending upon the direct-current resistance of the circuit. If the circuit had zero resistance, the current would lead the voltage by 90 degrees; but since all circuits contain some resistance, the angle of lead is reduced to a lesser value.

The leading effect of the current due to capacitance in the circuit is called capacitive reactance and is expressed by the ratio

$$X_c = \frac{1}{2\pi fc}$$

where X_c = capacitive reactance in ohms

π = 3.1416

f = frequency in cycles per second

C = capacity in farads

From this it can be seen that the effect of the capacity reactance on the current flow varies indirectly with frequency. Therefore, the reactance due to a capacity effect decreases with an increase in frequency.

In alternating-current circuits containing inductance only, the current lags behind the voltage by a certain number of degrees depending again upon the direct-current resistance of the circuit. Thus the angle of lag depends upon the ratio of the circuit reactance to the circuit resistance.

The inductive reactance is found by the formula

$$X_L = 2\pi f L$$

where X_L = inductive reactance in ohms
$\pi = 3.1416$
f = frequency in cycles per second
L = inductance in henries

It will be noticed that inductance has an entirely different effect on the circuit than has capacity, in that the reactance due to an inductance (inductive reactance) increases with frequency, and *vice versa*, causing the current flow to vary inversely with the frequency.

Now, since power represents the rate at which energy is expended in heat, it would seem logical that the product of the voltage times the current ($W = EI$) should be the total expenditure of the power in the circuit. This is true only if the current and voltage are in exact phase relationship to each other—that is to say, if the voltage and current reach their maximum and minimum values at exactly the same instants. However, owing to the reacting effects of either an inductance or a capacity, the current and voltage are out of phase with one another and this must be taken into consideration in the computation of the power expended in a circuit.

Therefore, to compute the power expended in an alternating-current circuit, the ratio of the total circuit reactance to the circuit resistance must first be determined. This ratio is called the power factor of the circuit, or cos ϕ, which equals the resistance of the circuit divided by the impedance of the circuit.

Thus, for an alternating-currrent circuit

$$W = E \times I \times pf. \text{ (Single phase)}$$
$$W = E \times I \times pf \times \sqrt{3} \text{ (Three phase)}$$

Ques. 572. What are capacitive and inductive reactance?

Ans. Capacitive reactance is the opposition offered to the flow of an alternating current by the capacity in the circuit.

Inductive reactance is the opposition offered to the flow of an alternating current by the inductance in the circuit.

Both capacitive and inductive reactance tend to oppose the flow of current in the circuit. Capacitive reactance results in a leading effect of the current of the voltage, while inductive reactance, conversely, results in a lagging effect, as explained in the preceding answer. Reactance, capacitive or inductive, is expressed in ohms.

Ques. 573. If the capacitive reactance equals the inductive reactance in a circuit, what governs the current flow in the circuit?

Ans. In a circuit of this kind the current flow is governed by the direct-current resistance of the circuit.

Ques. 574. How is the power factor in an alternating-current circuit computed?

Ans. The power factor in an alternating-current circuit may be computed by the ratio of the resistance divided by the impedance of the circuit, $\dfrac{R}{Z}$.

Ques. 575. Under what conditions has a circuit unity power factor?

Ans. A circuit can have unity power factor under conditions of resonance when the capacitive and inductive reactances of the circuit are equal or when resistance only is present in the circuit. For example, a resonant oscillating circuit has unity power factor; so also has a bank of lamps connected to an alternating-current circuit.

Ques. 576. What factors determine the phase difference between current and voltage in alternating-current circuits?

Ans. The phase angle in alternating-current circuits may be determined by any of the following relations:

$$\cos \phi = \frac{R}{Z} \qquad \sin \phi = \frac{X}{Z} \qquad \tan \phi = \frac{X}{R}$$

where ϕ = phase angle
R = resistance
X = reactance
Z = impedance

Ques. 577.   How does the resistance of conducting materials vary with an increase in temperature?

Ans. The resistance of all conducting materials, with the exception of carbon and electrolytes, increases with an increase in temperature.

Ques. 578.   What are two low-resistance metals?   Two high-resistance metals?

Ans. Two low-resistance metals are copper and silver.   Two high-resistance metals are manganin and nichrome.

Ques. 579.   Define conductance, susceptance, admittance, and impedance.

Ans. Conductance, susceptance, and admittance are the reciprocals of resistance, reactance, and impedance, respectively. Susceptance and admittance are used extensively in the calculation of parallel circuits.

The impedance Z is the combined resistive effects, in an alternating-current circuit, of the reactance and the direct-current resistance; but since their individual effects upon the phase angle of the voltage and current are at right angles to each other, the impedance cannot be determined by algebraic addition but must be calculated by vectorial addition,

$$Z = \sqrt{R^2 + X^2}$$

where R = direct-current resistance in ohms

   X = inductive or capacitive reactance in ohms

   Z = impedance of the circuit in ohms

Hence to find the conductance, susceptance, or admittance of a branch or circuit any expression like the following may be used:

Conductance, $G = \dfrac{1}{R_1}, \dfrac{R_2}{Z_2{}^2}, \text{ or } \dfrac{R_3}{Z_3{}^2}$

Susceptance, $B = \dfrac{X_2}{Z_2{}^2}, \text{ or } \dfrac{X_3}{Z_3{}^2}$

Admittance, $Y = \sqrt{G^2 + B^2}$

The sub-numbers in the above formulas represent the respective branches in a parallel circuit, it being assumed for calculation purposes that there are three branches, namely, one containing

resistance only and two containing reactance and resistance (impedance).

Now since the impedance is the reciprocal of admittance, the value one (1) divided by admittance (Y), or $\left(\dfrac{1}{Y}\right)$, will give the joint impedance of a parallel combination, or circuit. Therefore,

$$Z_{\text{eff.}} = \frac{1}{\sqrt{G^2 + B^2}}$$

Ques. 580.   State Ohm's law for alternating-current circuits.

Ans.

$$E = IZ \qquad\qquad I = \frac{E}{Z} \qquad\qquad Z = \frac{E}{I}$$

Ques. 581.   What is the difference between the effective and peak values of current and voltage in an alternating-current circuit?

Ans.   This difference may be seen by comparing the following formulas for finding both values:

$$E_{\text{max.}} \text{ or } I_{\text{max.}} = E_{\text{eff.}} \text{ or } I_{\text{eff.}} \times 1.414$$
$$E_{\text{eff.}} \text{ or } I_{\text{eff.}} = E_{\text{max.}} \text{ or } I_{\text{max.}} \times 0.707$$

The effective or average values of current or voltage in an alternating-current circuit are commonly known as the *root mean square* (r.m.s.) values.

Ques. 582.   Give a diagram and explain the operation of a wattmeter.

Ans.   The mechanism of the electrodynamometer-type watt-meter is shown in Fig. 98(a). This instrument consists of a set of fixed "current coils" which connect in series with the line, and a moving "potential coil" which connects in parallel to the line. A reaction between the fixed coils and the movable coil causes a movement of the latter which is proportional to the power flowing in the circuit. Instantaneous values of watts being expended in the circuit are indicated directly on a scale over which a pointer, attached to the movable coil, swings.

The wattmeter is used only on alternating-current circuits, power readings on direct-current circuits being generally more accurate when computed from instantaneous current and voltage readings. The power expended in alternating-current circuits containing inductance or capacity, or both, is dependent on the current, voltage, and power factor involved. The wattmeter automatically integrates the power curve and multiplies it by the power factor of the circuit giving a direct reading in watts being expended.
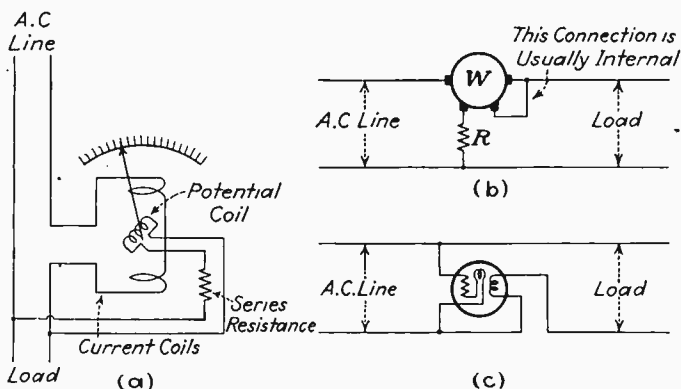
FIG. 98.—Wattmeter circuits and connections. (*a*) Mechanism of watt-meter; (*b*) conventional symbol for wattmeter in line; (*c*) another method of showing the wattmeter in the line.

The necessary connections from the coils in the wattmeter are brought out to three or four terminal posts depending on the style of wattmeter. The wattmeter may be shown in the circuit as illustrated in Fig. 98(*b*) and (*c*). Notice that a current-limiting resistor is always provided in series with the moving coil which is connected across the line. This resistance is generally placed inside the meter case and is an integral part of the instrument.

APPENDIX I

INFORMATION CONCERNING LICENSE EXAMINATIONS

License Law.—International and United States radio law requires that every person operating a radio transmitting station be licensed.

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 districts*, over each of which an Inspector in Charge has supervision. The district numbers and headquarters addresses are given below:

District	Headquarters	Address
1	Boston, Mass.	Custom House
2	New York, N. Y.	Subtreasury Building
3	Philadelphia, Pa.	35 South Ninth Street
4	Baltimore, Md.	Detention Building, Immigration Stn., Fort McHenry, Md.
5	Norfolk, Va.	Custom House
6	Atlanta, Ga.	528 Post Office Building
7	Miami, Fla.	1424 Dade County Building
8	New Orleans, La.	Custom House
9	Galveston, Texas	209 Prudential Building
10	Dallas, Texas	464 Federal Building
11	Los Angeles, Calif.	1105 Rives-Strong Building
12	San Francisco, Calif.	Custom House
13	Portland, Oregon	227 New Post Office Building
14	Seattle, Wash.	1012 Exchange Building
15	Denver, Colorado	Post Office Building
16	St. Paul, Minn.	413 Federal Building
17	Kansas City, Mo.	Federal Building
18	Chicago, Ill.	Engineering Building
19	Detroit, Mich.	David Stott Building
20	Buffalo, N. Y.	518 Federal Building

For information concerning radio operator's license examinations communicate with nearest Radio District office.

LIST OF LICENSED RADIO STATIONS AND LOWEST CLASS OF OPERATOR PERMITTED

A = Radiotelegraph, Second Class B = Radiotelegraph, Third Class
C = Radiotelephone, Second Class D = Radiotelephone, Third Class

Special & General Experimental B	Aeronautical C^2
Geophysical B	Aeronautical Point-to-point B
Motion Picture B or C	Airport D
Broadcast pick-up C	Aircraft[1] D
Point-to-point Telegraph B	Municipal Police C
Point-to-point Telephone C	State Police B
Coastal Telegraph A	Marine Fire C
Coastal Telephone C	Experimental Visual Broadcast C
Coastal Harbor B	Experimental Relay Broadcast C

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Marine Relay *B*	Special Emergency *B*
Ship *A*	Broadcast, *Radiotelephone, First*
Ship Harbor[1] *D*	*Class*
Mobile Press *A*	Amateur, *Amateur Operator, any*
	class

[1] If *A*-1 or *A*-2 emission is used, operator's license must bear code proficiency endorsement.

[2] If *A*-1 or *A*-2 emission is used, *A*.

Federal Radio Commission

Washington

RULES AND REGULATIONS GOVERNING THE ISSUANCE OF RADIO OPERATORS' LICENSES

RADIOTELEGRAPH OPERATOR LICENSES.

1. Commercial Extra First Class.—To be eligible for examination, an applicant for this class of license must hold a radiotelegraph operator 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 two years previous to his application and must not have been penalized for violation of any radio act, treaty or regulation binding on the United States. Applicants must pass code tests in transmission and reception at a speed of not less than 30 words per minute in Continental Morse Code and 25 words per minute in American Morse Code, five characters to the word. The questions in this examination will cover the same subjects required for radiotelegraph and radiotelephone class of operator license, but considerably wider in scope.

Holders of license of this class are authorized to act as chief operator at any licensed radiotelegraph or radiotelephone station except amateur.

2. Radiotelegraph Operator First Class.—To be eligible for examination, an applicant for this class of license must have been actually engaged as an operator at ship or coastal stations open to public correspondence for at least 12 months. Applicants 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, code groups, and 25 words per minute in Continental Morse Code, 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*) Theory, adjustment, operation, and care of modern radiotelegraph and radiotelephone transmitting apparatus.

(*c*) Receiving apparatus.

(d) General principles of electricity.

(e) Operation and care of storage batteries.

(f) Power supply apparatus.

(g) International regulations governing radio communication and the United States Radio Laws and Regulations.

Holders of this class of license are authorized to act as operator at any licensed radiotelegraph station except amateur, or to act as chief operator on a vessel in the first class engaged in international service.

3. Radiotelegraph Operator Second Class.—Applicants for this class of license must pass code tests in transmission and reception at a speed of not less than 16 words per minute in Continental Morse Code, code groups, and 20 words per minute in Continental Morse Code, plain language (5 characters to the word). The practical and theoretical examination will cover the same subjects as Radiotelegraph Operator First Class license.

Holders of this class of license are authorized to act as operator at any licensed radiotelegraph station except amateur, or as chief operator on a vessel in the first class engaged in international service. They will be authorized to act as chief operator on a vessel in the second class after license is endorsed certifying to six months or more satisfactory service as an operator at radiotelegraph stations open to public correspondence.

4. Radiotelegraph Operator Third Class.—Applicants for this class of license must pass a code test in transmission and reception at a speed of not less than 15 words per minute in Continental Morse Code, plain language (5 characters to the word) and a practical and theoretical examination consisting of comprehensive questions on the care and operation of vacuum tube apparatus and radio communication laws and regulations.

Holders of this class license will be authorized to operate any radiotelegraph station, except amateur, and stations open to international mobile public correspondence.

5. Holders of radiotelegraph operator licenses of the first, second, and third classes may qualify to operate radiotelephone stations by passing the regular radiotelephone operator examination of the class desired and having their licenses so endorsed.

6. Radiotelegraph operator first, second, and third class license examinations will include questions relative to the theory and operation of radiotelephone apparatus in order that the holders of these classes of licenses may operate radiotelephone apparatus employed in mobile and point-to-point service.

RADIOTELEPHONE OPERATOR LICENSES
No code test is required for these classes of licenses.

7. Radiotelephone Operator First Class.—Applicants for this class of license must pass a theoretical examination covering the following:

(a) Diagram of modern broadcast installation.

(b) Theory, adjustment, operation, and care of modern radiotelephone transmitters.

(c) Receivers.

(*d*) General principles of electricity.

(*e*) Operation and care of storage batteries.

(*f*) Power supply apparatus.

(*g*) Radio communication laws and regulations.

Holders of this class of license are authorized to act as operator at any licensed radio station except stations licensed for radiotelegraph service or amateur.

8. Radiotelephone Operator Second Class.—Applicants for this class of license must pass an examination similar to that required for radiotelephone operator first class, but not so comprehensive in scope.

Holders of this class of license are authorized to act as operator at any licensed radio station except broadcast or amateur or stations licensed for radiotelegraph service.

9. Radiotelephone Operator Third Class.—Applicants for this class of license will be required to pass an examination covering the laws and regulations governing radio communication and the general procedure of handling radiotelephone traffic between mobile and fixed points in aeronautical or marine harbor service.

This class of license will be valid for the operation of mobile radiotelephone stations equipped for operation on a single frequency and with apparatus so constructed as to prohibit any change in adjustment by operators.

AMATEUR OPERATOR LICENSES[1]

The operation of an amateur station will be permitted only by the holder of an Amateur Operator License.

10. Amateur Extra First Class.—To be eligible for examination for this class of license, an applicant must have had at least two years' service as a licensed amateur radiotelegraph operator and must not have been penalized for violation of any radio act, treaty or regulation binding on the United States. The applicant must pass code tests in transmission and reception at a speed of not less than 16 words per minute in Continental Morse Code, code groups, and 20 words per minute in Continental Morse Code, plain language (5 characters to the word), and a theoretical examination relating to amateur apparatus, both telegraph and telephone, and international regulations and acts of Congress affecting amateur stations and operators.

This license is valid for the operation of any licensed amateur radio station.

The amateur extra first class license examination will be sufficiently wide in scope to authorize the holder of this class of license the unlimited radiotelephone privileges set forth in paragraph 377 of the Federal Radio Commission's Rules and Regulations.

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[1] These regulations were changed Oct. 1, 1933. Write to Federal Radio Commission, Washington, D. C., for latest regulations.

11. Amateur First Class.—Applicants for this class of license must pass a code test in transmission and reception at a speed of not less than 10 words per minute in Continental Morse Code (5 characters to the word), and an examination similar to that given for Amateur Extra First Class License but not so comprehensive in scope.

This license is valid only for the operation of licensed amateur radio stations not utilizing special phone privileges as set forth in paragraph 377 of the Rules and Regulations of the Federal Radio Commission.

Holders of this class of license, after at least one year's experience as a licensed operator at an amateur station, may be accorded unlimited phone privileges as indicated in paragraph 377[1] of the Rules and Regulations of the Federal Radio Commission after passing the supplemental examination and having their license so endorsed.

12. Temporary Amateur Operator Class.—Application for this class of license will be accepted only from applicants residing more than 100 miles from examining point, which may be the district headquarters, a suboffice, or a city visited by an examining officer. 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, and complete a questionnaire pertaining to the operation of an amateur radio installation.

Applications for examination for unlimited amateur phone privileges will not be accepted from holders of Temporary Amateur Class Operator License. Applicants for this examination must appear personally before an examining officer and pass a written examination.

PASSING MARK FOR ALL EXAMINATIONS

13. The percentage that must be obtained as a passing mark in each examination is 75 out of a possible 100. No credit will be given for experience in the examination for any class of license.

EXECUTION OF OATH OF SECRECY

14. Licenses are not valid until the oath of secrecy has been executed and the signature of the issuing officer affixed thereto.

All examinations, including the code test, must be written in long hand by the applicant.

RENEWALS

15. Renewals.—(a) Commercial Operator Extra First Class: These licenses may be renewed without examination provided the record shows 12 months' satisfactory service at stations which the applicant is authorized to operate, at least six months of which must have been during the last 12 months of the license period.

Provided further that the 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 two-year license

[1] See footnote on p. 364.

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 holders of other classes (except amateur) without examination, provided the operator has had three months' satisfactory service during the last six months of the license term. One year's satisfactory service out of two years of the license term may be accepted for renewal at the discretion of the examining officer.

(c) No credit will be allowed for service unless it appears that such service was obtained under conditions that required the employment of a licensed operator.

(d) Amateur Extra First Class and Amateur First Class Operator Licenses may be renewed without examination provided proof is submitted indicating frequent use of the Continental Morse Code during the license period. An affidavit indicating at least three amateurs with whom applicant has communicated by code within the last three months of the license term will constitute ample proof; lacking such proof, a code test will be required.

(e) Temporary Amateur Class Licenses are not renewable. Holders of this class of license will be expected to pass the regular amateur examination during the license term. Failing to appear for examination when given an opportunity, or failing to pass examination, the temporary amateur class license held will be cancelled and holder will not be issued another license of this class upon subsequent application.

(f) Holders of radiotelegraph licenses endorsed for operation of radiotelephone stations whose service has been wholly at radiotelephone stations will be required to pass the code test for the class of license held and, failing this, will be issued a radiotelephone operator's license as a renewal of the class in which he previously qualified.

In cases where it is impossible for the applicant to appear for the code examination when making application for renewal, he will be issued a radiotelephone operator's license as above. However, in such cases the applicant may appear for code examination within three months after the date of the issuance of the radiotelephone license and be issued a license of the class formerly held, provided he passes the code examination. Failing to appear or failing to pass the code test during the three months period, the applicant forfeits this privilege.

(g) Renewals or new licenses may be issued a reasonable length of time prior 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.

(h) 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. After consideration by the Radio Division, advice will be forwarded to the supervisor of radio or examining officer in regard to the issuance of a renewal of the license.

(*i*) Service records must be completed and signed only by masters, employers, or the duly authorized agents of either.

(*j*) Any improper alteration of the service record or the forgery of the master's or employer's signatures, or any attempt to obtain a license by fraudulent means, or by attempting to impersonate another, or copying or divulging questions used in examinations, will constitute a violation of the regulations for which the operator may suffer suspension of license or debarment from further examination for a period not exceeding two years at the discretion of the *licensing authority*.

16. Duplicate Licenses.—Any operator applying for a duplicate license to replace an original which has been lost, mutilated, or destroyed, will be required to submit an affidavit to the Radio Division through a supervisor of radio or examining officer, attesting to the facts regarding the manner in which the original was lost. The Director of Radio will consider the facts in the case and advise the supervisor of radio or examining officer in regard to the issuance of a duplicate license. Duplicates will be issued under the same serial number and date as the original, and will be marked "duplicate" in red on the face of the license.

17. 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 radiotelegraph operator first class or second class license fails in the code examination, he may be reexamined the same day for any other class of license desired.

LICENSE INDORSEMENTS

18. Radiotelegraph Class Licenses to be valid for the operation of radiophone stations will be indorsed as follows: The holder of this license has qualified by examination for additional authority to operate any radiophone station. (If radiophone examination taken by applicant is for second class radiotelephone operator's license, indorsement should be followed by "except broadcast."

Date_____Examining Officer_____

Amateur First Class licenses to be valid for unlimited radiotelephone operation will be indorsed as follows: The holder of this license has qualified by examination for unlimited amateur radiotelephone operation as indicated in Federal Radio Commission Regulation No. 377.

Date_____Examining Officer_____

These regulations supersede "Regulations governing the issuance of radio operator licenses dated January 2, 1931," and all amendments thereto, and become effective July 1, 1932.

Revised April 23, 1932.

NOTE.—Ammendments to these regulations may be secured by writing direct to the Federal Radio Commission, Washington, D. C.

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.

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[1] The abbreviations take the form of questions when they are followed by question marks.

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TABLE I.—(*Continued*)

Abbrevi- ation	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
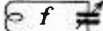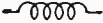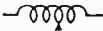
Abbreviation	Question	Answer
QAA....	At what time do you expect to arrive at ....?	I expect to arrive at .... at .... o'clock.
QAB....	Are you en route to ....?	I am en route to ....
QAC....	Are you returning to ....?	or Go to .... I am returning to ....
QAD....	At what time did you leave .... (place of departure)?	or Return to .... 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 ....
QAM....	Can you give me the latest meteorological message concerning weather for .... (place of observation)?	or Land .... 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?	I am calling you.
	or Are you calling .... (call signal of the aircraft station)?	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

Abbrevi-ation	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).

RADIO SYMBOLS

Most of the symbols appearing on this and the following page are Standardized and reproduced by courtesy of the Institute of Radio Engineers. Those symbols marked with an asterisk (*) are not Standardized by the I.R.E. but are adopted from electrical- and radio-engineering practice.

Ammeter

Antenna

Arc

Battery
(positive electrode, long line)

Buzzer*

Loop Antenna

Fixed Condenser

Fixed, Shielded Condenser

Variable Condenser

a   b
(a) Variable Condenser
(moving plate indicated)
(b) Variable, Shielded Condenser

Counterpoise

Transformer, Air Core

Transformer, Variable Coupling

Crystal Detector

Frequency Meter (wavemeter)*

Galvonometer

Ground

Inductor

Inductor, Iron Core

Inductor, Variable

Inductor, Adjustable (by steps)

Alternator, Single Phase*

Alternator, Two Phase*

Alternator, Three phase*

D.-C. Motor or Generator*

Ammeter Shunt*

Circuit Breaker*

Frequency Indicator*

Lamp Bank*

Fuse, Link Type*

Fuse, Enclosed*

Fuses, Plug*

Voltmeter
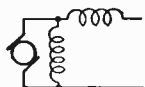
Motor, Compound*
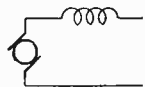
Motor, Series*
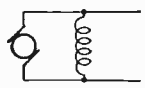
Motor, Shunt*
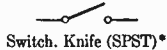
Switch. Knife (SPST)*

Transformer, Iron Core

Variometer*
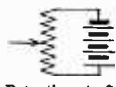
Potentiometer*

Wattmeter*

Jack

Key

Lightning Arrestor*

Resistor

Resistor, Variable

Resistor, Adjustable (by steps)

Spark Gap, Rotary Synchronous

Spark Gap, Quenched

Spark Gap, Plain

Spark Gap, Rotary Non-synchronous*

Piezo-electric Plate (crystal)

Telephone Receivers

Loud Speaker

Microphone (telephone transmitter)

Thermoelement

a   b

(a) Triode (with directly heated cathode)
(b) Triode (with indirectly heated cathode)

a   b
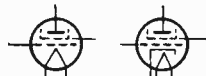
(a) Screen-grid Tube (with directly heated cathode)
(b) Screen-grid Tube (with indirectly heated cathode)

a   b
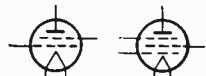
(a) Tetrode (with directly heated cathode)
(b) Pentode (with directly heated cathode)

a   b
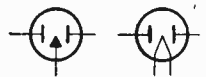
(a) Rectifier Tube, Full Wave (with cold cathode)
(b) Rectifier Tube, Full Wave (with directly heated cathode)

a   b

(a) Rectifier Tube, Half Wave (with cold cathode)
(b) Rectifier Tube, Half Wave (Diode) (with directly heated cathode)

Phototube

Wires, Joined

Wires, Crossed, Not Joined

a   b

(a) Closed core transformer*
(b) Closed Core Transformer with Adjustable Leakage Gap*

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: *a.* Broadcasting *b.* Maritime mobile services, waves of 1,365 kilocycles per second (220 meters) exclusively
1,300 to	1,500	230	to	200	
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.

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 0 to 23. 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	0000
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

AUDIBILITY SCALE

QSA1—Hardly perceptible; unreadable.

QSA2—Weak; readable only now and then.

QSA3—Fairly good; readable with difficulty.

QSA4—Good readable sigs.

QSA5—Very good signals; perfectly readable.

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.

Letter	Code
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 À (Spanish-Scandinavian)	• ▬ ▬ • ▬
CH (German-Spanish)	▬ ▬ ▬ ▬
É (French)	• • ▬ • •
Ñ (Spanish)	▬ ▬ • ▬ ▬
Ö (German)	▬ ▬ ▬ •
Ü (German)	• • ▬ ▬
1	• ▬ ▬ ▬ ▬
2	• • ▬ ▬ ▬
3	• • • ▬ ▬
4	• • • • ▬
5	• • • • •
6	▬ • • • •
7	▬ ▬ • • •
8	▬ ▬ ▬ • •
9	▬ ▬ ▬ ▬ •
0	▬ ▬ ▬ ▬ ▬

Signal	Code
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)	• • • ▬ • ▬

INTERNATIONAL CALL LETTER ASSIGNMENTS

Call signal	Country	Call signal	Country
CAA–CEZ	Chile.	PPA–PYZ	Brazil.
CFA–CKZ	Canada.	PZA–PZZ	Surinam.
CLA–CMZ	Cuba.	Q	(Abbreviations.)
CNA–CNZ	Morocco.	RAA–RQZ	Union of Soviet Socialist Republics (U. S. S. R.).
CPA–CPZ	Bolivia.		
CQA–CQZ[1]	Portuguese colonies.	RVA–RVZ	Persia.
CRA–CRZ		RXA–RXZ	Republic of Panama.
CSA–CUZ	Portugal.	RYA–RYZ	Lithuania.
CVA–CVZ	Rumania.	SAA–SMZ	Sweden.
CWA–CXZ	Uruguay.	SPA–SRZ	Poland.
CZA–CZZ	Monaco.	STA–STZ[1]	Egypt.
D	Germany.	SUA–SUZ	
EAA–EHZ	Spain.	SVA–SZZ	Greece.
EIA–EIZ	Irish Free State.	TAA–TCZ	Turkey.
ELA–ELZ	Liberia.	TFA–TFZ	Iceland.
ESA–ESZ	Estonia.	TGA–TGZ	Guatemala.
ETA–ETZ	Ethiopia.	TIA–TIZ	Costa Rica.
F	France and colonies and protectorates.	TSA–TSZ	Territory of the Saar.
		UHA–UHZ	Hedjaz.
G	Great Britain.	UIA–UKZ	Dutch East Indies.
HAA–HAZ	Hungary.	ULA–ULZ	Luxemburg.
HBA–HBZ	Switzerland.	UNA–UNZ	Kingdom of Serbs, Croats and Slovenes (Yugoslavia).
HCA–HCZ	Ecuador.		
HHA–HHZ	Haiti.	UOA–UOZ	Austria.
HIA–HIZ	Dominican Republic.	UWA–UZZ	Canada.
HJA–HKZ	Colombia.	VAA–VGZ	
HRA–HRZ	Hondouras.	VHA–VMZ	Australia.
HSA–HSZ	Siam.	VOA–VOZ	Newfoundland.
I	Italy and colonies.	VPA–VSZ	British colonies and protectorates.
J	Japan.	VTA–VWZ	British India.
K	Unites States of America.	W	United States of America.
LAA–LNZ	Norway.	XAA–XFZ	Mexico.
LOA–LVZ	Argentina.	XGA–XUZ	China.
LZA–LZZ	Bulgaria.	YAA–YAZ	Afghanistan.
M	Great Britain.	YHA–YHZ	New Hebrides.
N	United States of America.	YIA–YIZ	Iraq.
OAA–OBZ	Peru.	YLA–YLZ	Latvia.
OCA–OCZ[1]		YMA–YMZ	Free City of Danzig.
OFA–OGZ[1]	Finland.	YNA–YNZ	Nicaragua.
OHA–OHZ		YSA–YSZ	Republic of El Salvador.
OKA–OKZ	Czechoslovakia.	YVA–YVZ	Venezuela.
ONA–OTZ	Belgium and colonies.	ZAA–ZAZ	Albania.
OUA–OZZ	Denmark.	ZBA–ZHZ[1]	British colonies and protectorates.
PAA–PIZ	Netherlands.	ZKA–ZMZ	New Zealand.
PJA–PJZ	Curacao.	ZPA–ZPZ	Paraguay.
PKA–POZ	Dutch East Indies.	ZSA–ZUZ	Union of South Africa.

[1] Provisionally.

The call signals assigned to the United States are all three and four letter combinations, beginning with the letters K, N, and W. The international call signals assigned to the United States are reserved for Government stations and stations open to public and limited commercial service.

All combinations beginning with the letter N are reserved for Government stations, and, in addition, the combinations from WUA to WVZ and WXA to WZZ are reserved for stations of the United States Army.

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Radiotelephone. 1st Class
must pass the following
(a) Diagram of modern Broadcast Installation
(B) Theory, adjustment, operation, & care
of modern Radiotelephone

(C) Receivers.
(D) General Principals of electricity
(E) operation & care of Storage Batteries
(F) Power Supply apparatus
(G) Radio Communication laws & Regulations

Holders of this class of license are
authorized to act as operators at
any licensed Radio station except
stations licensed for Radiotelegraph
Service.