HOW TO PASS U.S. GOVERNMENT RADIO LICENSE EXAMINATIONS

COMPLETELY REVISED EDITION

ACTUAL QUESTIONS ANSWERED

HOW TO PASS

U. S. GOVERNMENT

RADIO LICENSE EXAMINATIONS

BY

RUDOLPH L. DUNCAN

AND

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Authors of

"RADIO TELEGRAPHY AND TELEPHONY"

"RADIO TRAFFIC MANUAL AND OPERATING REGULATIONS"

Completely Revised Edition

NEW YORK

JOHN WILEY & SONS, INC.

LONDON: CHAPMAN & HALL, LIMITED

1929

Printed in U. S. A.

PRESS OF
BRAUNWORTH & CO., INC.
BOOK MANUFACTURERS
BROOKLYN, NEW YORK

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BOOKS ON RADIO BY

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RADIO TELEGRAPHY AND TELEPHONY—
A Complete Textbook for Students of Wireless Communication

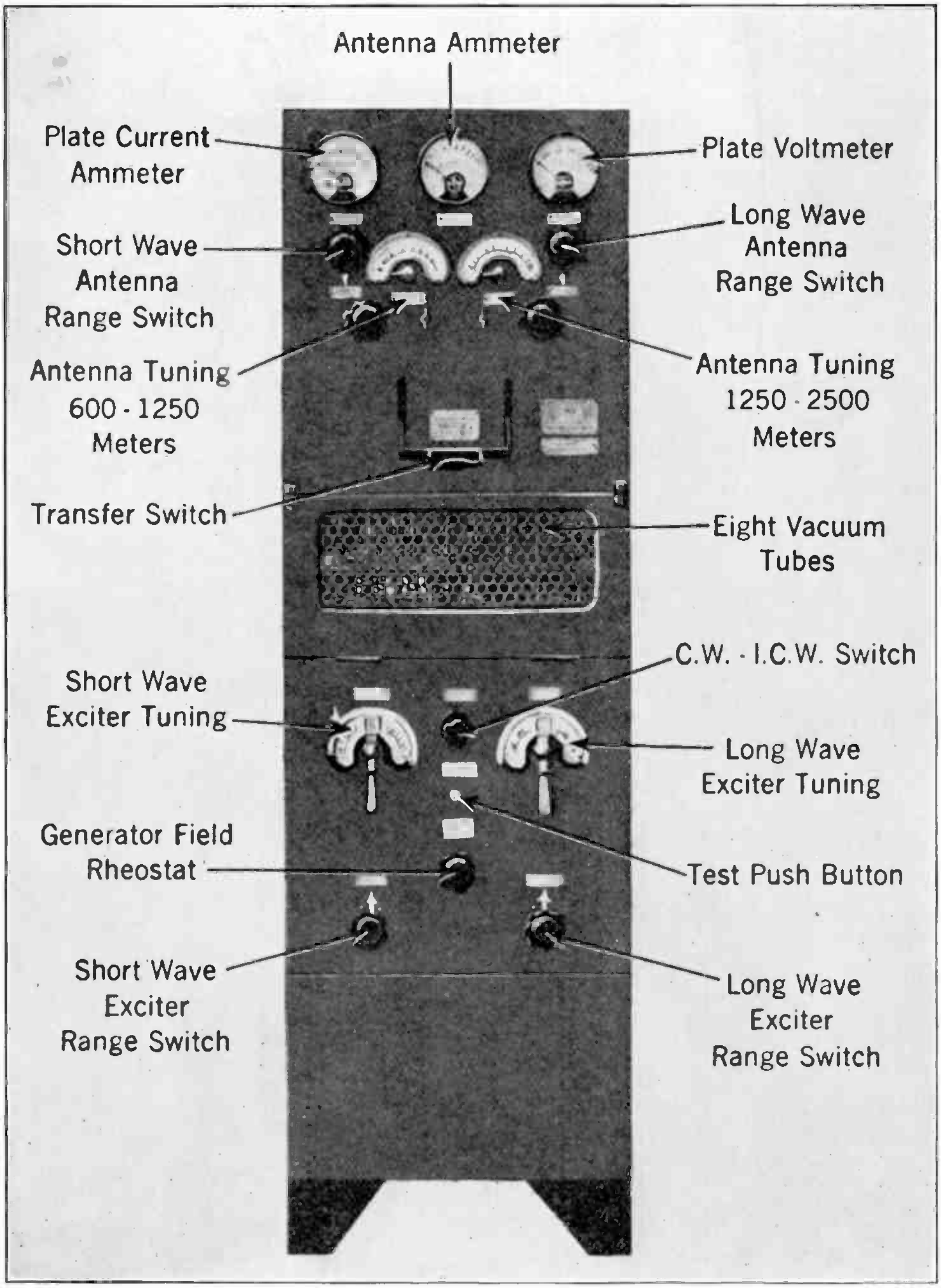
Prepared to serve both as textbook for technical and non-technical students and as a practical handbook for the radio field; makes clear the causes, effects and uses of radio phenomena. Cloth; 6 by 9 inches; 950 pages; 468 illustrations.

RADIO TRAFFIC MANUAL and OPERATING REGULATIONS

A volume that will help students, amateurs, and radio operators who contemplate entering the commercial field to acquire knowledge of commercial traffic, abstracting and commercial communication practice; and to understand the problems of the movement and handling of traffic in telegraph communication, especially in the marine service. Paper; 6 by 9 inches; 187 pages; radio communication forms.

HOW TO PASS U. S. GOVERNMENT RADIO LICENSE EXAMINATIONS

Planned to give to those, even though experienced radio men, contemplating taking the government radio license examinations, a familiarity they may not have had with commercial apparatus and commercial operating procedure. Paper; $6\frac{5}{8}$ by $9\frac{3}{4}$ inches; 169 pages; 92 figures; symbol tables.



Front panel view of the ET-3626B Radiomarine Corporation of America commercial tube transmitter. *Frontispiece.*

FOREWORD

The text and illustrations in this volume have been prepared for those who contemplate taking the government radio license examination. This book is not intended as a complete technical treatise pertaining to radio theory and practice or as a chronological discussion of the art. The reader is referred to standard radio textbooks for detailed instruction on the subject.

There are many experienced radio men who fail to pass the government examination because they are not familiar with commercial apparatus and commercial operating procedure. Then there are others who are more or less handicapped because they lack expression; they know the subject from the practical viewpoint but they are unable to put their knowledge into words. The real purpose of this text is to show how radio questions and examinations should be answered.

United States Government radio license examinations are conducted in Washington, New York, Boston, Philadelphia, New Orleans, San Francisco, Seattle, Chicago, and at other points in the United States. Full information concerning the time and place of holding radio examinations may be obtained by addressing an inquiry to the Radio Division, U. S. Department of Commerce, Washington, D. C.

THE AUTHORS.

June, 1929.

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2. **Commercial First Class.**—To be eligible for examination, an applicant for this class of license must have been actually engaged as an operator at stations open to public correspondence for at least 12 months. 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, in code groups, and 25 words per minute in Continental Morse Code, in plain language (5 characters to the word). The practical and theoretical examination will cover the same subjects as required for the commercial second class license. A total percentage of 75 will constitute a passing mark. Holders of this class of license are authorized to act as chief operator at any licensed radio station.

3. **Commercial Second Class.**—Applicants for this class of license must pass code tests in transmission and reception at a speed of at least 16 words per minute in Continental Morse Code, in code groups, and 20 words per minute in Continental Morse Code, in plain language (5 characters to the word). The practical and theoretical examination shall consist of comprehensive questions under the following headings:

(a) *Diagram of radio installation.*—Applicants are required to draw a complete wiring diagram of a modern marine radio installation as used aboard American vessels. The applicant may be required to draw either a spark, arc, or vacuum tube transmitter (with radiotelephone attachment).

(b) *General principles of electricity, theory, adjustment, operation, and care of modern radiotelegraph and radiotelephone apparatus.*

(c) *Receiving apparatus.*

(d) *Operation and care of storage batteries.*

(e) *Motors and generators.*

(f) *International regulations governing radio communcation and the United States Radio Laws and Regulations.*

(g) *Experience.*—The applicant's answers will be rated on the basis of 100 per cent. In addition to the percentage thus obtained, an allowance for experience will be added as follows: Three months' or more satisfactory service at a station open to public correspondence under a commercial license, 10 per cent; two months' satisfactory service at a station open to public correspondence under a commercial license, 7.5 per cent; one month's statisfactory service at a station open to public correspondence under a commercial license, 5 per cent; service at United States Government stations open to public correspondence, same as above; service at other United States Government stations of three months' or more duration, 5 per cent; less than three months, in proportion; graduates of residence radio schools, 5 per cent; amateur operators or graduates of correspondence radio schools, 2 per cent. In order to obtain due allowance applicants must present satisfactory written evidence of their experience. A total percentage of 65 will constitute a passing mark for this class of license.

This license is valid for the operation of any licensed land or aircraft radio station or on any vessel except as indicated in the following. Holders of this class of license are not authorized to act as chief operator on a vessel in the first class. They will be authorized to act as chief operator on a vessel in the second class upon submission of written evidence at any time during the term of the license indicating six months or more satisfactory service as an operator at a station open to public correspondence.

4. Broadcast Class.—Applicants for this class of license must pass code tests in transmission and reception at a speed of at least 16 words per minute in Continental Morse Code, in code groups, and 20 words per minute in Continental Morse Code, in plain language (5 characters to the word). The theoretical examination will cover the same subjects as indicated for the commercial second class license, except that under subject (a) the applicant is required to draw a diagram of a modern broadcast transmitter and under subject (b) the questions will relate strictly to broadcast apparatus. An allowance for service as an operator at a broadcast or other station will be made in accordance with the scale indicated under 3, Commercial second class. Holders of this class of license are authorized to act as operator only at a licensed broadcast station.

5. Radiotelephone Class.—No code test is required for this class of license. The practical and theoretical examination for this class of license shall consist of questions on adjustment and operation of radiotelephone apparatus and knowledge of international regulations governing radio communication and the United States Radio Laws and Regulations. The applicant must demonstrate his ability to transmit and receive clearly conversation by telephone apparatus. Whenever possible, a demonstration of the applicant's ability to operate radiotelephone apparatus will be required. A percentage of 75 will constitute a passing mark.

Holders of this class of license are authorized to act as operator only at licensed radiotelephone stations of 300 watts or less input power.

6. **Amateur Extra First Class.**—To be eligible for examination, an applicant for this class of license must have had at least two years' service as a licensed radio operator and must not have been penalized for violation of radio laws. The applicant must pass code tests in transmission and reception at a speed of at least 16 words per minute in Continental Morse Code, in code groups, and 20 words per minute in Continental Morse Code, in plain language (5 characters to the word). An applicant must pass a special examination relating to amateur apparatus and international regulations and acts of Congress affecting amateur stations and operators. A percentage of 75 will constitute a passing mark. This license is valid for the operation of licensed amateur radio stations only.

7. **Amateur Class.**—Applicants for this class of license must pass a code test in transmission and reception at a speed of at least 10 words per minute, in Continental Morse Code (5 characters to the word). An applicant must pass an examination which will develop knowledge of the adjustment and operation of the apparatus which he desires to use and of the international regulations and acts of Congress in so far as they relate to interference with other radio communications and impose duties on all classes of operators. A percentage of 70 will constitute a passing mark. This license is valid for the operation of licensed amateur radio stations only.

8. **Temporary Amateur License.**—Amateurs who can not present themselves for examination may be issued temporary licenses valid for the operation of a particular station until such time as they can be examined for a regular license but not to exceed a period of one year. The applicant must submit a sworn statement attesting to his ability to transmit and receive at a speed of not less than 10 words per minute in Continental Morse Code.

9. **Renewals.**—(a) *Commercial extra first class:* These licenses may be renewed without examination provided the record shows 12 months' satisfactory service in a land or ship station open to general public service at least 6 months of which must have been during the last 12 months of the license period. To 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 renewal of their licenses without examination, provided such employment has covered a period of 18 months out of the 2 year license period. Where the applicant has not regularly used the telegraph codes, he will be given the code examination as for an original license, and if he has used only one code, he will be examined in the code not used.

(b) *Other renewals:* Renewal licenses may be issued to operators of other classes without examination, provided the operator has had three months' satisfactory service during the last six months of the license term. One year satisfactory service out of two years of the license term may be accepted for renewal at the discretion of the examining officer.

(c) Holders of commercial first class or commercial second class radio operators' licenses who have not had sufficient service at commercial stations to permit the unconditional renewal of such licenses, but indicate satisfactory service at broadcasting stations for the length of time necessary for renewal, and are unable to pass the required code test or to present themselves for a code test, may be issued restricted renewals of their existing licenses. The licenses so issued should bear across their face, preferably in red, the following restrictions: "This license not valid for the operation of any limited or general public stations."

Applicants holding restricted commercial operators' licenses, or broadcast or radiotelephone operators' licenses may be issued renewals of such licenses provided the service records indicate three months' satisfactory service during the last six months of the license term. One year's satisfactory service out of the two year term of the license may be accepted at the discretion of the examining officer. Renewal commercial first class or commercial second class licenses so issued shall bear the indorsement, "This license not valid for the operation of any limited or general public station."

Holders of restricted licenses may have this restriction removed at any time during the term of this license by passing the code test required for the class of license held by them. This restriction will be removed by the supervisor of radio or examining officer by drawing lines through the restriction and adding on the license adjacent thereto the following: "Restriction removed," date and initials of the examining officer. The expiration date of the license will remain the same.

Applicants who have passed the regular commercial examination but who hold renewal commercial licenses indorsed, "This license is not valid for the operation of any limited or general public station," may be issued unconditional renewals of such licenses provided they have the required service as indicated above and pass the code test required by the regulations for the class of license held by them.

(d) Renewals or new licenses may be issued a reasonable length of time previous to the expiration of existing licenses but must bear the exact date of issue, which must correspond with the date on Form 756 forwarded to the radio division. Operators who fail to apply for renewal of their licenses on or prior to the date of expiration must be re-examined. If, because of circumstances over which the applicant has no control, an operator is unable to apply for renewal of license on or prior to the date of expiration, an affidavit may be submitted to the radio division through the supervisor of radio or examining officer, attesting to the facts, which will be considered by the radio division, which will advise the supervisor of radio or examining officer in regard to the issue of a renewal of the license without re-examination. Service records must be completed and signed only by masters, employers, or the duly authorized agents of either. Any improper alteration of the service record or the forgery of masters' or employers' signatures constitues a violation of the regulations, and the operator may suffer suspension of license for a period not exceeding two years, at the discretion of the Secretary of Commerce.

10. Duplicate Licenses.—Operators who have lost a valid operator's license may submit an affidavit to the radio division through the supervisor of radio or examining officer, attesting to the facts, which will be considered by the radio division which will advise the supervisor of radio or examining officer in regard to the issue of a duplicate of the lost license. Duplicates of licenses will bear the same date of issue and will expire on the same date as the original. If the original license is recovered, it must be forwarded to the radio division or one of its offices for cancellation and filing. Duplicates of amateur station licenses or of expired operator licenses will not be issued.

11. **Re-examination.**—No applicant who fails to qualify will be re-examined within three months from date of the previous examination. However, when an applicant for the commercial first class license fails in the code examination he will be re-examined the same day for any other one class of license desired. Those who pass the code test successfully but fail to attain a total percentage of at least 75 but do attain a total percentage of at least 65 will be issued a commercial second class license, if desired. Those who fail in the code examination for the broadcast class license will be examined the same day for either the radiotelephone or amateur class license, if desired. An applicant for the broadcast class license who fails to attain a total percentage of at least 75 but does attain a percentage of at least 65 will be issued a radiotelephone class license, if desired. All examination papers except amateur, whether the applicant qualifies or not, will be forwarded to the Department of Commerce, radio division, for filing.

Regulations Governing the Renewal of Commercial Operators' Licenses Expiring After January 1, 1929

Operators now holding commercial extra first class licenses will be issued renewal licenses of the same class without examination, provided they have the required length of service.

Operators now holding commercial first class licenses will be issued one of the new commercial first class licenses without theoretical examination, provided they can show satisfactory service for a period of at least 12 months as an operator at stations open to public correspondence, have knowledge of the operation of radiotelephone apparatus, and can successfully pass code tests as required under the new regulations.

Operators now holding commercial first class licenses who have had less than 12 months but more than 6 months' satisfactory service as operators at stations open to public correspondence will be issued commercial second class licenses without examination, authorizing them to act as operator in any station, except as chief operator on vessels of the first class.

Operators now holding commercial first class licenses, who have had less than six months' satisfactory service as an operator at stations open to public correspondence, will be issued a commercial second class license without examination, authorizing holder to act as operator on any vessel except as chief operator on a vessel in the first or second class.

No renewals will be made of present commercial second class licenses, and after January 1, 1929, licenses of this class still valid after that date will be valid only for the operation of broadcast, technical and training, experimental, limited commercial, or amateur stations. Holders of broadcast station operator licenses will be issued the new broadcast license provided they have the required service and pass the new code tests.

All present licenses will be valid for the term indicated, but at any time during the term of the old license an operator may make application for and be issued a new license provided he can meet the requirements therefor. In any event, if a new license is issued the old license must be canceled.

Effective January 1, 1930, holders of present commercial first class licenses are not authorized to act as chief operators on vessels in the first class. If they desire to obtain such authority, they must meet the requirements and make application for one of the new licenses. The regulations and instructions requiring that a first class operator must be the chief operator on a first class vessel applies only in the cases of vessels in the international service and not to vessels plying between ports of the United States.

CHAPTER II

COMMERCIAL AND BROADCAST TRANSMITTERS

1. *Question.* Draw a diagram of a standard tube transmitter of the type used on shipboard, without radiophone attachment. Include source ot power and name all parts and their function. State type and rating of the transmitter.

Answer. A schematic diagram of the ET-3628 ACCW 500-watt tube transmitter is shown in Figure 1. An auxiliary source of power and the IP-501 receiver are also shown. The legend for this complete installation is as follows:

1. D-C bus line from ship's generator.
2. Main line fuses.
3. Polarity reversing switch.
4. Circuit breaker contact to main line supply.
5. Circuit breaker contact to main line supply.
6. No voltage, or underload circuit breaker electromagnet.
7. Battery charging resistor. Number of resistors depend upon the size of the battery.
8. Battery charging resistor. Number of resistors depend upon the size of the battery.
9. One bank of 30 lead-acid type storage cells, 60 volts.
10. One bank of 30 lead-acid type storage cells, 60 volts.
11. Ampere-hour meter.
12. Trickle-charge lamp.
13. Trickle-charge lamp.
14. Contact on overload coil circuit which closes circuit to the short-circuiting contact pin on the face of the ampere-hour meter.
15. Another contact on overload coil circuit. An insulated rod closes the metal bar between contacts 15 and 14 when the circuit breaker is closed.
16. Current limiting resistor for coil 17.
17. Overload coil and iron plunger.
18. Voltmeter.
19. Multiplier resistance for voltmeter.
20. Push-button switch used to take voltage reading.
21. Voltmeter plug receptacles. The plug 23 is inserted in the upper right receptacle to read voltage of battery bank "B." The plug 23 is inserted in lower right receptacle to read voltage of battery bank "A."
22. Voltmeter plug receptacles. Plug 23 is inserted in the upper left position to read voltage, about 120 volts of both banks when connected in series, that is, when switch 24 is placed to the right for discharge, to use the battery for emer-

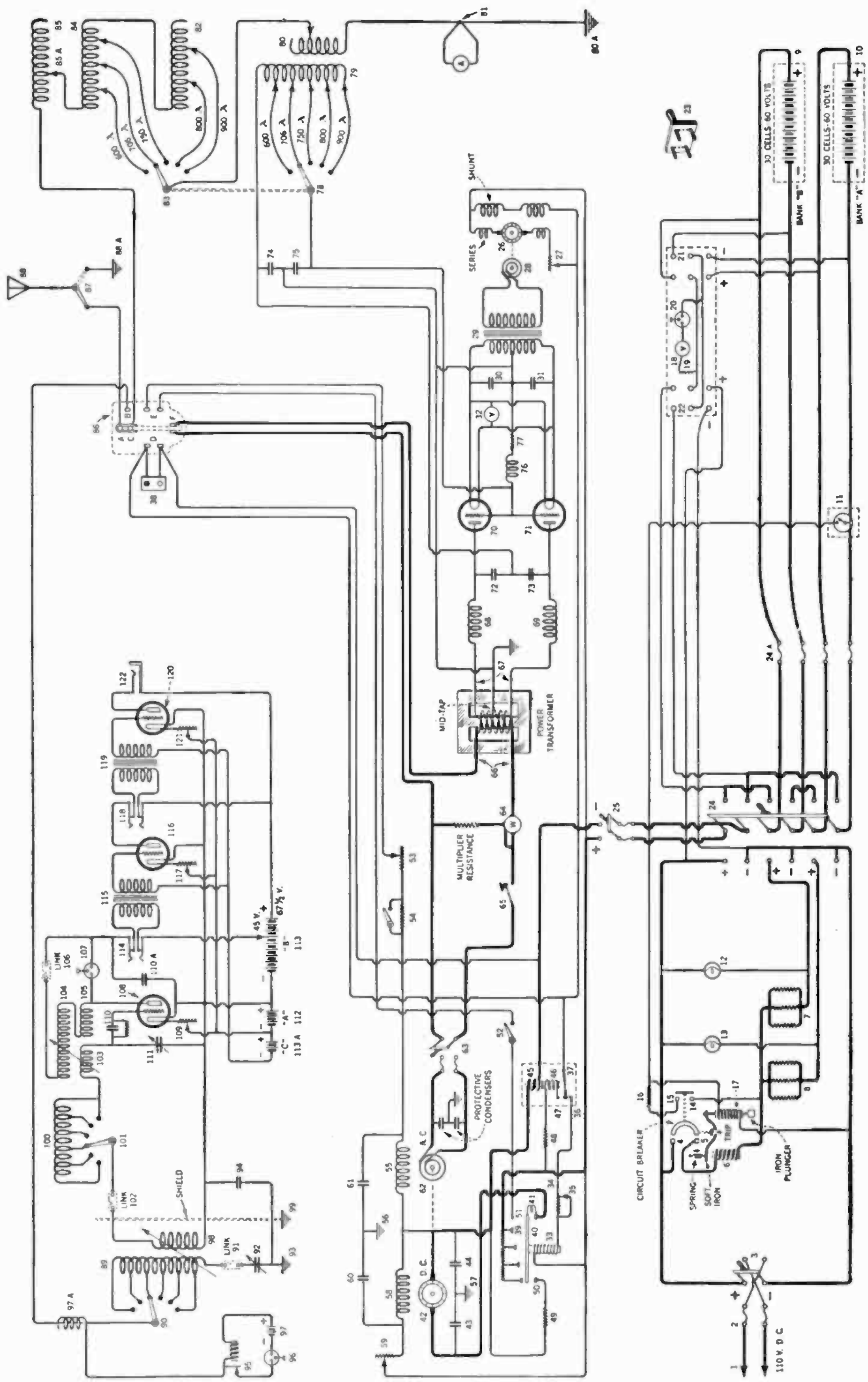


FIG. 1.—Diagram of a complete shipboard radio installation consisting of the ET-3628 ACCW 500-watt transmitter, IP-501 receiver, and emergency (battery) source of power.

gency power. Plug 23 is inserted in the lower left receptacle when a reading of the ship's main source of power is desired.

23. Voltmeter plug equipped with four prongs, each opposite two being connected together. When inserted in the four holes the prongs make proper electrical connections similar to the operation of a switch.

24. Six-pole double-throw charge and discharge switch. The switch is placed in the left position for charge and in the right position for discharge.

24A. Fuses.

25. D-C supply switch. This switch is mounted on the lower right of the transmitter panel.

26. Rotary converter for generating a-c. voltage for the vacuum tube filaments. This is the d-c. end or motor end of the machine.

27. Filament voltage rheostat in series with d-c. input to the rotary converter.

28. Collector rings and brushes on the converter which deliver a-c. voltage to the filament transformer, (29), primary winding.

29. Filament heating transformer.

30. Filament by-pass condenser (.5 mfd.).

31. Filament by-pass condenser (.5 mfd.).

32. A-C voltmeter to ascertain filament voltage.

33. Solenoid coil used to actuate the plunger bar of the automatic starter.

34. Protective resistor for limiting current through the solenoid is cut in automatically when plunger bar (40) is up in full operating position.

35. Short-circuiting contacts for protective resistor.

36. Fixed contact of overload relay solenoid.

37. Soft iron bar carrying movable contacts of overload relay.

38. Push-button "Start-Stop" switch connected in shunt to contacts *D* on the change-over switch (86) which perform a similar function as when throwing the handle of (86) in either send or receive position.

39. Starting resistors with contact fingers in series with motor armature until armature attains full speed.

40. Metal strip on plunger bar (40) makes progressive connection with contact fingers.

41. Flexible braided copper wire connecting the movable plunger bar to the fixed terminal.

42. D-C motor armature.

43. Protective condenser to prevent damage to windings by dissipating any high voltage surge developed in the circuit.

44. Protective condenser. Same function as (43).

45. Overload relay coil. Heavy current through (45) will increase magnetic flux and pull iron bar (37) upward and make contact with (47).

46. Holding coil. If bar (37) is pulled up it closes with contact (47) and current flows through (46) thus holding (37) up until the overload is removed or main switch is opened.

47. Holding coil contact.

48. Holding coil current limiting resistor.

49. Dynamic brake resistance.

50. Dynamic brake contact.

51. Generator field contact.

52. Generator field switch.

53. Generator field rheostat for regulating output voltage of the a-c. generator.

54. Low power resistor and switch for use when working with near-by station.

55. Generator field winding supplied from 120-volt d-c. source.

56. Protective condenser ground.

57. Protective condenser ground.

58. Motor field winding connected in shunt to motor armature.

59. Motor field rheostat for controlling speed of the motor and in turn the frequency of the a-c. output of the generator.

60. Protective condenser (1 mfd.). See (43).

61. Protective condenser (1 mfd.). See (43).

62. A-C generator armature.

63. Main a-c. line switch with fuses shown to the left of the switch.

64. Wattmeter consisting of a current or ampere coil and a voltage or potential coil. The high resistance shown above (64) is the multiplier resistance for the voltage coil.

65. Morse hand key.

66. Primary of plate transformer receives the low-voltage a-c. of the generator.

67. Secondary of plate transformer delivers high-voltage a-c. to the plates of the transmitting tubes..

68. Plate r-f. choke. Prevents loss of high-frequency energy in the transformer circuit.

69. Plate r-f. choke.

70. Transmitting tube. Type UV-204A.

71. Transmitting tube. Type UV-204A.

72. Plate blocking condenser (.001 mfd.). Keeps plate voltage supply out of oscillatory circuit and isolates this voltage from the grids of the tubes. The condenser readily by-passes the r-f. component of the plate current.

73. Plate blocking condenser (.001 mfd.). See (72).

74. Plate coupling condenser (.002 mfd). The feed-back energy from plate to grid passes through (74); also this condenser forms part of the oscillatory circuit capacitance.

75. Grid coupling condenser (.014 mfd.). The voltage drop obtained across (75) when oscillations circulate through the oscillatory circuit, (79) (74) and (75), is applied to the grids for excitation to maintain oscillation.

76. Grid r-f. choke coil prevents loss of r-f. energy in the grid d-c. circuit to the center-tapped filament transformer (29).

77. Grid bias resistor, 4000 ohms, for maintaining the grid at the proper negative potential.

78. Wave-changer switch for quickly selecting any one of 5 wavelengths provided by the transmitter.

79. Primary of the antenna coupling transformer. It is also called the "tank"

circuit inductance. Radio-frequency current generated by the tubes and their circuits oscillates through (79) and is transferred to (80) by electromagnetic induction.

80. Secondary of antenna coupling transformer.

80A. Ground.

81. Antenna ammeter and thermo-couple.

82. Antenna loading inductance.

83. Wave-changer switch for varying inductance of secondary or antenna circuit.

84. Antenna loading inductance.

85. Antenna fine tuning inductance.

85A. Adjustment handle for sliding contact on fine tuning inductance.

86. Antenna changeover switch or transfer switch.

- A. Antenna connection.
- B. Receiver connection.
- C. Transmitter connection.
- D. Motor starter contacts.
- E. Generator field contacts.
- F. A-C main line contacts.

87. Lightning switch.

88. Antenna.

88A. Ground for lightning switch.

89. Primary inductance of receiving transformer.

90. Primary inductance switch.

91. Link in place when long-wave attachment unit is not used.

92. Primary series tuning condenser (.0008 to .0045 mfd.).

93. Ground conductor and ground.

94. Grounding condenser.

95. Buzzer.

96. Buzzer push-button test switch.

97. Buzzer battery.

97A. Buzzer coil.

98. Section of secondary inductance used for coupling.

99. Metal shielding separating primary and secondary tuning elements.

100. Main secondary inductance.

101. Secondary inductance switch.

102. Link in place as shown when long-wave unit is not used.

103. Secondary inductance coupling for regenerative feed-back.

104. Tickler coil.

105. Tickler inductance coupling to secondary.

106. Long-wave attachment link. See (102).

107. Oscillation test button switch.

108. Detector tube, Type UX-201A.

109. Detector filament rheostat.

110. Grid leak and condenser.

111. Secondary tuning condenser (.00006 to .00032 mfd.).

112. "A" battery for filament supply.
113. "B" battery for plate d-c. supply.
113A. "C" battery for grid bias voltage on amplifiers.
114. Detector jack.
115. First stage audio-frequency coupling transformer.
116. First stage amplifier tube, Type UX-201A.
117. First amplifier filament rheostat.
118. First audio stage jack.
119. Secondary stage audio-frequency coupling transformer.
120. Second stage amplifier tube, Type UX-201A.
121. Second amplifier filament rheostat.
122. Second audio stage jack.

Function of Apparatus—The ET-3628 Transmitting Circuits.—With the transmitter in full operation the Morse hand key (65) is depressed to radiate signal energy. The key closes the generator circuit and a low-voltage a-c. is delivered to the transformer primary (66), the wattmeter (64) indicating the true power input to the transformer. The wattage should not exceed approximately 1.5 watts. The high voltage necessary to supply plate excitation to the transmitting tubes is induced in the turns of the mid-tapped secondary (67). Each half of secondary (67) supplies voltage to one of the UV-204A tubes, the plates being connected to opposite terminals of the winding, the mid-tap point being grounded. Plate r-f. choke coils (68 and 69) prevent the high-frequency current from backing into the plate-transformer circuit which would result in severe losses of energy. By the use of these chokes maximum flow of radio oscillations is maintained in the tank circuit, or load circuit of the tubes consisting of (74), (75), and (79). By-pass condensers (72) and (73) connected between each respective plate and the tank circuit serve as low reactance paths for the flow of the high-frequency component of the plate current from the plates to the tank circuit. Furthermore these condensers act as blocking condensers because they isolate the low-frequency a-c. output of the transformer secondary from the high-frequency oscillatory circuit, or tank circuit.

The plate supply winding on the transformer secondary would be short-circuited if these condensers broke down. Thus, the energizing plate current for tube operation flows through the plate radio-frequency chokes (68) and (69) and the transformer secondary (67). Plate excitation condenser (74), of .002 mfd. capacity, couples the output or plate circuit to the input or grid. Radio oscillations passing through condenser (74), tank inductance (79), and grid excitation condenser (75), provide the proper voltage drop across (75) to supply the requisite excitation voltage on the grids for the generation of high-frequency oscillations. The frequency of the generated oscillations is determined by the selection of inductance and capacitance values of which the tank circuit consists.

Coil (76) is an r-f. choke required to prevent losses of high-frequency energy in the grid d-c. circuit and also acts to suppress the generation of unwanted additional frequencies (parasitic frequencies) of a higher order which would interfere with normal operation.

The filament by-pass condensers (30 and 31) allow the radio-frequencies to flow readily between the filaments and the tank circuit, the condensers being required because the only other path for the r-f. current would be through the secondary winding of the filament heating transformer. The large number of turns on the latter and the presence of the iron core would set up a high reactance or opposition which would choke out the r-f. and consequently stop oscillation. The grid resistor of 4000 ohms, connected in the grids of both oscillator tubes, maintains the proper negative grid bias for efficient operation.

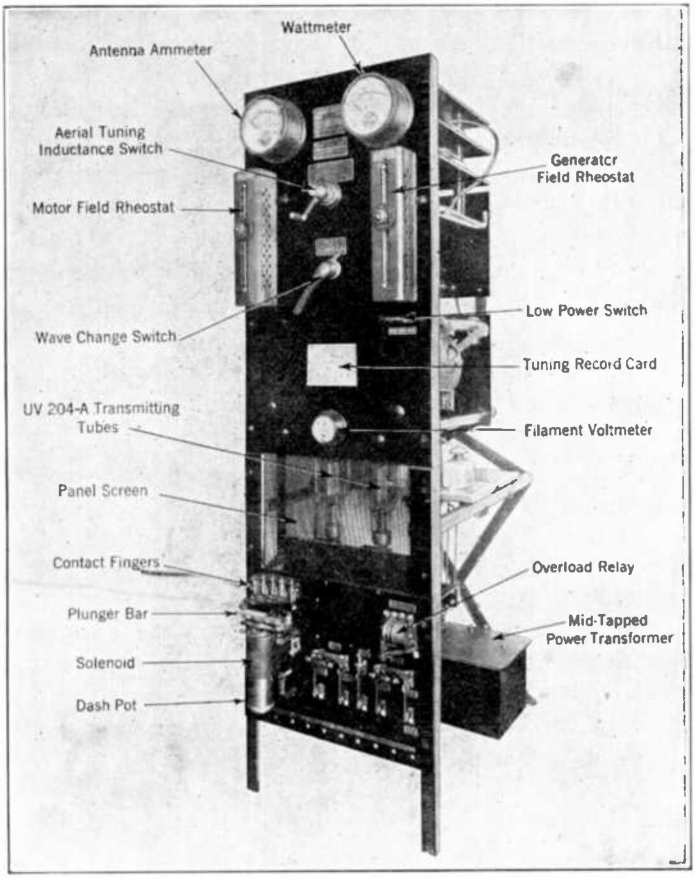


Fig. 2.—Front panel view of P-8 converted tube transmitter, type ET-3628.

A five-position switch (78), shown in the photograph Figure 2, is used to change the wavelength of the tank circuit and is mechanically connected to (83) which simultaneously changes the wavelength of the secondary or open radiating circuit. The loading inductances (82 and 84) are equipped with adjustable leads which permit the antenna circuit to be resonated to the primary or tank circuit for each of the available five wavelengths.

The aerial tuning inductance (85) is a continuously variable inductance fitted with a sliding clip thus permitting a critical resonant adjustment to be obtained on all wavelengths. Primary or tank inductance (79), sometimes called plate coil, is used for obtaining the proper amount of inductance for varying the frequency of the primary oscillatory or tank circuit and also functions to transfer part of its energy to the secondary inductance (80) by electromagnetic induction, thus setting the antenna system into excitation. The antenna radio-frequency ammeter equipped with a thermo-couple (81) measures the current at the particular point where it is located in the antenna system and indicates maximum deflection when antenna circuit reasonance is established with the tank oscillatory circuit for each wavelength provided by the transmitter. The antenna (88) and ground (80A) together with the several elements of inductance (80, 82, 84, and 85) make up the open or radiative circuit of the transmitter. Electromagnetic waves are propagated when the antenna system is energized.

The filaments of the UV-204A, 250-watt power transmitting tubes (70 and 71) are supplied with the proper terminal voltage from the filament transformer secondary (29) which steps down the a-c. voltage it receives from the rotary converter (28).

The a-c. voltmeter (32) indicates the filament voltage of the tubes. The d-c. motor end of the 100-watt rotary converter is indicated by the commutator (26), and the a-c. side of the machine, which supplies the filament transformer with the required voltage, is indicated by the collector rings (28). The arrangement of the series and shunt field windings is shown. The speed of the machine is controlled by rheostat (27) and, consequently, it regulates the output a-c. voltage supplied to the filament transformer and in turn the voltage impressed across the filaments.

When making adjustments, the generator (62) output should be increased by manipulating the field rheostat (53) until the safety spark gaps on the tank circuit condenser begin to spark over. When this condition occurs the voltage should be decreased slowly to a value just below this point, until sparking ceases.

Sending key (65) should not be closed while changing from one wavelength to another because the high-frequency circuits would then be open and damage to the equipment might result from arcing.

The lightning switch (87) should be closed in order to ground the antenna directly when the operator is not on duty or at other times in case of local electrical storms.

Operation of Apparatus. Auxiliary Apparatus—Operation of Motor-generator, Automatic Starter and Power Circuits.—During an emergency the transmitter can be operated from the auxiliary storage battery bank by placing the six-pole double-throw switch (24) in the right position. The switch is placed in the left position under normal conditions when the ship's 120 volt d-c. power supply is used. The automatic starter, in addition to acting as a starter, performs the function of a main-line circuit-breaker through the medium of an overload relay switch.

Upon closing the polarity reversing switch 3 and the d-c. supply switch (25) on the transmitter panel current flows through the motor field (58) and through the speed regulating rheostat (59). When the handle of change-over switch (86) is thrown in the down position for sending, or the push-button switch (38) is closed, the d-c. circuit through the starting solenoid (33) will be completed, and current will flow from the positive side of the d-c. line through this coil and through the protective resistor (34), through the lower contact on the overload relay (36), through the contact bar (37), through switch (38) or across contacts D, and thence to the negative side of the line. Plunger bar (40) will be drawn upward and immediately upon touching the first contact finger current flows from the positive line through the starting resistors (39), through flexible lead (41), through the motor armature (42), through the overload winding (45), and thence to the negative side of the line. The starting resistors are required to compensate for lack of sufficient counter e.m.f. until the armature attains full speed. The acceleration of bar (40) is regulated by a piston drawn through a vacuum chamber (dash pot). The motor armature now begins to rotate; and, as its speed increases, bar (40) continues to rise, touching each contact finger in succession which progressively short-circuits each one of the starting resistors (39) of the motor armature circuit. All of the starting resistors are cut out of the armature circuit when bar (40) of the automatic starter makes contact with next to the last finger and then the armature is connected directly to the d-c. line. At this moment the solenoid protective resistor (34) is automatically cut in the circuit by contact (35) which operates mechanically.

When the plunger bar reaches its uppermost position it touches the last finger contact (51) which connects the generator field winding (55) in shunt to the d-c. line through low-power resistor (54) and voltage regulating rheostat (53). The generator field circuit continues to contacts *E* on the antenna changeover switch (86), through the single blade switch (52) and finally to the last finger contact (51) on the automatic starter as stated. The output a-c. voltage of the generator is regulated by field rheostat (53). Low power is obtained by opening a switch shunted around resistor (54), which puts this resistor in series with the generator field and thus decreases the generator voltage. Generator field switch (52) should be opened as a protective measure whenever it becomes necessary to make repairs or adjustments to the equipment, or in such cases as when the motor-generator is running but the transmitter is not to be operated.

The motor-generator may be stopped by moving the handle of the change-over switch in the "Up" position, or receiving position, which opens the following circuits: Key circuit in the transformer primary generator field, solenoid circuit of the motor starter, and shifts the antenna from the transmitter inductance to the receiving set. If the motor-generator may have been started by using the push-button switch (38) then it will be necessary to stop the machine with this switch, in addition to throwing the change-over switch (86) into the "Up" position. When the motor-generator is to remain idle for a long period, the main line d-c. switch should be opened to stop the flow of current through the field winding of the motor.

The action of the dynamic brake resistor (49) is as follows: When the circuit to the solenoid (33) is interrupted either at switch (38) or at contacts D of the changeover switch (86), the plunger bar (40) drops downward, and through the connection made between bar (40) and contact (50) the fixed resistor (49) is placed in series with the motor armature, the circuit being completed through flexible lead (41) and thence back to (40). The motor armature then becomes a generator temporarily and is brought to a quick stop because of the power expended in setting up a current through resistor (49) and the powerful braking action set up against the armature because the magnetism now produced by the armature current is opposed by the magnetic flux of the field poles.

Practical Operation and Description of the IP-501 Receiver.—A rear view of the IP-501 is shown in Figure 3. To place the receiver in a condition for the reception of an incoming signal wave the handle of the aerial change-over switch (86) is thrown upward to the receiving position, which allows the signal oscillations to flow from the antenna through contact *B* to primary inductance switch (90), through the turns selected in the inductance (89), through the antenna series tuning condenser (92), and thence through the ground conductor to ground (93). The winding marked (98) is part of the

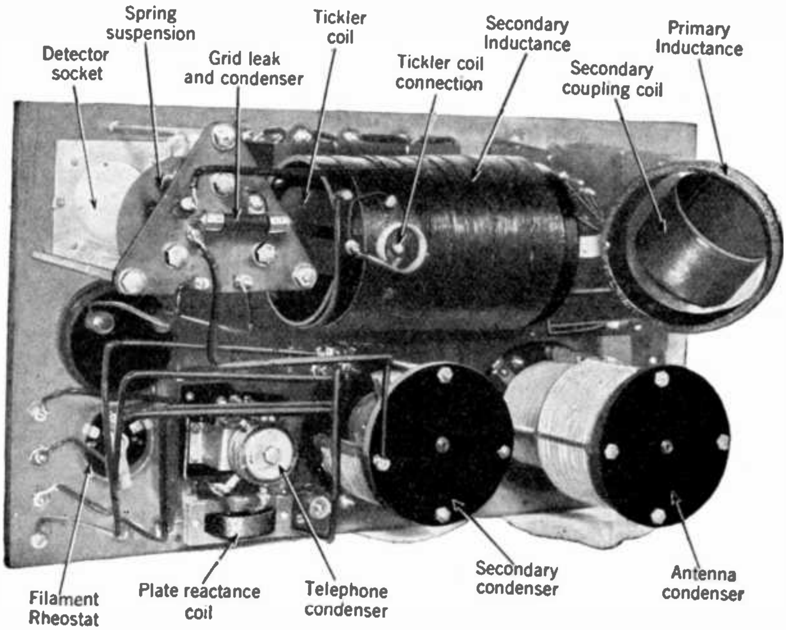


Fig. 3.—Rear view of the IP-501 receiver.

secondary inductance and is used to provide a variable coupling between the primary and secondary circuits. The filament side of the secondary is grounded through condenser (94). Condenser (111) is used to tune the secondary in conjunction with switch (101) in the tapped secondary inductance (100). When the primary circuit, tuned by (90) and (92), is placed in resonance with the secondary, tuned by (101) and (111), and the coupling at (98) is properly adjusted, then maximum signal current will circulate through the secondary and it follows that a maximum radio-frequency voltage will be applied between grid and filament of the detector tube (108).

The coil (103) is part of the secondary inductance and is used to provide coupling between the plate and grid circuits of the detector through tickler coil (104) (105). The tickler coil permits the receiver to be used either for regenerative amplification or for regenerative beat reception.

The circuit should be operated as a regenerative amplifier (known as non-oscillating detector) for the reception of signals from a spark transmitter, modulated continuous waves (either tone modulated or ACCW), and interrupted continuous waves (ICW).

During the reception of signals of the above type the tickler coupling (105) should be adjusted carefully until the circuit is just at the verge of oscillation; that is, the coupling should be only close enough to reinforce the plate current variations through the feed-back action of the tube. The current variations represent in electrical form the substance of the message being communicated.

If the tickler coupling (105) is increased to a point where the plate energy transferred to the grid is greater than the energy lost in the grid circuit due to oppositions therein, the tube and its associated circuits will generate continuous oscillations which are adjusted to some frequency slightly different from the signal frequency. The circuit should be set into oscillation to receive continuous wave signals (c.w.), and by proper adjustment the two sets of oscillations interact or heterodyne and a beat current, suitable for actuating the diaphragms in the telephone receivers, will result.

The aluminum shield isolates the primary and secondary main tuning inductances, thus preventing undesirable induction between them. When the push-button (107) for oscillation test is depressed the ticker coil is short-circuited, which prevents inductive feed-back from taking place. Hence each time the button is pressed oscillations will cease, this condition being manifested by a click in the headphones.

Headphones may be used in jack (114) directly in the output of the detector if the signal can be received with satisfactory volume. The balance of the receiver circuit consists of a typical two-stage audio amplifier with reception provided through jack (118) in the output of the first stage or jack (122) in the output of the second stage. Audio-frequency transformers (115) and (119) are used to couple respectively the detector to the first stage tube (116), and the first stage tube to the second stage tube (120). The signal is successively increased in volume after passing through the audio amplifier circuits. Separate rheostats are provided in the filament circuits of each tube for regulating the filament terminal e.m.f.'s of the tubes.

A crystal detector may be employed by connecting it to binding posts on the panel provided for that purpose; these connections are not shown in the diagram. A buzzer circuit is included in the receiver to aid in adjusting a crystal to its maximum sensitivity. The buzzer circuit, consisting of (95)-(96)-(97), generates a damped form of energy which is carried into the receiver through a small coil (97*A*) inductively coupled to the antenna circuit.

To operate the IP-501 receiver the headphones should first be placed in one of the jacks, the filament rheostats should be turned on and the switch on the receiver panel marked "Send-Receive" should be placed in the receive position. The receiver circuit is now adjusted to what is known as a "listening-in" or "stand-by" position by tightening the coupling (98) and using maximum primary condenser capacity (92), but employing only a minimum amount of secondary condenser capacity (111) and minimum tickler coupling (103)-(105).

When tuning for spark signals or I.C.W., coupling (98) should be loosened as much as possible and the secondary (101) and primary (90) inductance switches should be moved from tap to tap in a progressive manner. For each change in the primary inductance, tune over the entire range of the secondary circuit; and at some time the point of resonance will be found and signals will be heard.

For the reception of c.w. follow the general procedure for tuning in spark signals but increase coupling (98) until the circuit oscillates, the test being made with push-button (107). However, in c.w. reception the signal is often tuned in and out with a small variation in capacity and therefore the condensers should be rotated very slowly. For every change in the adjustments of inductance (90) and capacitance of the primary condenser (92), the secondary condenser (111) should be slowly rotated back and forth. Each time the point is reached when the secondary is tuned to resonance with the primary it will be indicated by a slight click heard in the phones. After varying the primary capacity continuously but very slowly with the left hand and at the same time swinging the secondary condenser back and forth slowly past the resonant point with the right hand, the characteristic note of a c.w. signal will be tuned in at some location on the dial close to the resonant point. Now loosen the tickler coupling as much as possible, but maintaining oscillation, to secure selective reception and also employ the loosest coupling (98) possible between the primary and secondary.

The links (91), (102), and (106) are removed when a long-wave loading inductance unit is supplied with the receiver. The link terminal posts of the receiver and long-wave units are diametrically opposite and connecting leads can be installed with complete sureness of accuracy.

2. ***Question.*** **Draw a diagram of a complete radio telegraph installation utilizing an arc transmitter.**

Answer. The complete schematic wiring diagram of the arc transmitter shown in Figure 4 is the 2-kw. Federal arc transmitter, models K and Q. The back-shunt method of signaling is employed in this transmitter. The apparatus for models K and Q are identical in every way except for the wavelengths employed.

The legend for the complete arc installation is given in the order in which the parts are numbered.

1. Main line d-c. switch, 120 volts.

2. Hand starter resistor units. These units limit the current to the motor armature until it builds up sufficient counter e.m.f. and attains full speed.

3. Circuit breaker. In case of trouble the arm of the motor starting panel is automatically released by means of the low-voltage release coil.

4. D-C motor armature.

5. Field windings of the d-c. shunt-wound motor.

6. Condenser functions as a protective device. The condenser absorbs any stray radio-frequency currents which may leak back into the motor-generator circuit.

7. Condenser functions as a protective device. The condenser absorbs any stray radio-frequency currents which may leak back into the motor-generator circuit.

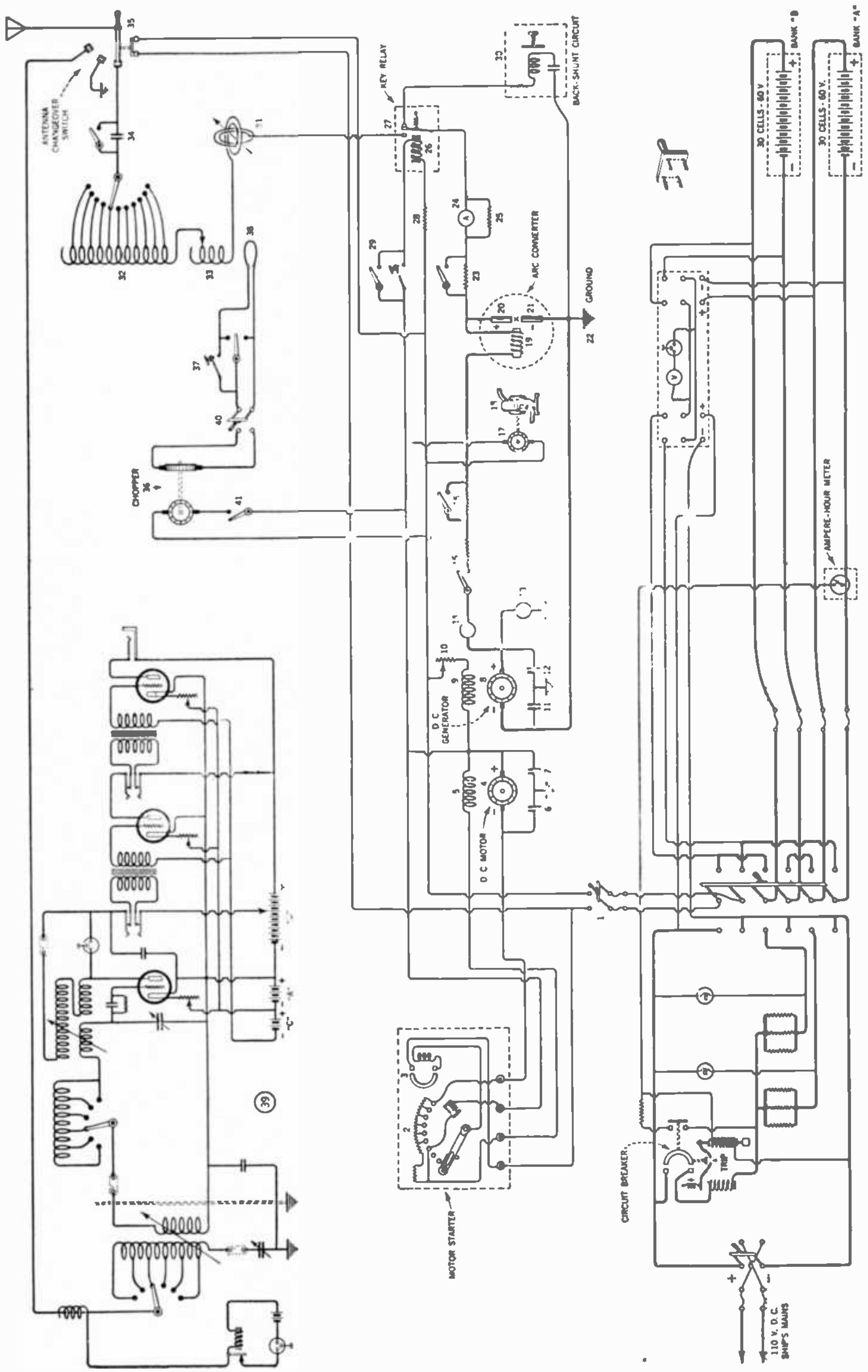


FIG. 4.—Diagram of a complete shipboard radio installation consisting of an arc transmitter, IP-501 receiver, and auxiliary (battery) power supply

8. D-C generator armature. The arc requires direct current power supplied at 250 to 400 volts.

9. D-C generator field. The field is wound for separate excitation from the 120-volt d-c. supply.

10. D-C generator field rheostat used to control the d-c. voltage supplied to the arc.

11. Protective condenser. Serves same purpose as condenser (6).

12. Protective condenser. Serves same purpose as condenser (6).

13. D-C voltmeter indicating generator output e.m.f.

14. D-C ammeter indicating d-c. current drawn by the arc.

15. Main arc starting switch with overload release coil.

16. Arc starting resistor and switch.

17. D-C motor for operating water pump and carbon drive mechanism.

18. Centrifugal pump in water circulation system.

19. Represents several blow-out magnet coils connected in series, which serve both as magnetizing windings to blow out the arc flame at periodic intervals and as choke coils to prevent the flow of radio-frequency current back into the generator and power supply circuits.

20. Anode. This electrode consists of a water-cooled copper tip brazed to a short piece of brass tubing. The anode is the positive electrode of the arc.

21. Cathode. This electrode is a carbon rod ½ in. in diameter and 7 in. long which is rotated slowly at a uniform speed to allow carbon deposits to build up evenly on the tip of the rod and thus steady the radio-frequency output of the arc. The cathode is the negative electrode of the arc.

22. Ground for the complete arc converter. The arc chamber is a gas-tight and water-tight compartment within which the arc burns. It converts d-c. power into high-frequency a-c. power.

23. Antenna low-power resistor and switch. The resistor is connected in the circuit to permit reduction of antenna current when communicating with a nearby station.

24. Antenna high-frequency ammeter with a self-contained thermo-couple.

25. Antenna ammeter protective coil.

26. Relay key equipped with extra heavy contacts operated magnetically by the hand key.

27. Key relay. The movable contacts on the relay are controlled by an electromagnet and a spring.

28. Current controlling resistor of relay key.

29. Morse hand key. The switch around this key may be closed when the chopper circuit is placed in operation.

30. Complete back-shunt unit consisting of a fixed condenser, fixed resistor and iron plate mounted immediately in front of a small inductor coil. A knob permits the iron disk to be screwed in and out thereby changing its distance from the coil. Eddy currents and hysteresis losses occur in the disk when r-f. oscillations pass through the coil and this causes an increase in the resistance of the back-shunt circuit. The back-shunt circuit is a local non-radiating oscillatory circuit included in an arc equipment in order that the arc converter may

have a circuit upon which to oscillate during the intervals between dots and dashes.

31. Variometer used to vary slightly the frequency of the outgoing wave and hence the tone of the signal heard by the operator at the receiving station.

32. Main loading inductor with tapped turns which permits tuning the transmitter to the assigned frequency.

33. Inductor consisting of a few turns used for fine tuning adjustment.

34. Antenna series condenser and short-circuiting switch. This condenser is connected in series in the antenna circuit on all wavelengths below 2000 meters.

35. Antenna changeover switch, or "Send-Receive-Ground" switch.

36. Motor-driven chopper. The d-c. motor operated from 120-volt d-c. ship's supply is shown on the left and the chopper commutator wheel on the right. The segments on the wheel are alternate copper and insulated bars which serve to alternately open and short-circuit the compensation loop. The chopper is used to transmit signals to receivers using either a crystal detector or non-regenerative vacuum tube detector.

37. Auxiliary hand key in chopper circuit. This key is slightly heavier than the usual Morse hand key and is equipped with silver contacts.

Immediately below 37 is the transfer switch for chopper and auxiliary hand key. It is a single-pole double-throw switch which permits the coupled compensation loop around the bottom of the antenna loading inductor to be connected either to the chopper or the auxiliary hand key, or to the two in series.

When the switch is thrown to the right, on the panel itself, the coupled compensation loop is connected directly with the auxiliary hand key. Signaling may then be accomplished by the coupled compensation method.

When the switch is thrown to the left the chopper is connected directly to the coupled compensation loop. Signaling may then be accomplished by the use of the back-shunt relay key.

When the switch is open, the auxiliary hand key is connected in series with the compensation loop and the chopper. Signals may then be transmitted with the chopper by using the auxiliary hand key.

38. Coupled compensation loop. This loop consists of a single turn of high-frequency cable placed around the lower end of the antenna loading inductor. The loop may be short-circuited at will by means of the auxiliary hand key. With the arc in operation and the auxiliary hand key open, radio-frequency energy will be radiated at a certain wavelength. If the key is depressed, the energy will be radiated at a shorter wavelength than before, the change in wavelength being due to transformer action and mutual inductance between the main inductance and the loop.

39. The IP-501 receiver.

40. Main chopper switch.

41. Switch controlling chopper motor circuit.

Practical Operation of the Arc Transmitter. How to Start and Stop the Arc.—To start the arc after a short period of rest: (1) Place the "Send-Ground-Receive" switch in sending position and start the motor-generator, if it has been stopped. (2) Close the arc main line switch, strike and adjust the arc. (3) Close the arc starting resistor and again adjust the arc. These and other units of the arc transmitter are clearly shown in Figure 5.

To stop the arc for a short period: (1) Open the arc main line switch (this automatically opens the arc starting resistor switch). (2) Place the "Send-

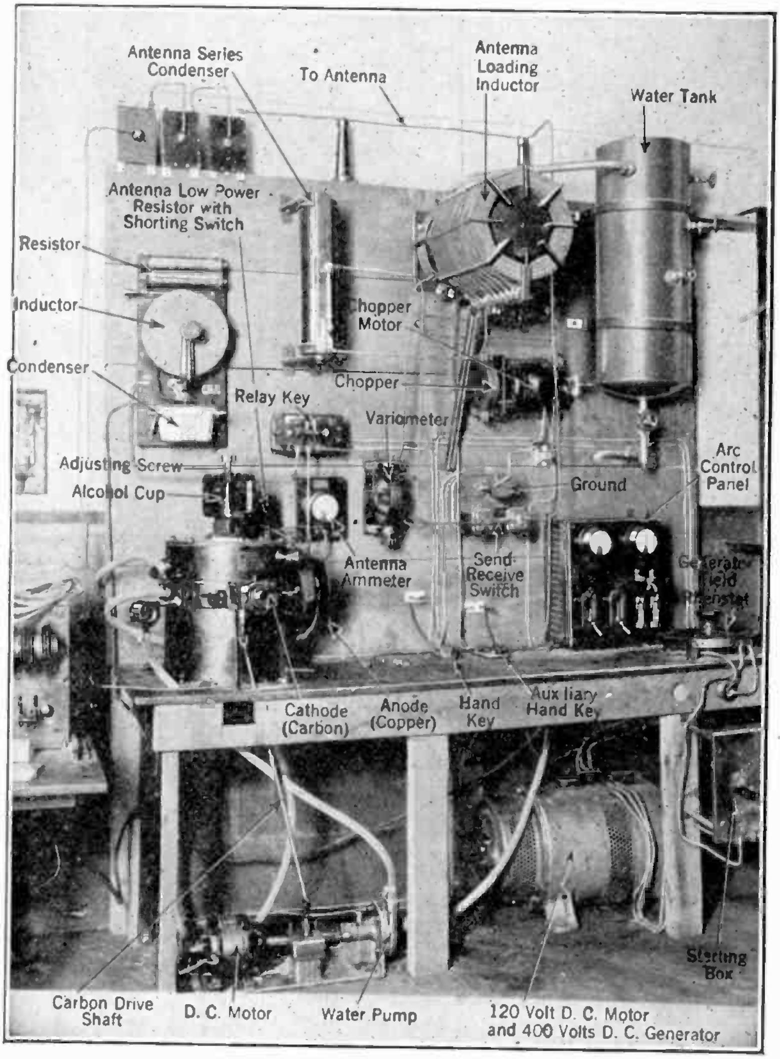


FIG. 5.—The 2-kw. Federal arc transmitter. The three Dubilier condensers shown in the extreme upper left are included in this equipment as a "phantom" or "dummy" antenna for laboratory demonstration.

Ground-Receive" switch in receiving position. (3) If it is desired to stop the motor-generator, this may be done by opening the "Set Supply" switch or the circuit breaker on the motor starting panel.

To shut down the arc transmitter for a long period of rest: (1) Open the arc main line switch. (2) Open the set supply switch (this automatically releases the arm of the motor starting panel by means of the low voltage release coil). (3) Cut off the alcohol flow. (4) Place the "Send-Ground-Receive" switch on "Send" or "Ground" as desired.

To start the arc after a long period of rest: (1) Close the d-c. main-line switch. (2) Place the "Send-Receive-Ground" switch in the sending position which connects the antenna to the loading inductor and also starts the d-c. motor operating the water pump and carbon drive shaft. (3) Close the circuit breaker on the starting panel, move the starter arm across the contact studs, bringing the motor up to full speed gradually. Adjust the generator field rheostat until the d-c. voltmeter reads about 250 volts. (4) Adjust the needle valve on the alcohol cup until the alcohol drips through the sight feed rather rapidly. (5) Next adjust the carbon on the arc so as to allow about $\frac{1}{32}$ inch motion when the arc is struck. (6) Now close the arc main-line switch and strike the arc. Draw it out as long as possible without causing it to break. Do not draw out the arc too quickly when starting for the first time; it is best to keep the arc quite short for perhaps a minute or two until sufficient alcohol has been decomposed by the arc flame to provide a partial hydrogen atmosphere in the chamber. When the arc begins to generate radio-frequency oscillations in the oscillatory circuit, this will be apparent by an indication of current in the antenna ammeter. (7) Adjust the arc until maximum reading on this meter is obtained and then close the arc starting resistor, which cuts out this resistor, and again adjust the arc for maximum reading. (8) The final adjustments to be made are the reduction of the alcohol flow to a few drops per minute and the regulation of the generator voltage by the field rheostat to obtain the desired antenna current.

Auxiliary Power Supply.—The auxiliary (battery) power supply for this installation is identical to that used in conjunction with the ET-3628 installation covered in answer to Question 1.

Receiver.—The arc installation may include the IP-501 receiver. The legend and theory of operation of this receiver is given in answer to Question 1.

3. *Question.* Draw a diagram of a complete ship-board radio installation including a tube transmitter with radiophone attachment. Include source of power and name all parts and give their function. State the type and rating of the transmitter.

Answer. A complete schematic diagram is shown in Figure 6. The transmitter is the ET-3627A with a power rating of 200 watts. The radiophone attachment employs the Heising (constant-current) system of modulation. The legend is as follows:

A. Antenna ammeter (0-10 amps.) is used to indicate resonance between the tank circuit (closed oscillatory circuit) and the open antenna circuit.

A. Plate ammeter (0-2 amps.) indicates the total plate current supplied to the tubes by the d-c. generator.

C-1. Master oscillator plate excitation condenser (.003 mfd.) is connected in series with the grid excitation condenser and tank inductance forming the oscillatory circuit. The plate condenser couples the output to the grid and assists in supplying the proper grid excitation voltage for feed-back purpose. This is a Colpitt's type oscillator.

C-2. Filter condenser (1 mfd.) serves to smooth out ripples in the direct current from the 1000-volt generator due to communtation. It also serves to by-pass r-f.

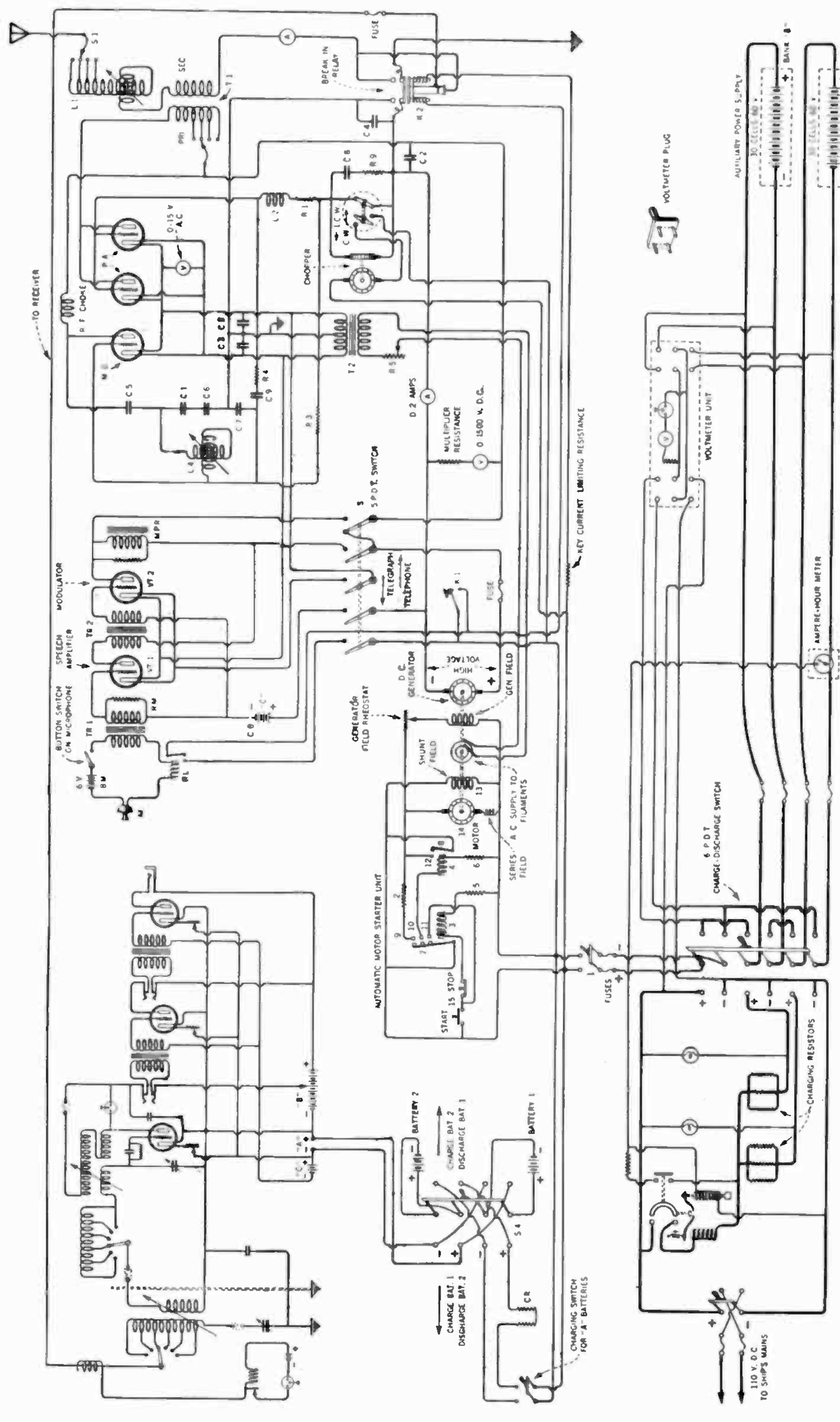


FIG. 6.—Complete shipboard radio installation consisting of the ET-3627A 200-watt tube transmitter with radiophone attachment, the IP-501 receiver, an "A" battery charging unit, and auxiliary (battery) main power supply.

C-3. Filament by-pass condensers (.5 mfd. each) furnish a low reactance path for the flow of r-f. oscillations between the grid and filament circuits.

C-4. Key condenser (.015 mfd.) functions to absorb and dissipate high voltage surges set up while keying, a condition which is manifested by arcing at the key contacts.

C-5. Master-oscillator plate blocking condenser (.003 mfd.) permits the r-f. component of the plate current to flow through readily, but prevents the d-c. component of the plate supply from passing into the high-frequency circuit.

C-6. Master-oscillator plate condenser (.002 mfd.) functions similarly to C-1 and forms part of the oscillatory circuit.

C-7. Master-oscillator grid condenser (.002 mfd.), or grid-excitation condenser, supplies the requisite voltage drop to be impressed between grid and filament for maintaining the oscillator tube and associated circuits in a state capable of generating continuous oscillations.

C-8. Chopper condenser (.003 mfd.) used in conjunction with resistor R-9 assists in smoothing out any uneven characteristics in the chopper note in order to produce a clear and distinct tone in the telephone receivers.

C-9. Power-amplifier grid condenser (.0003 mfd.) permits the high-frequencies generated in the master-oscillator circuit to pass through and properly excite the grids of the two power tubes.

Fuse. Receiver antenna fuse (.5 ampere) protects the receiver inductance in case of induction which would have damaging effects.

K-1. Morse hand key used for controlling the stream of radio oscillations generated by the transmitter into dots and dashes. Both the negative plate circuit and the grid current are broken by the keying action; thus the plate current ceases and the grid quickly builds up a high negative voltage with the result that oscillations stop.

K-2. Break-in relay (key relay) permits a rapid changeover from send to receive, being operated magnetically by hand key K-1. It acts as an automatic antenna transfer switch and power relay and makes it possible for the sender to listen-in while sending and perhaps receive a request for a repeat or urgent information from the distant station before completing a long series of messages.

L-1. Antenna variometer and four-tap inductance used for loading the antenna circuit and permitting very fine tuning adjustments to be made in order to place this circuit in resonance with the tank circuit.

L-2. Power-amplifier grid radio-frequency choke. This is used to prevent losses of the high-frequencies in the grid leak circuit which are necessary to supply the proper excitation voltage on the amplifier grids.

R. F. Choke. Master oscillator plate r-f. choke. This is in series with the positive lead of the 1000-volt generator and serves to block out the radio-frequencies from this circuit, thus preventing losses. The r-f. oscillations readily find a path through condenser C-5.

L-4. Master oscillator variometer is used to adjust the transmitter's frequency to any of the transmission frequencies selected.

R-1. Power amplifier grid resistor (500 ohms) used to provide proper grid bias voltage for stable operation of the two UV-211 power amplifier tubes.

R-3. Master-oscillator grid resistor (7500 ohms) maintains the oscillator grid at the proper negative potential (grid bias voltage).

R-4. Power amplifier feed resistor (150 ohms) used to maintain the radio-frequency voltage supplied to the power amplifier grids from the master oscillator circuit at the proper working value.

R-5. Filament rheostat (20 ohms) used to control the filament terminal e.m.f. of all tubes for proper electron emission.

Generator Field Rheostat. Plate rheostat (250 ohms) permits regulation of the positive plate voltage on all tubes.

R-9. Chopper resistor (50 ohms) functions in conjunction with C-8 to smooth out any unevenness in I.C.W. energy.

Key Current Limiting Resistance. Key relay resistor (400 ohms) limits the current through the solenoid of the key relay.

S-1. Antenna inductance switch permits convenient change of wavelength from calling wave to communicating (working) wave.

T-1. Antenna coupling transformer consists of tank inductance, or primary and antenna inductance, or secondary, and is used to provide magnetic coupling between the closed and open circuits. The high-frequency currents flowing through the primary set up lines of force which act on the secondary turns generating in the latter oscillations of similar frequency which traverse the antenna system and cause it to radiate electromagnetic waves through space. The tapped inductance permits the proper selection of inductance for either form of transmission, that is, c.w. or I.C.W.

T-2. Filament Transformer (.125 kva.) serves to step-down the a-c. voltage received from the rotary converter to a suitable value for supplying the filaments.

Filament voltmeter (0 to 15 volts a-c.) is used to indicate the voltage impressed on the filaments and should read 10 volts for the tubes used in this equipment after completing the voltage adjustment by means of the filament rheostat R-5.

Plate voltmeter (0 to 1500 volts d-c.) permits the amount of positive plate potential applied to the tubes to be ascertained at any time during operation.

M. Microphone. This is used to convert the sound pressure waves impressed upon a thin diaphragm into feeble electrical impulses which are passed through a vacuum tube amplifier to increase their amplitudes. The diaphragm indirectly exerts a mechanical pressure against small carbon granules. The diaphragm vibrations continually vary the resistance of the granules, by compressing or loosening them in varying degrees and thus causing a fluctuating current to pass through the primary of transformer TR 1.

RL. Microphone relay. This relay is operated by a button switch and functions automatically to close the key circuit of the transmitter for the purpose of starting oscillations whenever the microphone is to be used.

BM. Microphone battery. This 6-volt battery supplies the energizing direct current which flows through the microphone and transformer primary, TR 1.

TR 1. Speech input transformer. This audio-frequency transformer is used to couple the microphone output to the single-stage vacuum tube amplifier. The variations in current through the primary induce an alternating e.m.f. of similar frequency characteristics in the secondary and this is applied to the grid or input of the tube.

VT 1. Speech amplifier tube. This single-stage amplifier tube is required to raise the level of the feeble impulses it receives from the microphone circuit to provide variations of high amplitude. These audio-frequencies then will supply the grid of the modulator with proper excitation voltage for modulating the transmitter's output.

TR 2. Audio-frequency transformer. The variations in the plate current through the primary induces an alternating e.m.f. in the secondary, and this speech-frequency voltage in turn is applied to the modulator grid. The transformer thus serves as a coupling device between the output of the speech amplifier and the input to the modulator.

RM. Grid resistor. This serves as a path for the grid direct current and provides this circuit with good speech-frequency characteristics.

VT 2. Modulator tube. The plate circuit of this tube and the oscillator are connected in parallel and are supplied from the d-c. generator through the modulation plate reactor MPR, the latter tending to maintain a steady plate supply to both tubes. Assume that the set is operating and the oscillator is producing high-frequency oscillations at the frequency (or wavelength) selected. When the microphone is idle the modulator plate current flows steadily but when speech-frequency voltages are passed on to the modulator grid, the plate current through this tube varies according to the e.m.f.'s applied to the grid. Variations in the modulator plate current effect the oscillator plate current in the following manner: Increases in modulator plate current cause corresponding decreases in oscillator plate current, and vice versa, this action being due to the fact that the modulation plate reactor keeps the total plate current supply at practically a constant value. Thus when the oscillator plate current varies, the amplitudes of the generated high-frequency oscillations must also vary accordingly, or it can be said that the high-frequencies produced by the oscillator have been modulated by the audio-frequencies in the output of the modulator.

CB. Grid bias battery, called "C" battery. This is used to maintain the proper negative voltage on the grid at all times in order to prevent the grid potential from ever actually becoming positive when impressed with speech-frequency voltages. Excessive grid current, which might be the possible cause for distortion, is prevented by the negative bias.

MPR. Modulation plate reactor. This unit possesses a high impedance or opposition to audio-frequency changes in the direct current passing through it and therefore maintains a practically steady supply to the modulator and oscillator plate circuits.

S. Five-pole double-throw changeover switch is used for placing the microphone and radiophone apparatus in and out of operation.

M.O. Master-oscillator tube. This tube operating into the Colpitt's oscillator circuit (tank circuit) generates continuous oscillations at the frequencies assigned to the transmitter.

P.A. Power amplifier tubes. These tubes, operated in parallel, receive the high-frequency oscillations generated in the oscillator circuit and increase their amplitudes. Consequently they deliver a large radio power of similar frequency to the antenna through the coupling transformer T_1.

Chopper. Used to break up the continuous oscillations into audible group frequencies by the use of brushes and alternate copper and mica bars on the periphery of the commutator wheel which make and break the grid circuit and thus interrupt the flow of grid current.

A d-c. motor shown at the left of the chopper is used to drive the commutator wheel of the chopper.

Front and rear views of the ET-3627A transmitter are shown in Figures 7 and 8, respectively.

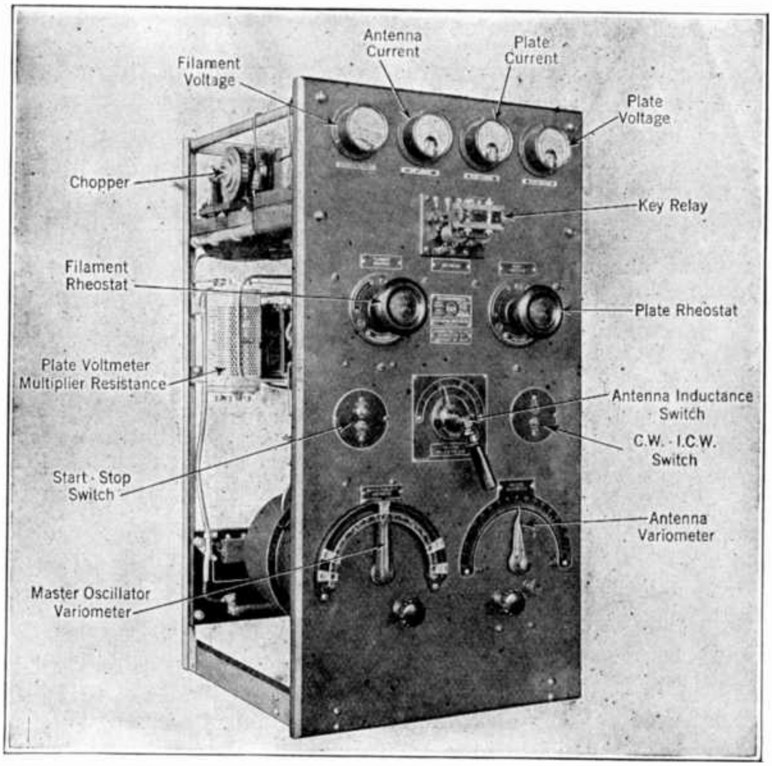


Fig. 7.—Front panel view of the 200-watt RCA tube transmitter type ET-3627A.

Standard Radiomarine Corporation "A" Battery Charger

Two 6-volt storage batteries are included with each shipboard installation for supplying filament voltage to the receiving tubes. Thus, a charged battery is always available.

In Figure 6 switch S4 is a four-pole double-throw switch which connects one battery to the "A" battery binding posts on the receiver and at the same time places the other battery on charge, and vice versa. CR represents charging resistors in series with the positive side of the main d-c. line. Batteries 1 and 2 are 6-volt 100 ampere-hour batteries, each having a normal charging rate of 5 amperes.

Two-step counter e.m.f. type motor starter. Refer to Figure 6.

1. D-C main-line switch. Puts voltage on the transmitter circuits from the d-c. source and supplies current to the motor fields.

2. Starting resistors. Used to limit current through motor armature until counter e.m.f. builds up.

3. Starter relay solenoid. This coil becomes energized when start button is closed and pulls over contact bar (7), thus setting armature (14) into rotation.

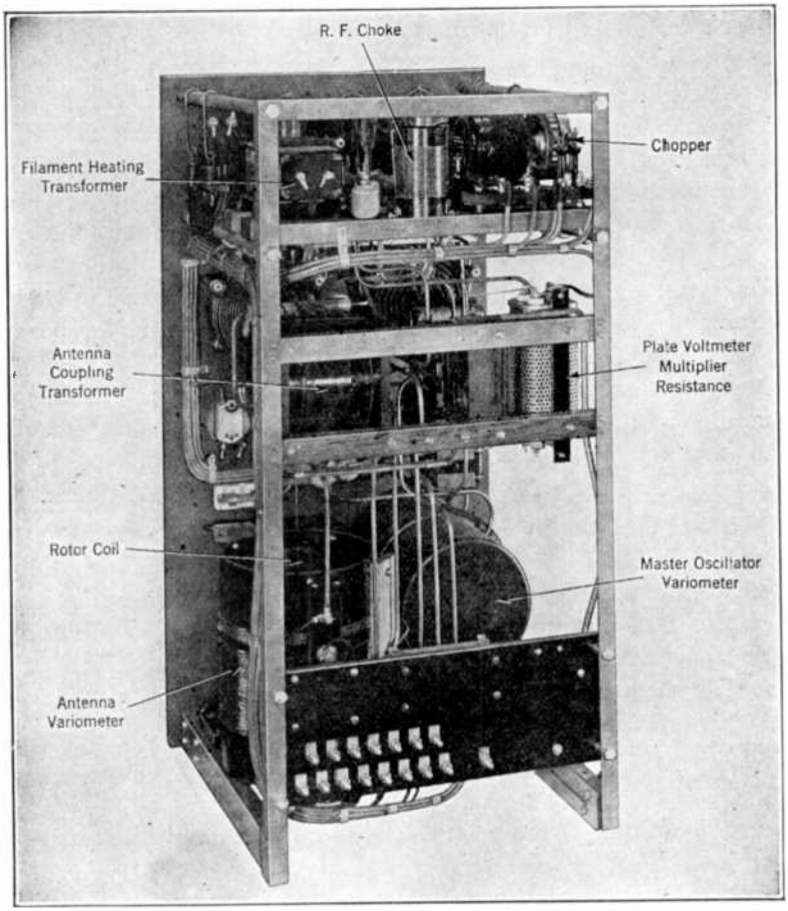


FIG. 8.—Rear view of ET-3627A tube transmitter.

4. Starter relay solenoid. This coil is supplied with sufficient current to cause its magnetic field to attract contact bar (8) when the proper counter e.m.f. builds up to permit the short-circuiting of the starting resistors.

5. Starter relay protective resistor. This limits to a safe value the current through solenoid (3).

6. Starter relay protective resistor. The current through relay solenoid (4) is controlled by this resistor in series.

7. Relay contact bar. The contacts on this bar close the proper circuits

to cause the motor-generator to function. It closes the d-c. line to the motor armature, generator field, and also supplies current to relay solenoid (4).

8. Relay contact bar or running contactor. This bar, when making connection with contact (12) short-circuits the starting resistors and permits full current to flow to the motor armature.

9. First contact starter. This closes immediately upon pressing the start button and the motor-generator begins to rotate. In about one or two seconds the running contactor closes and the motor-generator comes up to full speed.

10. Second relay contact. The circuit completed by the closing of this contact energizes solenoid (4) of the running contactor.

11. Holding contact.

12. Short-circuiting contact on starting resistor.

13. Series and shunt field winding of motor. Used to set up a strong steady flux in the soft iron field poles to act upon the flux set up by the armature current and cause rotation of the armature.

14. Motor armature. This is coupled directly to and drives the generator armature.

D-C Generator. The high plate voltage required to excite the transmitting tubes is generated in the armature coils. A fuse is inserted in the positive side of the line as shown.

A-C supply to filaments is obtained from collector rings. These are fitted on the motor end of the motor-generator and deliver alternating current generated in the armature to the filament heating transformer T 2.

Auxiliary Power Supply.—The auxiliary power supply for this installation is identical to that used with the ET-3628. Refer to the answer to Question 1.

Receiver.—The IP-501 radio receiver may be employed with this installation. Refer to the answer to Question 1 for instruction concerning it.

4. *Question.* Draw a diagram of a complete shipboard installation including a spark transmitter. Name all parts and give their function.

Answer. The schematic diagram of this installation, including the P-8 spark transmitter, is shown in Figure 9. The legend is as follows (Refer to Figure 1 for identification of parts from 1 to 65, inclusive):

1. D-C supply from ship's generator.

2. Fuses. These protect the main d-c. circuit by melting if excessive current flows.

3. Polarity reversing switch permits d-c. of the proper polarity to be applied to the battery terminals for charging.

4. Main fixed contact completes d-c. circuit through circuit breaker for battery charging.

5. Main fixed contact of circuit breaker (see 4).

6. Underload circuit breaker electromagnet. If ship's d-c. voltage drops or is discontinued the magnetic pull on the iron trip is released, thus actuating the circuit breaker.

7. Charging resistors. Used to control the number of amperes of charging current flowing through battery bank B.

8. Charging resistors. Used to control the charging current through battery bank A.

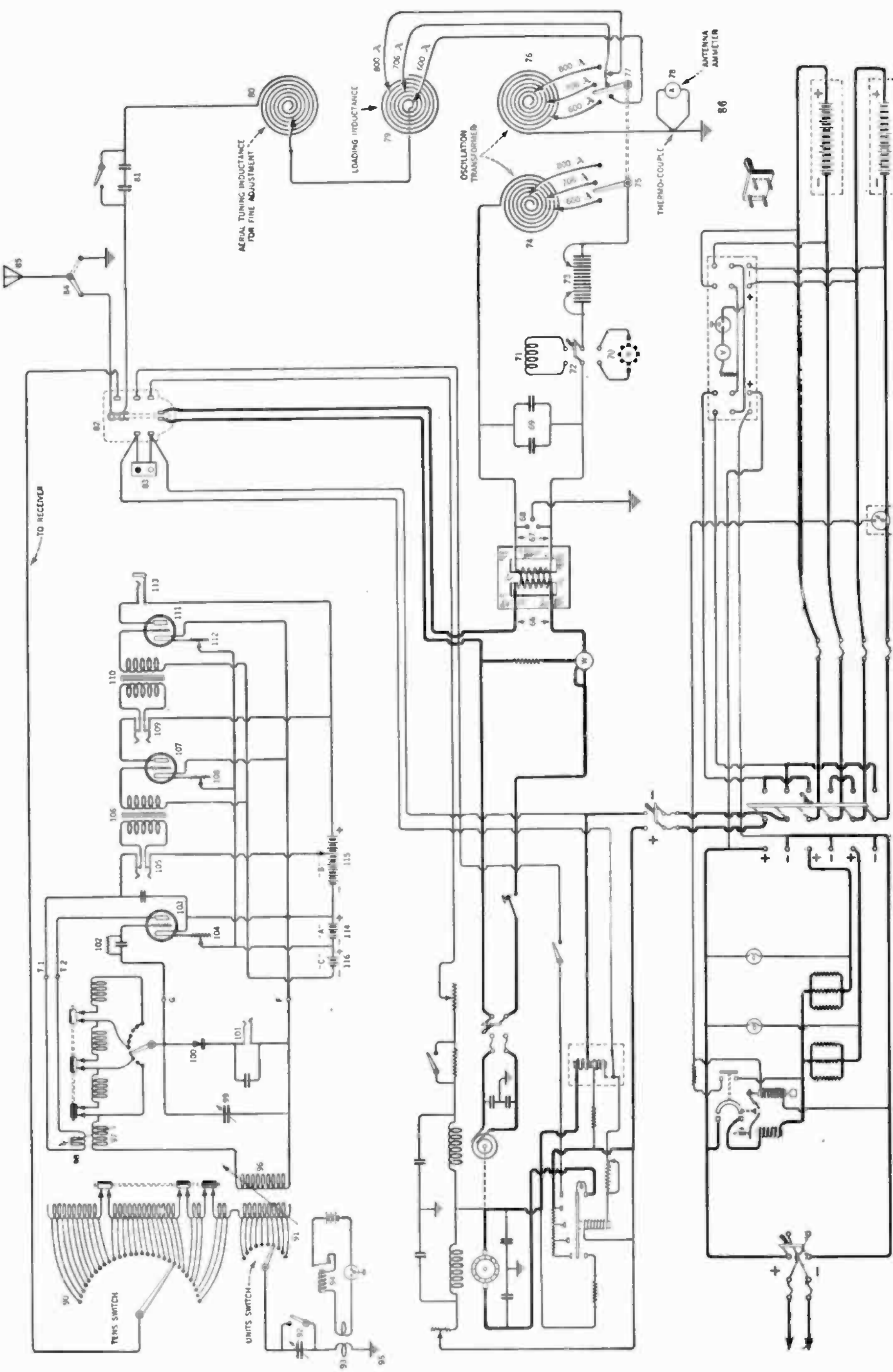


FIG. 9.—A diagram of a complete radio installation on shipboard, consisting of the 2-kw. type P-8 spark transmitter, type 106-D receiver, and auxiliary (battery) power supply.

9. One bank of 30 lead-acid storage cells, 60 volts.

10. One bank of 30 lead-acid storage cells, 60 volts.

11. Ampere-hour meter. The state of charge and discharge of the batteries may be ascertained on this meter at any time during the charging and discharging periods. The charging period can be regulated by a black hand, which, at the end of the period touches a contact pin, short-circuiting the coil of electromagnet (17) which in turn trips the circuit breaker and opens the battery charging circuit.

12. Trickle-charge lamp. A slow internal action goes on continually within a battery when it is not used, thus causing a slight sulphation of the plates. A low rate charging current put into the batteries by means of the high resistance lamps tends to minimize sulphation, thus keeping the batteries in good condition.

13. Trickle-charge lamp (see 12).

14. Overload coil circuit contact. When the metal bar makes connection with contacts (14) and (15) current flows through the overload coil.

15. Overload coil circuit contact (see 14).

16. Current limiting resistor. This unit allows the proper current to flow through solenoid coil (17) until the pointer on the ampere-hour meter reaches full-charge position and at this moment a short-circuit is placed around the coil causing the latch on the underload breaker to trip, thus opening the charging circuit.

17. Overload solenoid coil. The magnetism set up by this coil is utilized to operate the trip mechanism of the circuit breaker.

18. D-C voltmeter. This instrument is used to take voltage readings of the following: the ship's source of power, the complete battery bank when discharging, or the individual *A* and *B* banks when charging or discharging. Readings are obtained by inserting the voltmeter plug in the proper position and pressing the push-button (20).

19. Voltmeter multiplier resistor. Used to limit the current flow through the small movable coil in the meter.

20. Voltmeter switch. This is a push-button switch which closes the voltmeter circuit when readings are desired.

21. Voltmeter plug receptacle. Consists of a suitable number of holes fitted with contact springs connecting to the various circuits which require voltage readings to be taken.

22. Voltmeter plug receptacle. (Same as 21.)

23. Voltmeter plug. This device is fitted with four long prongs which act as a switch when inserted in the proper holes in the voltmeter plug receptacles.

24. Six-pole double-throw charge and discharge switch. Four blades of this switch alter circuit connections and divide the auxiliary 120-volt battery into equal banks of 60 volts each, placing banks *A* and *B* in parallel for charging and in series for discharging. The other two blades connect the d-c. line to the transmitter.

24A. Fuses. The individual battery banks *A* and *B* are protected in the event excessive current flows by melting of the fuses.

25. Main d-c. supply switch on the transmitter panel. This switch allows current to flow to the motor field and automatic starter.

Motor-generator and Power Circuits

33. Automatic starter solenoid coil. When this coil is energized it raises the plunger bar slowly, setting the motor armature into rotation.

34. Protective resistor for solenoid coil. This unit is automatically placed in series with the coil when the motor reaches full speed and thereafter limits the amount of current which continually flows through the coil.

35. Short-circuiting contacts for protective resistor. A mechanical arrangement, through suitable contacts, shorts out the resistor when the motor is idle or during the starting period.

36. Fixed contact on overload relay. The iron contact bar (37) normally rests on contact (36) and closes the d-c. circuit through the starting solenoid (33).

37. Movable iron contact bar of overload relay. This bar is drawn up when excessive current flows through coil (45) by the strong magnetism set up. When the contact bar disconnects from fixed contact (36) the circuit through starting solenoid (33) is opened, and plunger bar (40) drops, thus breaking the armature circuit and stopping the motor.

38. "Start-stop" push-button switch. When the d-c. circuit is closed by the switch, current flows through solenoid coil (33), setting in operation the automatic starter. When the switch is opened, however, coil (33) is de-energized and plunger bar (40) drops down with the result that current to the motor armature is discontinued and consequently it stops running.

39. Starting resistors and contact fingers. These resistors keep the current through the armature coils at a safe value as the counter e.m.f. in the coils builds up until the armature attains full speed.

40. Plunger bar. This bar lifts vertically at a predetermined rate when current is supplied to solenoid (33) and acts to short-circuit, gradually, each starting resistor (39) in succession through the finger contacts while the motor armature builds up speed, all resistors being cut out when the armature rotates at full speed. The generator field is supplied with current when the plunger bar is in the uppermost position, making connection with the last finger contact.

41. Flexible connection to permit one leg of the circuit to remain closed while the plunger bar moves.

42. D-C motor armature. The motor is used to drive the generator armature. Direct drive is usually employed through a suitable coupling between the armature shafts.

43. Protective condenser (1 mfd.). This condenser and others used for a similar purpose are shunted across some winding of the power machinery to absorb and dissipate any destructive high-voltage high-frequency currents set up in these conductors by induction.

44. Protective condenser (1 mfd.). (Same as 43.)

45. Overload relay coil. Excessive current through this coil sets up a strong magnetic flux which attracts the iron contact bar (37) and closes the d-c. circuit through contact (47) and through holding coil (46).

46. Holding coil. The magnetism set up by this coil is used to hold up contact bar (37) after it has once been drawn up by the action of coil (45) when an overload current flows through the motor armature circuit.

47. Holding coil contact. This serves to complete the circuit through coil (46) when contact bar (37) is pulled up by the action of overload coil (45).

48. Holding coil limiting resistor. This resistor is in series with the holding coil and limits the current through it, thus preventing the coil from becoming hot during an overload.

49. Dynamic brake resistor. This resistor is placed in series with the motor armature when plunger bar (40) drops and makes connection with contact (50).

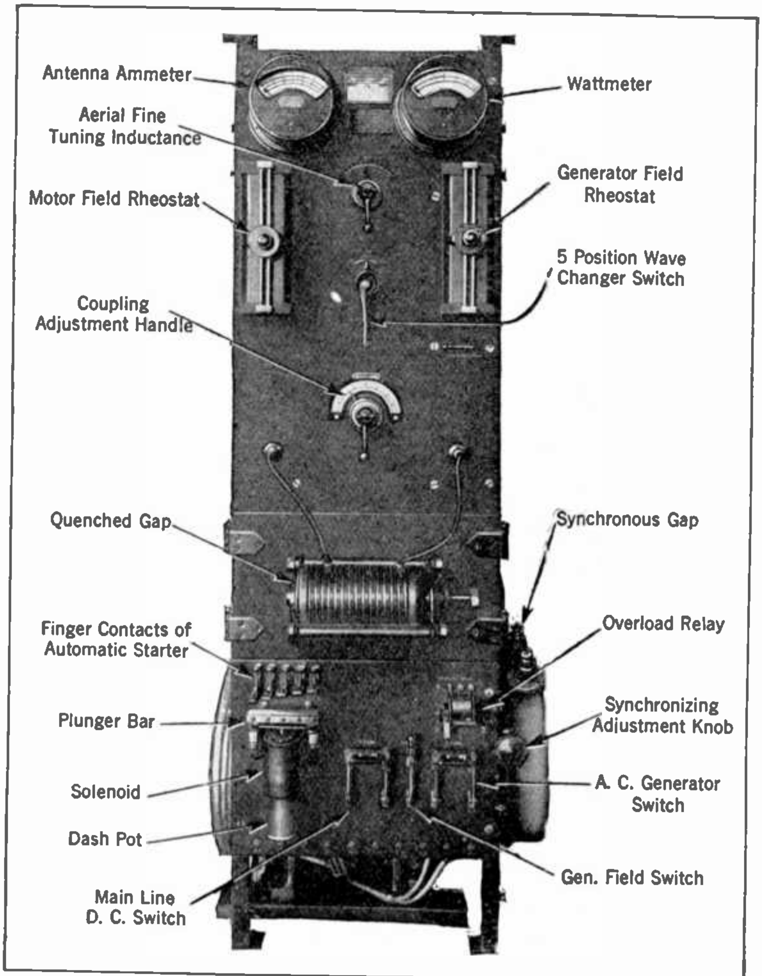


FIG. 10.—Front panel view of 2-kw. 500 cycle spark transmitter, type P-8.

The motor momentarily becomes a d-c. generator and its armature will be slowed down quickly and stopped because of the drag placed upon it when trying to force current through the resistor and by the opposition or bucking of the two magnetic fields, one field being set up by the armature coils when current is flowing momentarily and the other by the field poles of the motor.

50. Dynamic brake fixed contact. The circuit between the motor armature and resistor (49) is made and broken through this contact when plunger bar (40) is in the down or up position, respectively.

51. Generator field contact on automatic starter. The generator field coils are supplied with excitation current when plunger bar (40) is in the full-running position making connection with contact (51).

52. Generator field switch. This switch is supplied as a protective measure and should be opened whenever inspections or adjustments are made to the radio transmitter while the motor-generator is running.

53. Generator field rheostat. This device controls the power of the transmitter by regulating the amount of current passing through the field coils, and hence the a-c. voltage output of the generator.

54. Low-power resistor and short-circuiting switch. When communication is established with a nearby station, interference is reduced by opening the switch and thereby adding the resistor in series with the generator field. This reduces the field current and lowers the a-c. voltage output of the generator supplied to the power transformer primary (66).

55. Generator field windings. These are supplied with direct current and are necessary to set up a steady magnetic flux in the field poles in order that a-c. voltage may be generated in the armature coils when the latter are rotated by the motor.

56. Ground for protective condensers.

57. Ground for protective condensers.

58. Motor field windings. These coils are supplied with direct current which set up a strong and steady magnetism in the field poles, so that when the armature coils are also supplied with current there will be an interaction between the fields, thus causing the motor armature to rotate.

59. Motor field rheostat. This device controls the current in the field coils, setting up stronger or weaker magnetism in the field poles, which affects the speed of the motor armature and in turn regulates the frequency of the a-c. output of the generator.

60. Protective condenser (1 mfd.). (Same as 43.)

61. Protective condenser (1 mfd.). (Same as 43.)

62. A-C generator armature. Alternating e.m.f. or voltage at a certain value and frequency is generated in the armature coils, which causes alternating current to flow through the power transformer primary whenever this circuit is closed. This is the source of a-c. power.

63. A-C main switch, which is fused. This switch connects the power transformer with the a-c. source of power, namely, the generator.

64. Wattmeter. The true wattage or power supplied to the power transformer may be read on this meter when the sending key is closed.

65. Morse hand key. Used for controlling the a-c. input to the power transformer and to form the dots and dashes representing the characters of the Morse Code.

Refer to Figure 9 for identification of the following parts:

66. Primary of power transformer. This winding receives a low voltage a-c. (0 to 250 volts) at approximately 500 cycles. The alternating current sets up a strong fluctuating magnetic flux in the laminated iron core.

66 and 67 are the primary and secondary windings, respectively, of the

power transformer. This transformer is required to step-up the low voltage a-c. received from the generator to a high voltage, approximately 10,000 volts, suitable for charging the high-potential condensers employed in the closed oscillation circuit.

67. Secondary winding of power transformer. The proper high voltage necessary to operate the transmitter is obtained from the secondary. This winding consists of thousands of turns which are acted upon by the strong flux set up in the iron core by the alternating current in the primary.

68. Safety gap. This device consists of three electrodes, two being connected to the secondary terminals and the third to ground. A small air gap, about 1/16 inch, is maintained between the electrodes to furnish a direct path to ground for high potential surges which are likely to develop at any time, thus affording protection to the secondary winding.

Transmitter Circuits—P-8 Spark Transmitter

69. High-voltage transmitting condensers. These condensers are charged to maximum voltage twice every cycle by the 500-cycle a-c. output of the secondary (67). The condenser voltage, when reaching a certain value, breaks down the resistance of the gap and makes it electrically conductive. This discharge of the condensers across the gap and through inductance (74) generates a series of radio-frequency oscillations which rapidly diminish in amplitude (usually expressed as damping) because the gap resistance is quickly restored by the gap's quenching action, to await another maximum charge to be built up in the condensers. Condensers having capacity of .002 or .004 mfd. are used.

70. Synchronous rotary type spark gap. This device is mounted on the end of the generator shaft and consists of a disk fitted with as many electrodes as there are field poles in the generator. The fixed and movable electrodes are so adjusted that a spark discharge will occur between them when maximum voltage is reached during each alternation of the a-c. which is charging the condensers. The action of the gap is somewhat like that of a trigger since it functions to start oscillations in the closed circuit and also quickly stops them by extinguishing the spark. The continuously changing distance between the rotating and fixed electrodes accounts for this action.

71. Compensating inductance. This coil is added to the circuit by throwing switch (72) upward when quenched gap (73) is used while the synchronous gap (70) is disconnected, this being necessary in order to maintain the closed oscillatory circuit in the same resonant condition with the secondary regardless of which gap is used.

72. Double-pole double-throw switch. This is employed to control the use of the synchronous gap or the compensating inductance.

73. Quenched spark gap or spark discharger. This device consists of a series of short gaps which provide the closed oscillatory circuit with proper resistance that will force the condensers to build up maximum voltage before they become capable of breaking down this resistance to produce a spark discharge across the gap. This action causes radio-frequency oscillations to flow through inductance (74). Deep grooving in the gap plates causes rapid quenching of the spark

which in turn prevents undesirable reactions between the open and closed oscillatory circuits.

74. Primary inductance of oscillation transformer. This inductance in conjunction with high-potential condensers (69) forms an oscillatory circuit in which damped r-f. oscillations are generated by the discharge of the condensers through the gap. A variable inductance is used to permit adjustment of the

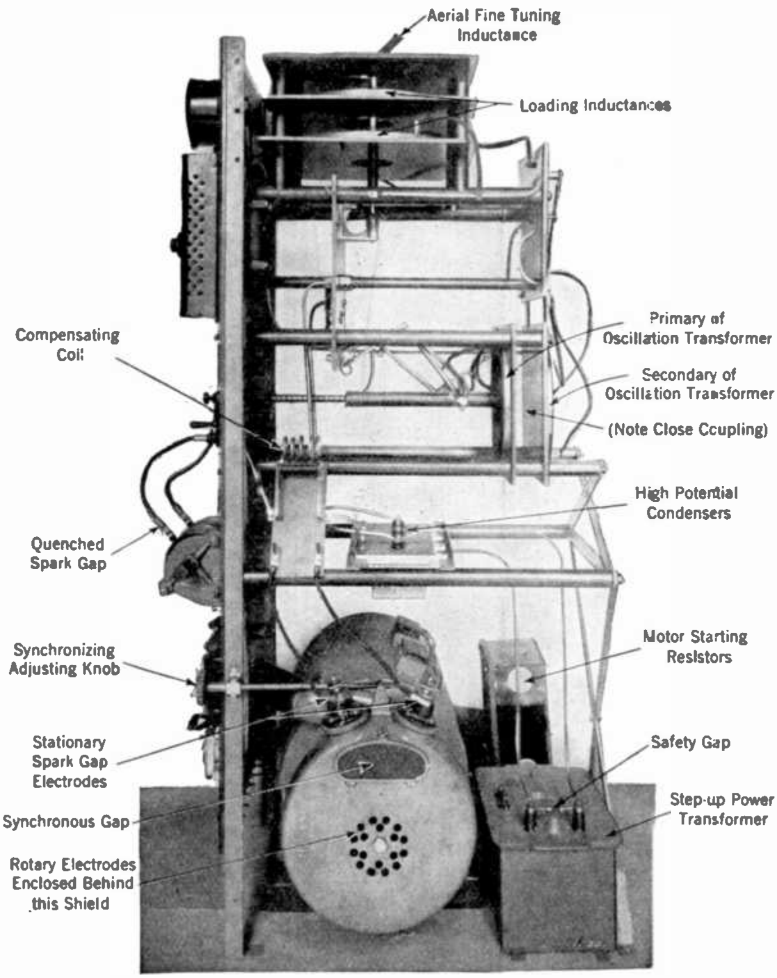


FIG. 11.—The 2-kw. spark transmitter, type P-8. Observe the close mechanical relationship between the primary and secondary coils of the oscillation transformer. This adjustment is known as "close" or "tight" coupling.

oscillatory frequency (wavelength) of the closed circuit. Also, oscillations through this coil set up a radio-frequency field which induces an r-f. voltage in secondary inductance (76). This transference of energy by electromagnetic induction results in the flow of r-f. oscillations through the antenna system at a similar frequency.

75. Wavechanger switch. This switch permits quick selection of any of the available five wavelengths. It is connected mechanically to (77).

76. Secondary inductance of oscillation transformer. This is used to supply inductance to the antenna circuit and also to act as a coupling coil to receive high-frequency energy from the primary for the purpose of exciting the antenna. It is variable to allow the proper amount of coupling inductance to be selected.

77. Wavechanger switch. This switch simultaneously alters the secondary inductance (76) and loading inductance (79), thus permitting a rapid change from one wavelength to another.

78. Antenna ammeter and thermo-couple. A maximum deflection on this instrument is indicated whenever resonance is established between the open and closed circuits for any of the wavelengths provided by the transmitter.

79. Antenna loading inductance. Variations in the amount of inductance used in this coil permit the antenna circuit to be resonated with the primary at all wavelengths.

80. Antenna fine tuning inductance. This variable inductance permits close adjustment of the antenna circuit frequency with the closed circuit to obtain the best conditions of resonance on all wavelengths.

81. Short wave condensers and short-circuiting switch. These condensers are employed when it is desired to operate on a wavelength lower than the antenna's fundamental wavelength; they are added in series with the antenna when the switch is opened. Their use is not now generally required since wavelengths lower than 600 meters are not assigned for commercial telegraphy.

82. Antenna changeover switch. This switch shifts the antenna from the transmitter to the receiving circuit and vice versa and also controls the following circuits. When this switch is placed in the "Up" position for receiving, the antenna is connected to the receiver, whereas the transformer primary circuit, which includes the sending key, is opened; the generator field is opened; and the circuit to the plunger solenoid on the automatic starter is also opened. When the switch is placed in the "Down" position for transmitting, these circuits are closed and the antenna is shifted to the transmitting inductance.

83. The motor-generator may be controlled by the "Start-Stop" push-button switch. This switch opens and closes the circuit to the plunger solenoid.

84. Lightning switch. This is used to connect the antenna directly to ground whenever it is desired.

85. Antenna. This represents the elevated portion of the antenna, including lead-in, and, when set into excitation by the primary oscillations, electromagnetic waves will be radiated therefrom.

86. Ground. A ground conductor and ground connection are required to complete the open oscillatory circuit which includes all elements between the antenna and ground.

Commercial Receiver Type 106-D.

90. Primary inductance. This coil is divided into sections and tapped every ten turns to permit close adjustment of the receiver primary to any wavelengths within its range.

91. Primary inductance. This coil of 10 turns is part of (90) but is tapped at every turn and permits close regulation of wavelength. Both (90 and 91) are varied by a "dead-end" drum switch as indicated on Figure 9.

92. Primary variable condenser. This device is used to alter the capacitance of the antenna circuit for the purpose of tuning in signals.

93. Buzzer transformer. It supplies the antenna with a test signal generated by the buzzer for the purpose of adjusting the receiver, this procedure being particularly necessary when a crystal detector is employed.

94. Buzzer circuit used to supply a local test signal.

95. Ground connection.

96. Secondary coupling coil. This coil provides the proper coupling between the primary and the secondary circuits for transference of signal energy.

97. Secondary inductance. Used to vary the inductance of the secondary, thus placing it in resonance with the primary. It is adjusted by a "dead-end" drum switch.

98. Tickler coil. This is a movable coil that is connected in series with the plate circuit and provides a variable coupling between the plate and grid for the purpose of feeding back to the grid a part of the energy in the plate circuit. The

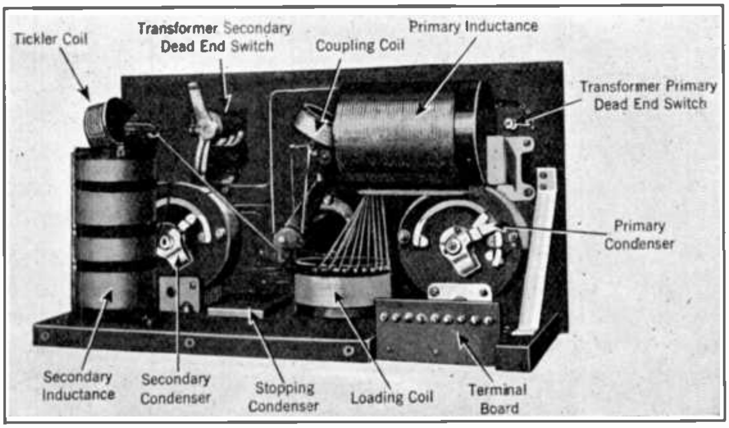


FIG. 12.—Rear interior view of the type 106-D commercial receiver.

coupling may be adjusted to reinforce signal oscillations applied to the grid just sufficient to produce regenerative amplification. Also the coupling may be tightened or increased to set the detector circuit into self-oscillation for continuous wave reception to produce the necessary audio beat frequency by heterodyning these locally generated oscillations with the incoming signal oscillations.

99. Secondary tuning condenser. This is used in conjunction with the secondary inductance for resonating the secondary to the primary.

100. Crystal detector. This device may be used and located as shown in the circuit to produce a suitable rectified current for actuating the telephone diaphragms.

101. Detector phone jack and phone condenser. Telephone receivers are plugged in the jack only when signals are to be received when a crystal detector is used.

102. Grid leak and condenser combination. This unit is used to provide a larger change in plate current in the detector output for a given signal strength, thereby increasing the volume.

103. Vacuum tube detector. This tube is operated with proper voltages to convert the incoming signal oscillations into an audio current, suitable for setting up vibrations in the telephone headset.

104. Filament rheostat. This is used to regulate carefully the voltage applied to the detector filament.

105. Detector phone jack. This permits signals to be heard in the output of the detector.

106. Audio transformer. This is the first stage audio transformer used to couple the detector output with the vacuum tube amplifier input and assists in stepping up the signal voltage to a higher level for applying to the grid, thereby increasing volume.

107. Vacuum tube amplifier. The varying plate current in this tube's output repeats the audio wave form and frequency of the voltages impressed upon its grid but due to the tube's amplifying properties the signal is greatly amplified in form, thus producing increased volume.

108. Filament rheostat. Used for regulating the filament voltage of the first audio amplifier tube.

109. First stage phone jack. This permits signals to be heard in the output of the first amplifier tube.

110. Audio transformer. This is the second stage audio transformer used as a coupling device between the output of the first audio amplifier and the input to the second audio amplifier. It has a step-up turns ratio and therefore raises the level of the signal voltages applied to the second amplifier.

111. Vacuum tube amplifier. This is the second stage or last amplifier tube and is used to step up further the signal currents passing through it to produce large variations in its plate current, and hence cause greater movements of the telephone diaphragms, resulting in loud signals.

112. Filament rheostat. Used to control, individually, the voltage applied to the filament of the second amplifier.

113. Output jack. This jack permits phones to be plugged into the output of the last amplifier to receive signals.

114. "A" battery. Used to supply the requisite voltage for the filaments. When current flows the temperature of the filaments is raised to a point where electron emission is obtained.

115. "B" battery. The proper positive plate potentials for all tubes are supplied by this battery.

116. "C" battery. This provides proper grid bias to the amplifiers.

5. *Question.* Draw a fundamental diagram of a broadcast installation and explain its operation.

Answer. A simplified schematic diagram of a broadcast transmitter is shown in Figure 13. The transmitter is divided into its important component parts, namely: (*A*) microphone circuit, (*B*) speech amplifier circuit, which is really one stage of audio-amplification, (*C*) audio-amplifiers consisting of two stages of audio amplification (only one stage shown to simplify the drawing), (*D*) modulator tube circuit consisting of two tubes of similar type, connected in parallel and performing the same function, and (*E*) oscillator tube circuit con-

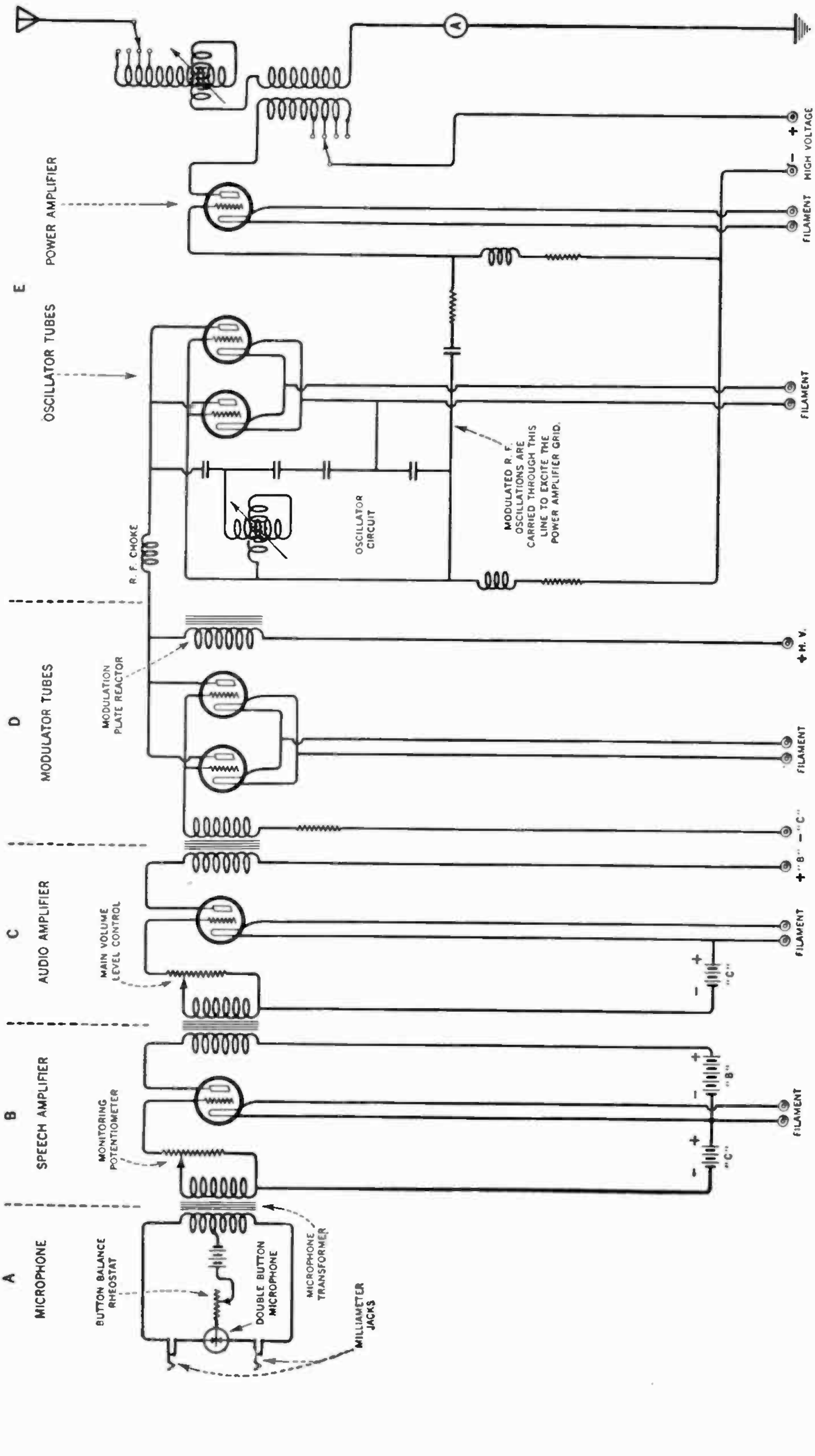


FIG. 13.—Simplified schematic diagram of a broadcast transmitter utilizing the Heising method of modulation. This transmitter employs a double-button microphone; one speech amplifier; two audio-amplifier tubes (only one shown); two modulator tubes; two oscillator tubes and one high power amplifier tube working into the antenna system.

sisting of two tubes of similar size, connected in parallel, and a power amplifier, working into the antenna system. The theory of operation is as follows:

(*A*) During broadcasting, sound waves, either of the voice or of musical renditions, are impressed upon the diaphragm of the microphone and it functions to translate the sound waves into electrical impulses varying in frequency and intensity proportionately to the air pressure waves. This electrical counterpart of sound waves is called an audio-frequency current and is carried through the balance of the circuits *B*, *C*, and *D*, to act upon the high-frequency oscillations generated in the oscillator circuit *E*.

Vibrations of the diaphragm cause the carbon granules in the two cups to vary continually the pressure between the small granules, with the result that the resistance of the microphone circuit varies accordingly, and in turn a fluctuating or audio-frequency current is made to pass through an iron core transformer. The signal energy is extremely weak and not sufficient to operate the large power vacuum tubes and therefore the microphone impulses are carried through several successive stages of amplification. A potentiometer supplied in the grid circuit of an amplifier permits the operator on watch to monitor the equipment. That is, the volume level of the microphone frequencies can be controlled to supply the grid of the amplifier with the proper voltage to prevent distortion or blocking effects.

B. The voltage level of the signal is raised considerably after passing through the first-stage amplifier, generally called the speech amplifier. The fluctuating e.m.f.'s applied to the grid of this tube cause a varying plate current to flow in its output which is passed along to the input or grid of the following tubes (*C*).

C. After being amplified by the tubes employed in this section of the transmitter the audio variations are strengthened to a suitable value so that they may be delivered to the grids of the modulator tubes.

D. The modulator tubes function in conjunction with the oscillator tubes. When the microphone is not in use the oscillator tubes generate continuous oscillations having amplitudes of uniform size. Now it is the purpose of the modulator tube to force the amplitudes to vary in size according to the characteristics of the audio-frequencies; that is, according to the sounds directed toward the microphone.

This is accomplished by means of a large choke coil, known as the modulation plate reactor, inserted in the main d-c. supply to the plate circuits of the modulators and the oscillators. The modulators deliver the audio-frequencies in their output, as variations in the strength of the plate current, while at the same time the oscillators are generating radio-frequency oscillations at the frequency assigned to the transmitter. The choke coil for all practical purposes prevents changes in the plate current supplied to these tubes; therefore whenever the modulator receives plate current increases the current to the oscillator plate decreases, and vice versa. Hence the result of the audio energy in the modulator plate circuit acting upon the oscillator plate circuit is to add to or subtract from the amplitudes of the continuous oscillations. Their amplitudes are no longer of equal value, but undergo variations which conform exactly to the wave form of the audio-frequency output of the microphone in section *A*. The variations in the high-frequency amplitudes are called the audio or modulation component, and the action is known as modulation. This method was invented by Heising and is known as the "constant current" system.

E. This portion of the transmitter is required to generate the high-frequency current, called the carrier frequency, which is transferred to the antenna system through a power amplifier tube and a coupling transfomer for the purpose of

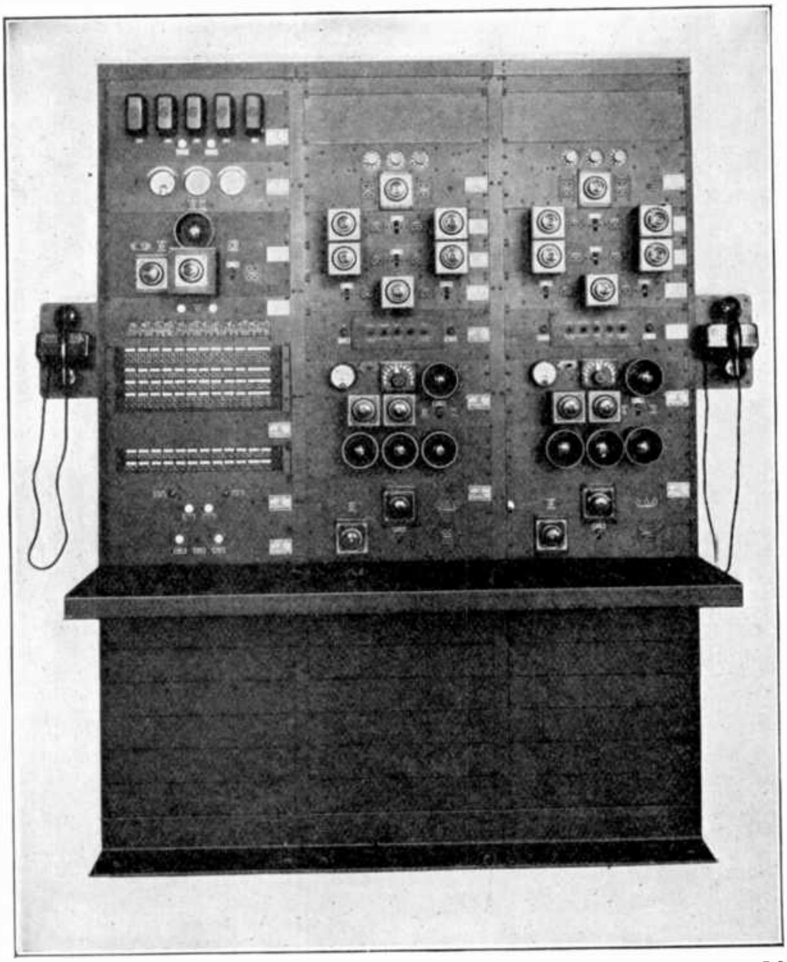


FIG. 14.—Control room speech input apparatus for a double studio installation. Monitoring (volume control) rheostats and speech amplifiers are shown on this control room speech input apparatus for a double radio installation. The high-level switching arrangement provides for rapid changeover from one program to another.

energizing the antenna to radiate electromagnetic waves carrying the audio-frequency characteristics. The radio waves radiated by a broadcast antenna are of the type known as continuous waves modulated by speech or music, or abbreviated c.w. (phone).

6. ***Question.*** **Draw a diagram and explain the action of a filter system suitable for use in the plate supply circuit of a vacuum tube transmitter?**

Answer. The network of choke coils (reactors) and high voltage condensers arranged as shown in the diagram in Figure 16 constitutes a filter system. A system of this general design is required to smooth out the slight rise and fall, or ripples, in the direct current from the generator to provide a practically steady or non-varying current for plate excitation of the vacuum tubes. A d-c. generator does not deliver a pure or steady d-c. such as that obtained from a storage battery. The ripples are due to the overlapping of the e.m.f.'s induced in the numerous armature coils as each one successively passes through the magnetic fields set up by the poles of the machine. These induced e.m.f.'s are applied to the line through the brushes and commutator segments, and the current variations resulting therefrom are called "commutator ripples."

In brief, the action of the combined reactors and condensers in smoothing out the current variations is as follows: When current flows the chokes set up

FIG. 15.—Transmitting room at WJZ.

magnetic lines of force in great numbers which tend to oppose any change in the amount of current flowing through the coils. This opposition effect, always present whenever current tends to vary in strength, is due to the changing lines of force acting upon the turns comprising the coils. It is to be remembered that the current in a circuit is responsible for setting up magnetic lines, thus for any variation in current the lines will also change accordingly. This property of a coil in opposing either increases or decreases in current strength by the action of its magnetic lines is termed its "self-inductance." Choke coils, used for this purpose are designed to possess a high inductance value by winding them with many turns and then mounting the finished coil over a laminated iron core of comparatively large dimensions.

What actually happens during a rise in current is that the passing through the turns of the changing lines of force induces a voltage within the turns, or in other words, within the circuit. This induced voltage acts against the line voltage which is causing the current flow and in this way tends to prevent the current rise, and at the same time places a charge in the filter condenser. On the other hand, when current through the choke tends to decrease in value the lines decrease in numbers and thus act on the turns with an effect the opposite of that obtained when the current increased. The induced voltage due to the current decrease is in the same direction as the applied voltage on the line and this tends to keep the current flowing at substantially the same value; and the condensers, functioning like a reservoir, give up part of their stored energy and furnish a new voltage to the line. It is to be understood that the condensers discharge whenever the voltage falls during a ripple for at that particular time the

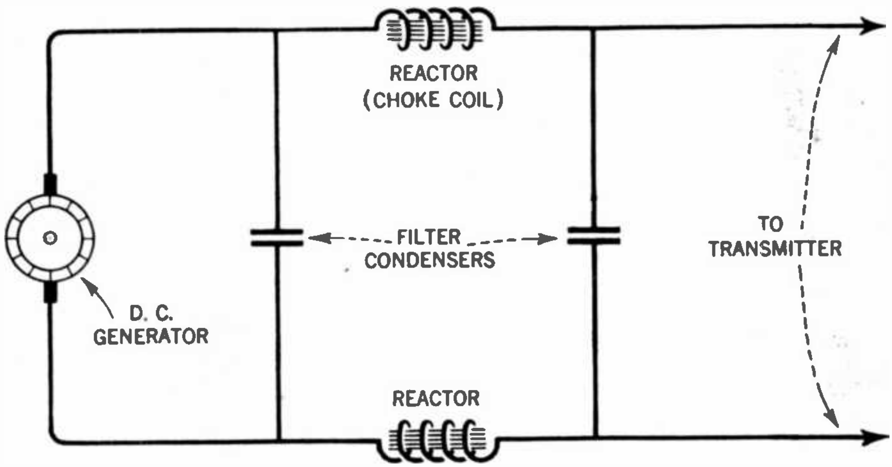


FIG. 16.—A fundamental filter system suitable for use in the plate supply circuit of a vacuum tube transmitter.

generator output voltage is slightly less than the voltage existing in the condensers.

Hence by the use of chokes and condensers of proper size and rating the output of a filter system can be made to deliver a steady flow of direct current to the plates of the tubes at substantially a uniform pressure or voltage.

7. *Question.* What protective devices are used in the plate circuit of a tube transmitter?

Answer. Tube transmitters are equipped with a fuse of proper rating or an overload relay set to trip at a predetermined value, these devices being located in the main plate supply lead. In certain types of high power apparatus we find each tube plate circuit equipped with a relay which drops and displays a disk in the case of tube trouble. For this type of equipment the protective apparatus is usually designed to distinguish between a surge high enough to cause immediate trouble, and excessive current which would have damaging effects only if continued for an appreciable time. In the case of a high surge the trip will act instantly and open the circuit but in the event of continued excessive current the trip functions only after a certain period of time.

8. *Question.* Draw diagrams of two methods for keying a modern commercial tube transmitter and explain their operation.

Answer. (1) One method utilized in keying a telegraphic tube transmitter, where plate excitation is obtained with direct current, is to impress the grids with a high negative biasing voltage of sufficient value to block the flow of plate current and stop oscillations. This biasing voltage, obtained usually from a potentiometer, but in some types of transmitters from a rectifier, is controlled by heavy contacts on a key relay. When the large bias voltage is removed oscillations are generated.

The diagram in Figure 17 shows how a potentiometer is connected in the circuit for this purpose. The circuit functions as follows: Transmission of messages

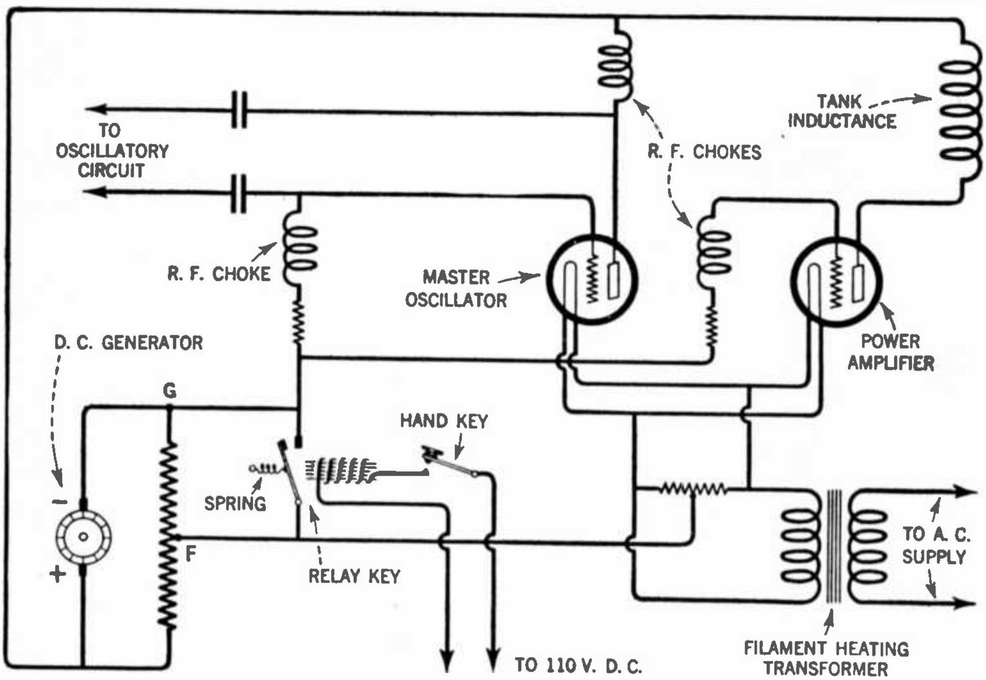


FIG. 17.—Showing how keying may be accomplished in a tube transmitter by the application of a high negative bias voltage on the grids.

is accomplished by the keying relay controlled by the hand key, the relay solenoid being energized through a current-limiting resistor from the 110-volt d-c. source. The resistor, which serves as a potentiometer, has a resistance value of several thousand ohms and is shunted across the d-c. generator supplying the plate circuits. All of the grid return leads of the transmitting tubes, including the oscillator and power amplifiers, connect to a common junction formed between the negative side of the generator and one end of the potentiometer, shown in the diagram at the location marked *G*. Observe that the filament circuit connects to a tapped point on the potentiometer at *F*. Thus, a certain amount of resistance is included between the grid and filament circuits, or between points marked *G* and *F*.

When the hand key is up, the relay contacts open and at this time the high voltage drop is obtained from across the resistance between *G* and *F*, the voltage drop being due to the flow of direct current through the potentiometer from the generator. With the electron flow to the plates completely blocked by the heavy negative potential on the grids, the plate current drops to zero and oscillations cease, for it is to be remembered that the movement of electrons constitutes the plate current. In certain types of transmitters employing 50-watt tubes, the biasing potential required is 250 volts negative.

Now when the hand key is depressed, as in sending, the relay contacts close and, as can be readily seen in the diagram, this action causes the grids to be connected directly to the filaments through these contacts, resulting in the removal of the biasing voltage.

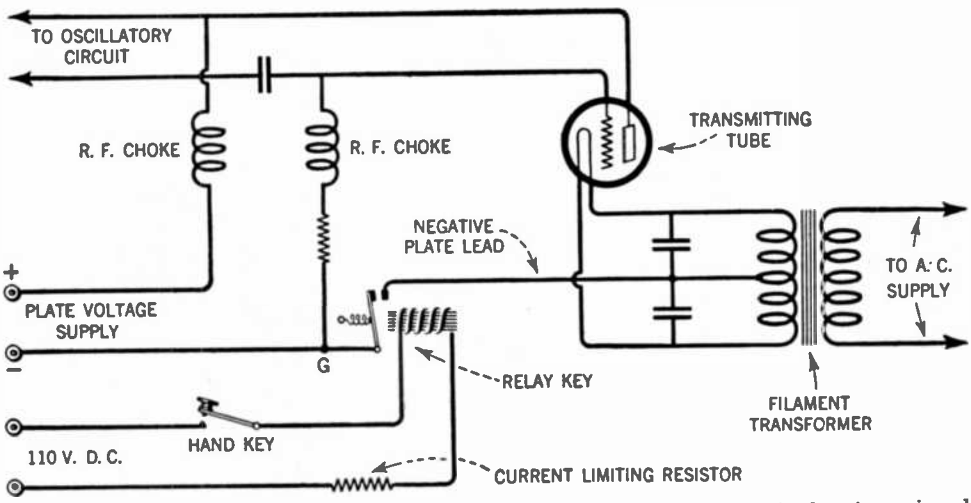


FIG. 18.—Another method for keying a tube transmitter. In this system the key is equipped with relatively large contacts and inserted in the negative return lead of the plate circuit to open and close this circuit.

When normal grid potential is restored plate current flows and r-f. oscillations build up immediately.

The operation of this keying system is explained by one of the fundamental principles of electricity—Ohm's Law.

(2) Another keying method commonly employed in installations designed for d-c. plate excitation is to insert large key contacts in the negative return lead of the plate circuit to open and close this circuit. This negative lead is called the low-potential side of the plate circuit. A hand key controls a relay key solenoid which actuates the armature carrying the contact points.

Reference to the schematic diagram in Figure 18 shows the location of the key, one contact of which goes to the negative lead from the d-c. generator and the other contact to the mid-tapped secondary of the filament heating transformer. The return grid leads of the power amplifier and master oscillator (only one tube shown) connect to the negative side of the plate circuit at point

G. Hence both the negative plate circuit and the grid current are broken by the keying action. Whenever the contacts open, oscillations stop immediately because a high blocking voltage builds up quickly due to the accumulation of negative electron energy on the grids. When the sending key is depressed, these circuits are closed by the relay contacts, thus permitting oscillations to be produced.

(3) A third method for keying. A tube transmitter which radiates a wave of the ACCW variety uses the a-c. output of a high voltage transformer for plate excitation; in this type of equipment the sending key is located in the primary circuit or input to the transformer. Closing and opening the key interrupts the plate voltage supply.

9. *Question.* Describe and explain the theory of a step-up transformer.

Answer. The term step-up transformer describes a device for transferring alternating current of a low voltage from one circuit to an alternating current of some higher voltage to another circuit by electromagnetic induction. The transformer consists of two coils wound on a common magnetic circuit of iron. The winding which receives the alternating current at low voltage is called the primary or input, whereas the winding which delivers alternating current at a higher voltage is called the secondary or output. The ratio of transformation of voltage between the primary and secondary is practically in direct proportion to the number of turns on the respective windings. In a step-up transformer the ratio is always greater than 1 to 1 as the name implies. The two windings are heavily insulated from each other and from the iron core to prevent puncture and breakdown. In certain types of transformers where high potentials are handled the secondary winding is composed of several sections or "pies," connected together, which facilitates the replacement of damaged parts in the event that the insulation of the secondary breaks down due to a high voltage surge in the circuit. The "pie" sections are heavily taped with dry linen impregnated with an insulating varnish and connected together with short pigtail flexible leads.

The theory of operation is as follows:

Whenever a continuously varying current flows through the primary winding magnetic lines are set up which permeate the iron core. These magnetic lines follow the characteristics of the primary current and as they thread in and out and act on the secondary turns they cause an alternating e.m.f. to be induced within the secondary winding. However, current will flow in the secondary under the e.m.f. produced only when this winding is connected to a load circuit which is closed to form a continuous electrical circuit.

The frequency of the e.m.f. induced in the secondary is always the same as the frequency of the primary current because the magnetic lines in changing through one cycle of alternating current simply cut back and forth once through the secondary turns.

In a step-up transformer the secondary voltage is raised above the primary voltage by practically the ratio of the number of turns comprising the secondary to those of the primary as just mentioned. For example: If a primary consists of 100 turns and receives an alternating e.m.f. of 110 volts then the flux produced by this coil acting upon a secondary of 10,000 turns will generate in the latter an alternating e.m.f. of 11,000 volts, which is a ratio of 100 to 1.

The core of a closed core transformer is usually rectangular in shape and consists of thin stampings of iron, called laminations, which are insulated one from another. It may or may not employ a magnetic leakage gap to prevent saturation of the core. The iron stampings are either oxidized, dipped in shellac, or japanned, so that when the core is assembled no iron-to-iron contact is possible between them. The insulation thus provided between the laminations reduces the losses in the transformer. Open core transformers usually employ a bundle of fine iron wire, the iron being treated as suggested above for laminations.

A photograph of a typical high voltage transformer equipped with a safety gap is shown in Figure 19.

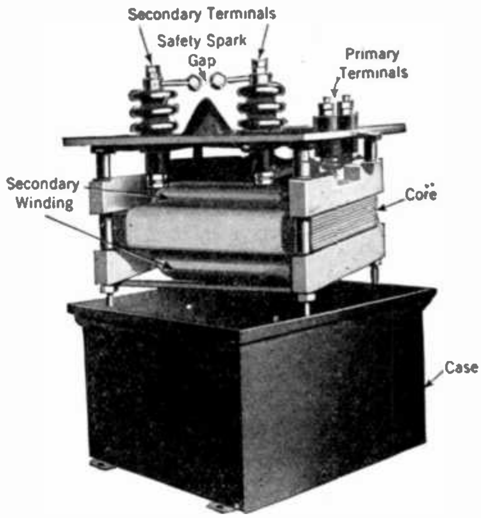


FIG. 19.—A high voltage transformer of the closed core type used in radio transmitting installations.

10. *Question.* What effect would an improper grid voltage have on a transmitting tube?

Answer. The grids of transmitting tubes are continually supplied with a negative voltage (bias voltage) of a predetermined amount so that during operation the potential on the grid never actually becomes positive at all, but simply operates with a fluctuating voltage of negative characteristics. This is done to keep at a minimum value the direct current flowing in the grid circuit and to give the tube proper amplifier characteristics. A large grid current is undesirable.

If the negative bias is lowered or removed, an excessive amount of electrons will pass to the plate, which is the same thing as saying that excessive current will flow in the plate circuit. In this event the plate will no doubt become exceedingly hot and show more than the permissible cherry-red color. If this condition is not corrected immediately the tube will be damaged.

If, on the other hand, the negative bias is raised above its proper working value, the grid will act to turn back or repel electrons in great numbers and consequently fewer electrons will reach the plate. This, of course, reduces the plate current to a value less than that required for normal operation.

The amount of grid bias, then, has a direct effect on the plate current and the tubes' characteristics. So, with improper grid bias the variations in the tubes' plate current will not repeat the wave form and frequency of the input voltages impressed on the grid. It is essential that the fluctuating plate current shall be an exact copy of the current circulating in the grid circuit, only enlarged or amplified, or else the tube will distort the characteristics of the radio-frequency energy transferred by it.

In the case of an oscillator, the circuit will no doubt be placed in an unstable condition giving erratic results.

11. ***Question.*** **How could you detect a defective transmitting tube?**

Answer. A defective transmitting tube can sometimes be located by merely observing the tube, for the plate may heat and show color exceeding a dull cherry red; a dull cherry red indicates a normal condition. Also, the interior may show a milky white color or blue haze between the plate and filament or a small discharge may occur between the electrodes. A burned-out filament is self-evident upon inspection. Abnormal current indications on the meters may suggest a defective tube; and where several amplifiers are operating in parallel one tube may be removed and the results noted. Now, with one tube out, interchange all other tubes of similar type, also using a spare tube—one known by previous test to be perfect; in this way the defective tube will usually be located.

A defective or poor oscillator tube will not oscillate, that is, it will not generate the requisite radio-frequency current, a trouble which is quickly noticed because antenna current cannot be read on the antenna ammeter. Occasionally a tube unsuited for use as an oscillator will work satisfactorily as an amplifier. If antenna current cannot be obtained, and the circuit conditions seem normal, always try interchanging tubes until one possessing good oscillating characteristics is located in the oscillator socket.

12. ***Question.*** **Suppose your antenna was carried away by a storm, how would you rig a temporary antenna and what precautions should be taken?**

Answer. Suspend a single length of wire, supported by insulators, above the deck in a most convenient manner, so as not to permit the wire to swing or to touch any of the rigging or parts of the vessel. Do not place the wire where persons are apt to come into contact with it. The wire should be pulled taut and elevated as high as possible according to the surrounding conditions and should be long enough to permit it to be attached to the deck insulator terminals, after first removing the regular lead-in in order to disconnect any parts of the damaged antenna from the transmitter. After the temporary antenna is erected the antenna circuit of the transmitter should be carefully tuned until the highest antenna current is obtained. A piece of marlin rope which has been soaked in oil will make a suitable insulator in an emergency.

13. ***Question.*** **How would you clean a quenched type spark gap?**

Answer. If a set screw or lock nut is provided it should be loosened and the gap should then be opened with a wrench and the plates lifted out. If the plates and gaps stick together take special care when separating them so as not to damage the gaskets or sparking surfaces. A new gasket should be used when reassembling the gap, provided that the old gasket has become damaged or clings to the metal. Always clean off the plate flanges carefully before inserting a new gasket. The sparking surfaces should have a light, pink color with a somewhat dull finish. A rough black surface indicates that the gap was not air-tight. The sparking surfaces are cleaned with a piece of very fine sandpaper. This may be done by laying the sandpaper on a flat surface, and, with the gap to be cleaned placed face down on the sandpaper, the gap is moved in a circular to and fro motion with the palm of the hand pressing on the gap with a slight pressure.

This method insures that the surface will be cleaned evenly. Extreme care must be taken to polish each plate thoroughly, removing all carbonized desposits and foreign material left on the gaps during the cleaning process. Use care in replacing the gaskets; and when reassembling the plates they should be tightly clamped.

14. ***Question.*** **How would you ascertain the quality of the signal emitted by an arc transmitter?**

Answer. The signal can be heard by the operator in the station's own receiver after proper tuning adjustments have been made. The arc is adjusted until a steady and smooth note is heard.

15. ***Question.*** **Briefly describe the care and upkeep of an arc converter.**

Answer. Refer to the answer to Question 31.

16. ***Question.*** **Give two methods for utilizing an a-c. source for energizing the plates of transmitting tubes.**

Answer. One method utilizes an a-c. generator connected to a transformer primary while the secondary terminals of the transformer are connected to the respective plates of two rectifier tubes. An additional winding on the transformer is required to provide the filament voltage for the rectifiers. The output of the rectifiers is a direct current.

Another method utilizes raw alternating current supplied directly to the plates of transmitting tubes from the transformer secondary. Rectifiers are not used in this circuit because the transmitter is designed to send out a signal of the tone modulated type, called ACCW.

17. ***Question.*** **How would you reduce the power of a tube transmitter to transmit over a comparatively short distance?**

Answer. Power may be easily controlled by adjustment of the generator field rheostat which governs the voltage supplied to the transmitting tubes. Do not reduce the filament voltage. For this purpose it should always be maintained at the recommended value and never varied. By the addition of a resistor of proper value in series with the high voltage plate lead the plate potential may be lowered to any desired value.

18. ***Question.*** **How are tubes in a transmitter protected from overload?**

Answer. Fuses of the correct rating and circuit breakers set to trip at a predetermined current flow constitute the principal protective devices. It is imperative that the correct negative biasing voltage shall be maintained on the grids during operation and also that the calibration of the oscillatory circuits shall be carefully executed in order to provide normal current values and prevent overload. The correct feedback voltage applied to an oscillator grid must be found by careful adjustment of the elements comprising the oscillatory circuits, that is, by adjustments of either the inductances or capacitors, or both. Adjustment of the oscillatory circuits is especially critical in high-frequency (short-wave) transmitters, since over-loads are more apt to occur in sets operating at wavelengths of 100 meters and less than would be the case in equipment utilizing the longer waves. In the case of high power transmitters employing water-cooled tubes, if the water supply becomes inadequate for any reason, then flow-operated devices are employed which act to shut down the transmitter. As a further protection to high power tubes on starting the transmitter the filament voltage is first applied at a low value, which automatically increases to normal after a certain time interval.

19. ***Question.*** **Give three major causes of trouble which prevent a tube transmitter from operating properly.**

Answer. (1) The radiating antenna circuit and the transmitter circuit not in resonance.

(2) A vacuum tube used in the oscillator socket which does not possess good oscillating characteristics. Try interchanging all tubes, for it is more than likely that one of the amplifier tubes will be found to be a good oscillator.

(3) Examine all switch blade connections, all terminals, lugs, soldered connections and insulators as possible causes of trouble on shipboard installations. Do not permit any connections or terminals to become loose, corroded or oxidized.

20. ***Question.*** **How are radio-frequency oscillations generated by an arc converter?**

Answer. The action explained herewith applies to an arc converter employing blowout magnet coils. See Figure 20 for a fundamental diagram of an arc circuit. After the circuit is set into operation and the electrodes carefully adjusted, then current from the d-c. generator comes to the arc anode and divides, most of it going through the arc and part of it going through inductance L to charge condenser C. Condenser C actually is the distributed capacitance of the antenna system.

The current through the inductance increases in value and continues to charge the condenser until the voltage across the condenser equals the voltage across the arc. In the meantime the strong transverse magnetic field set up by the magnets bows out the arc until it breaks and the gap resistance is practically restored to normal. When the arc flame goes out the arc voltage equals the full generator voltage. This causes a sudden heavy rush of current to be sent through inductance L, charging condenser C until the condenser voltage equals the extinction voltage. The extinction voltage is the voltage across the electrodes when the arc goes out. At this moment the potential at both ends of inductance L is equal and therefore current stops flowing through L.

When the current stops flowing the magnetic field set up by L begins to recede or fall back on the turns comprising L and by this action of the changing lines of force a new e.m.f. is induced within the circuit in the same direction as the impressed e.m.f. which caused the current to flow in the first place. This new e.m.f. sends an additional charge into the condenser which makes the voltage in it greater than the extinction voltage. This new e.m.f. reaches a very high value, in fact it is sufficient to break down the resistance of the gap and current again flows between the electrodes, that is to say, the arc is reignited. This completes the first alternation of the arc cycle. Due to the peculiar relation of current and voltage in an arc the heavy flow of current now causes the arc voltage to drop to a value less than the generator voltage. The condenser now discharges and sends current through the oscillatory circuit in a direction reverse to that of the original flow of current which charged the condenser in the first place, thus beginning the second alternation of the arc cycle. Current continues to flow from condenser C through inductance L to the arc until the condenser voltage equals the arc voltage. When the voltages are equalized the current through *L* stops, and once more the magnetic lines encircling *L* dissipate and act on the turns of *L* to set up a new e.m.f. in the circuit. The new e.m.f. causes a movement of current through the oscillatory circuit in such a direction that it tends to discharge the condenser further, thus completing the second alternation and the full cycle. The discharge of the condenser causes the condenser voltage to fall below the arc voltage, and this action in turn forces current to flow again from the arc through inductance *L* and to condenser *C*. We are now at the beginning of another cycle and the sequence of events will be repeated as heretofore explained. The blow-out magnet coils used in arc transmitters serve a double purpose: (1) They tend to blow out the arc flame at regular intervals, which removes the ionized atmosphere existing between the arc electrodes, thereby reducing the

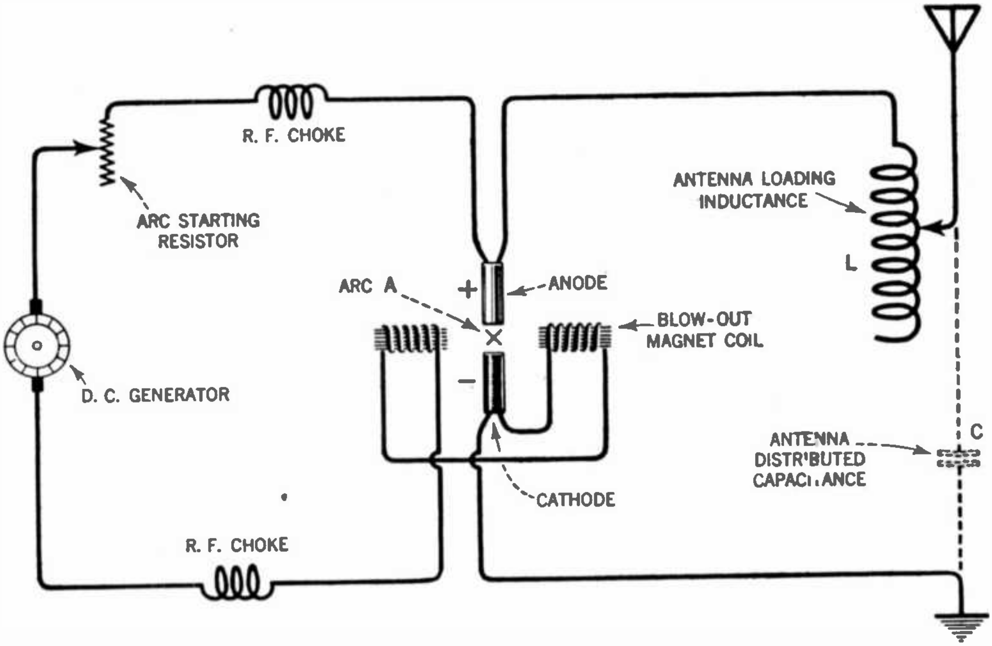


Fig. 20.—A fundamental arc circuit.

heat at this point and restoring the arc resistance to normal; and (2) they function as radio-frequency choke coils, thus excluding r-f. oscillations from the d-c. generator circuit.

21. ***Question.*** **How would you temporarily replace a burned-out grid leak?**

Answer. Should the grid leak of a transmitting tube burn out, it may be replaced by any resistance of approximately equal value, or about 4000 to 10,000 ohms. A satisfactory substitute may be made up with a rubber hose about 10 in. long, filled with water and plugged at each end with a connecting wire passing through each one of the end plugs. The wires are made to protude a short distance into the water to form suitable electrodes. A small amount of salt or washing soda should be added if the resistance seems too high.

22. *Question.* Explain fully why the filament temperature should be operated at a certain specified voltage.

Answer. If the e.m.f. applied to the filament terminals is in excess of the voltage specified by the manufacturer, it will force additional current through the filament wire heating it to a temperature beyond that necessary for efficient operation. If subjected to excessive heat either the oxide coated wire or thoriated *X-L* filament wire will undergo a rapid evaporation, which means that after comparatively short usage the filament will become incapable of furnishing the requisite electron energy by which the tube functions. It is obvious that if electrons are not available the tube is rendered useless. It is likewise inadvisable to operate the filament at voltage lower than the rated voltage, since the effect of this condition is to cause a more rapid breaking down of the wire than would be expected from normal use, due to a certain molecular disintregation that takes place in the wire when operated at other than its normal working temperature. Moreover, the transmitting circuits in which a tube of a certain type is to be used are designed to work efficiently provided the rated filament e.m.f. is maintained.

23. *Question.* If the gap circuit and the antenna of a 500-cycle spark transmitter were coupled too closely what would happen?

Answer. If the coupling is too close the transmitted wave will be spread over a wide band of wavelengths, causing considerable interference in receivers not tuned to receive its signals. This undesirable condition is due to a retransference of energy between the two oscillatory circuits which cause the radiation of electromagnetic waves of two frequencies of oscillation. Only one frequency is necessary for communication. The government statutes especially prohibit the radiation of a wave possessing this characteristic, which is known as a broad wave.

24. *Question.* Explain the theory of operation of the double-button type microphone.

Answer. Transmitter is the technical name for the microphone. Refer to the diagram in Figure 21 showing a double-button microphone connected to a source of e.m.f. of about 12 volts, and to a split transformer. A carbon transmitter of this type contains two small cups of carbon granules through which current will pass from a small battery. The granules in the buttons press against either side of a thin diaphragm which has its areas gold plated. (See Figure 22.) The potential across the buttons is carefully regulated to equalize the current in each button for proper operation in order to insure that the output current of the microphone will resemble as closely as possible the wave form of the original sounds. A split transformer is required with the two-button microphone and, as the diagram clearly indicates, the current furnished by the battery flows in opposite directions through either half of the transformer primary. When the diaphragm moves under the impact of the sound waves the pressure against one set of granules is increased while the other is decreased. This differential action (sometimes called push-pull) sets up a varying flux in the iron core of the transformer which induces a fluctuating a-c. voltage in the secondary possessing all of the characteristics of the sound waves. By this arrangement the voltage in the secondary reaches a value considerably greater than would be possible if only one button were employed. The current through each button is read on a milliameter plugged in the circuits when tests for button balance are made.

The action of each button is as follows: When sound waves strike the diaphragm the movement of a disk changes the pressure on the granules, either packing them close together or allowing them more freedom. This disturbance

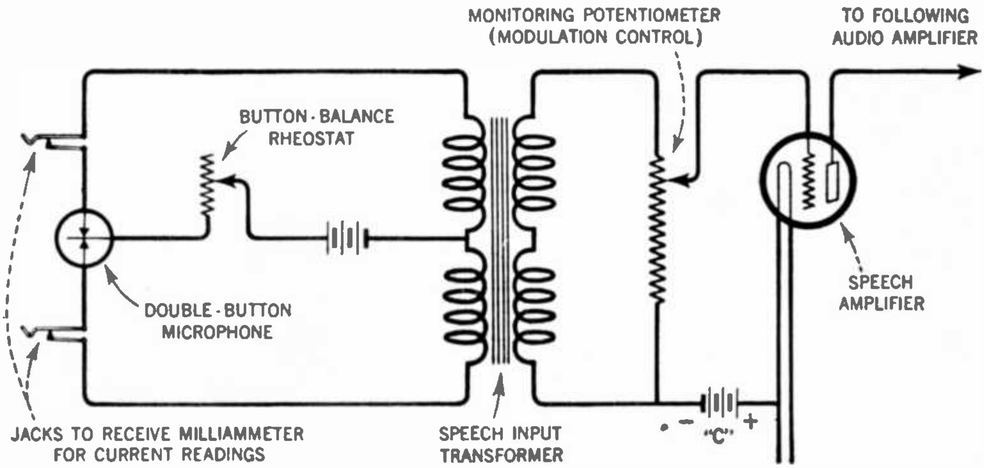


FIG. 21.—A double-button carbon-type microphone connected in an amplifier circuit.

of their normal arrangement or positions permits more or less current flow because of a certain change in their resistance. For example, when the granules rest against each other quite closely, they offer less resistance to current passing through them than would be the case if the granules were less firmly packed. The

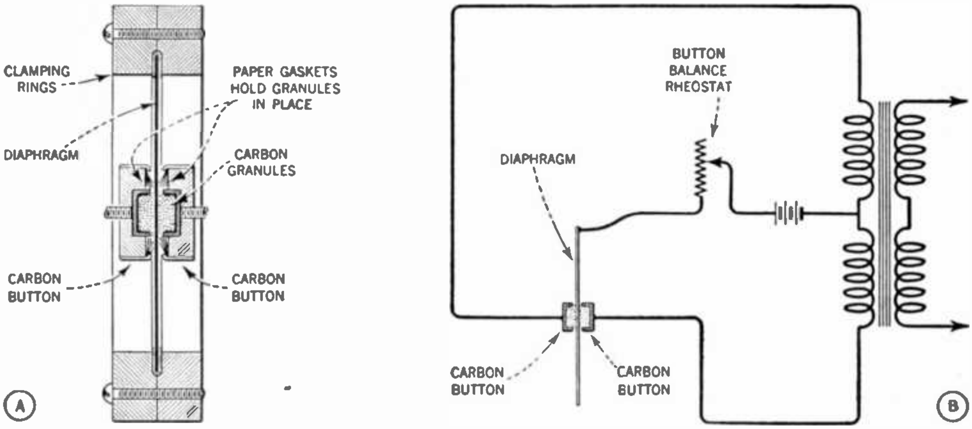


FIG. 22.—The double-button microphone. View (A) shows in general the method of mounting the front and rear carbon buttons against opposite areas of the thin diaphragm of a double-button microphone, and view (B) illustrates how the electrical circuit is completed through the carbon granules themselves and the microphone transformer.

process is one of allowing various amounts of current to pass through the carbon cup by varying the normal pressure of the disk against the granules. Consequently the current passing through the primary of the transformer will also change since this winding completes the continuity of the microphone circuit. The magnetic flux permeating the iron core of the transformer will also vary in accordance with the characteristics of the current changes, and it follows that the fluctuating e.m.f. induced in the secondary will likewise possess similar characteristics. In other words, the secondary carries a fluctuating current which varies at audio-frequencies, repeating the wave form and frequency of the sound pressure waves acting on the diaphragm. This fluctuating voltage is impressed upon the grid of an amplifier tube and in turn this tube's plate current will vary in exact accordance with the output of the microphone circuit. The necessarily feeble microphone output has been increased in strength by the use of the amplifier tube and this energy may now be passed through several stages of amplification before finally being delivered to the modulator circuit.

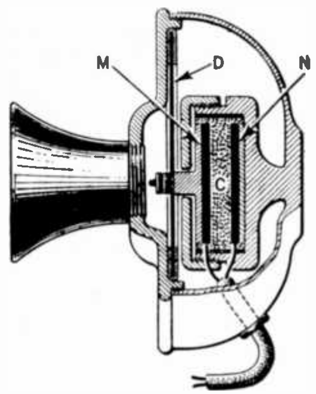


FIG. 23.—Cross-sectional view of a single-button carbon type transmitter (microphone). *M* and *N* are movable and fixed plates, respectively. *D* is the diaphragm and *C* the carbon granules.

A single button carbon microphone, used in some shipboard installations, is shown in Figure 23.

25. *Question.* Draw a diagram of a wavemeter and name the parts.

Answer. All wavemeters consist essentially of an inductance, a variable condenser, and some form of resonance-indicating device.

A wavemeter is usually equipped with one or more inductances, called exploring coils, previously calibrated from known standards of inductance.

The variable condenser is supplied with a dial calibrated either in wavelength in meters or frequency in kilocycles. If the condenser scale is marked in degrees as found in certain types these values can be interpreted from a chart or graph curve which accompanies the meter. There will be as many curves drawn on the graph as there are exploring coils supplied with the wavemeter instrument, each being marked for easy identification. The indicating device usually consists of a sensitive meter which gives a maximum deflection when resonance is established between the wavemeter and the circuit under test while adjusting the condenser dial. A neon tube may also be used to indicate resonance. The diagram in Figure 24 shows two typical wavemeter circuits with the essential elements identified.

26. *Question.* Name and describe the four circuits of the quenched type spark transmitter.

Answer. (1) The low frequency, low potential circuit consists of all of the apparatus from the armature of the a-c. generator up to and including the primary winding of the power transformer. Other parts are the transmitting key and wattmeter, and in some equipment an a-c. voltmeter and frequency meter are supplied.

(2) The low frequency, high potential closed oscillation circuit comprises the secondary winding of the power transformer and the high potential condensers.

(3) The high frequency, high potential closed oscillation circuit consists of the quenched spark discharger, the high potential condensers, and the primary of the oscillation transformer.

(4) The high frequency, high potential open oscillation circuit or radiating

circuit comprises the secondary of the oscillation transformer, the antenna ammeter, the loading inductances, the ground conductor, and the antenna system. The new assignments of wavelengths, 600 meters and above, for telegraphic communication makes the use of a short wave condenser in a spark transmitter unnecessary.

27. ***Question.*** **Draw a diagram of the constant current (Heising) system of modulation and explain its operation.**

Answer. One of the most important processes that occurs in every broadcast transmitter is the combining of the audio-frequency output of the microphone circuit with the high-frequency carrier produced in the oscillator and power amplifier circuits. This is accomplished by means of a large choke coil, known as the modulation plate reactor, inserted in the main d-c. supply to the plate circuits of

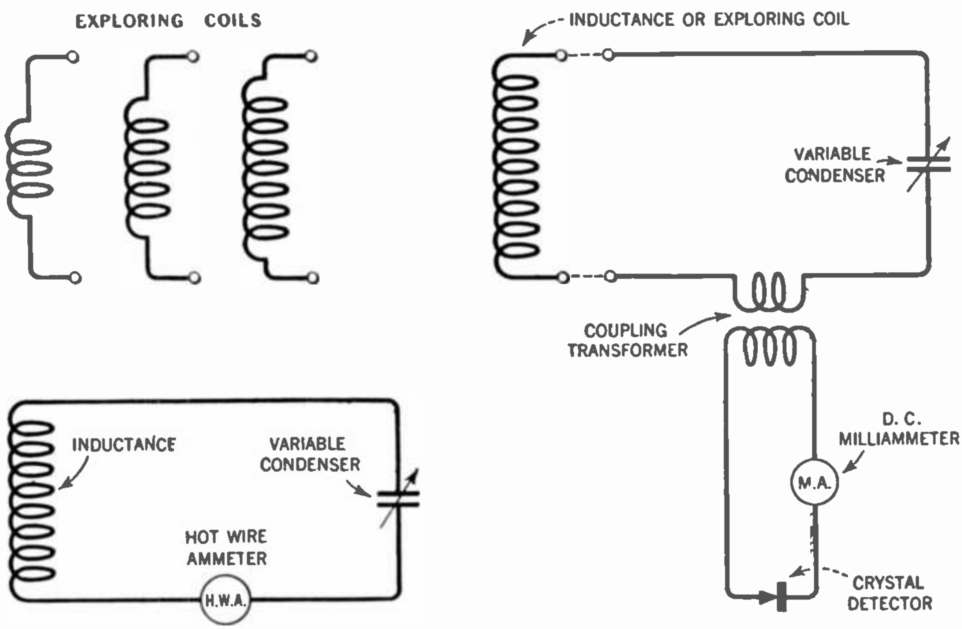


FIG. 24.—Showing two methods of utilizing a current indicating device in a wavemeter circuit.

an oscillator and modulator tube. As the schematic diagram in Figure 25 indicates, the oscillator and modulator plate circuits are connected in a parallel arrangement.

Audio-frequencies from the microphone circuit pass to the modulator and its output is superimposed upon the oscillations of constant amplitude in the output of the oscillator, the net result being that the amplitudes of the oscillations are either increased or decreased from their usual uniform value.

A few remarks about the choke coil or reactor just mentioned and its effect upon the operating conditions of a circuit will assist in clarifying the explanation.

The choke coil or reactor consists of a winding made up of many turns of wire mounted on an iron core of large dimensions. Consequently when direct current flows through its turns magnetic lines of force are set up in great numbers and these naturally permeate the iron core. Now, if for any reason, the steady current passing through the coil tends either to increase or decrease in strength, these lines of force will act upon the turns and will produce within them a reactance voltage which will oppose such current changes. This effect may be said to be due to the high self-inductance of the choke coil. A coil of this kind possesses an infinite amount of inductance for audio-frequency current changes. This property of the coil is utilized in the action to be described, for it maintains the current supplied to the plate circuits of the oscillator and modulator at almost

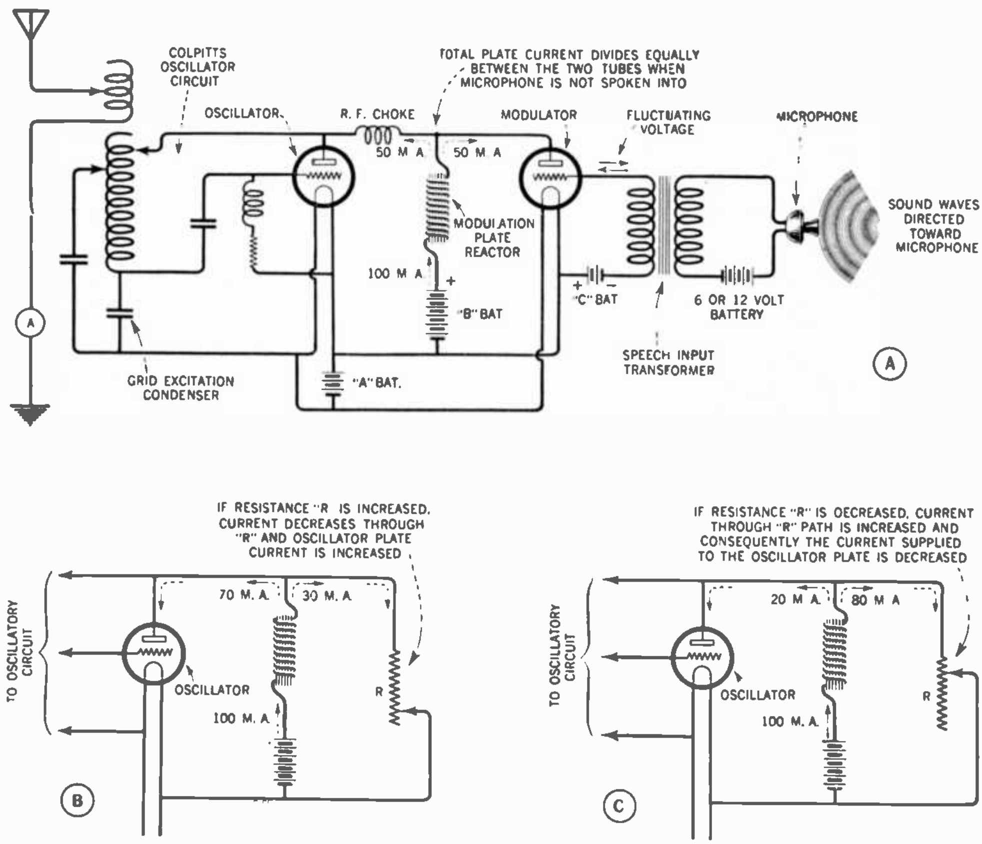


FIG. 25.—Diagrammatic explanations of the Heising (constant current) system of modulation.

a uniform value for all practical considerations. Remember that the oscillator and modulator plate circuits are arranged in parallel and that by the presence of the reactor a steady current is supplied to these circuits. We will now analyze how the output of the modulator tube is superimposed upon the radio-frequency oscillations generated in the oscillator circuit. This can best be done by employing a resistance analogy, setting up two resistances in parallel and supplying the resistance circuit with a direct current of constant value. It is known that when direct current flows in a parallel circuit consisting of two branches or members, the current will divide equally between them, provided, of course, that the two branches are of equal resistance. This represents the conditions when two tubes of similar power rating are connected in parallel. The views marked *B* and *C* in Figure 25 are for the purpose of showing how the modulator tube (see view *A*) may be compared to a variable resistance, and how a change in this resistance affects the distribution of current in the two branches.

The following arbitary values are selected as practical examples in order to explain the action. The constant d-c. supply through the choke is, let us say, 100 milliamperes, which is divided equally between the two resistance branches or plate circuits of the two tubes, hence 50 m.a. will pass through each branch. Suppose, then, the resistance of one of the branches marked *R* in view *B* is altered, and, let us say, is increased to the extent that the current in this branch is lowered from 50 m.a. to 30 m.a. We can conclude that the other branch, which is the oscillator, will be forced to take an increase of 20 m.a. because the supply through the choke does not change. Consequently the current in the oscillator plate circuit will increase from 50 m.a. to 70 m.a. since the total between the two branches remains unchanged at 100 m.a. This simple illustration explains how the current variations through the two paths are inversely proportional. Again, if resistance *R* is decreased as in view *C* and this branch draws possibly 80 m.a., the remainder of the total current or 20 m.a. will pass through the oscillator.

In this discussion it is quite obvious that we treat the plate circuit of the oscillator as one resistance path, and the plate circuit of the modulator as the other resistance path, or *R*.

Thus, for any change in the current flowing through the modulator plate circuit *R* the oscillator current will also vary, but in an inverse ratio. The modulator plate current can be made to vary gradually and continuously at any given frequency by impressing a fluctuating voltage upon its grid, for we know that the grid has the power to exercise such control over the plate current. The fluctuating current in the microphone output is utilized to communicate the necessary voltage changes upon the modulator grid. In practical operation this is usually accomplished through one or more stages of audio-frequency amplification. To summarize the action briefly it could be stated that the amplitudes of the r-f. oscillations are varied according to the speech frequency voltages impressed on the modulator grid, or stated otherwise, speech frequency voltages on the modulator grid effect a certain control in the value of the oscillator plate current at any moment while the latter tube is consistently generating radio-frequency oscillations.

As will be noticed when inspecting the curves in Figure 26 which illustrate this action, the contour of a line drawn through the ever-changing peaks of the oscillations duplicates the wave form of the voice or musical sound pressure waves directed toward the microphone.

A radio wave sent out by a broadcast transmitter has two frequency components as is clearly depicted by the curves. One component is represented by the generated high-frequency oscillations, or carrier frequency, and the other is the audio or modulation component conveying the intelligence to be communicated.

28. *Question.* If an arc transmitter suddenly stopped, give the order in which you would look for the trouble and the method of repair for each possible cause.

Answer. The order in which the most likely troubles would be encountered is summarized as follows:

The arc electrodes might possibly be out of adjustment. Readjust the spacing very carefully.

The alcohol may not be dropping into the arc chamber. Observe the sight feed and adjust the needle valve which regulates the flow, if this proves to be necessary.

The d-c. voltage may be discontinued. Observe the d-c. voltmeter, inspect all the line fuses, and circuit breaker, and note whether the proper voltage is at the main line switch. The ship's supply may have been temporarily lowered, which would cause the trip to operate.

The antenna ammeter could burn out and if this trouble was suspected a wire jumper could be attached across the meter terminals.

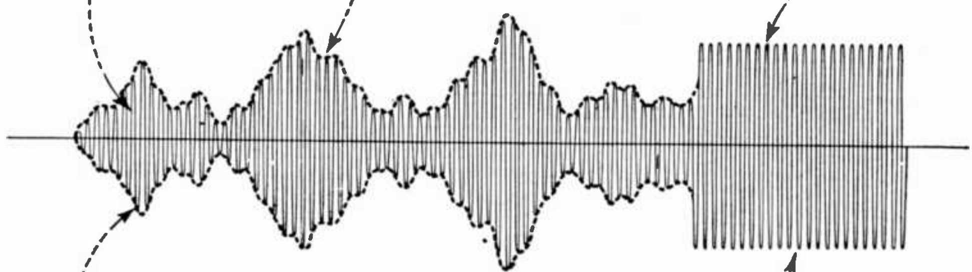


FIG. 26.—Curves illustrating how high-frequency oscillations are modulated according to the characteristics of voice or music.

The spacing of the arc electrodes, the alcohol feed and the d-c. voltage are the principal items that might affect the operation of the arc under ordinary circumstances.

Look for spread switch blades, loose connections, and poor electrical contacts especially in the radio-frequency circuits of the transmitter, for a high resistance connection will seriously affect the arc.

29. *Question.* **What is meant by "blocking" a modulator tube?**

Answer. If the grid working voltage, called bias voltage, is permitted to become excessively negative the grid will repel large quantities of electrons, or in other words the plate current will be lowered to some value less than that required for normal operation, or the plate current may actually be reduced to zero under extreme conditions.

Also, excessive overloading of the modulator grid with speech frequency voltage from an audio amplifier circuit will choke the grid and block the flow of plate current. In this event, distortion of the speech frequencies will result because the plate current cannot vary in a normal way to repeat the wave form and frequency of the speech voltages applied to the grid.

30. *Question.* In the event that the generator of a tube transmitter burned out, by what method would you effect a temporary repair?

Answer. If the field or armature coils of a modern generator burned out it would necessitate disassembling the machine before repairs could be affected.

If one of the field windings became damaged it could be shunted out by connecting a jumper around it if the design of the machine permitted convenient access to the connecting leads. In some cases where a damaged armature coil causes excessive sparking the machine may be continued in operation by soldering a jumper wire across the defective coil, this being done at some convenient place where the coil leads are attached to the commutator bars; however, this remedy requires special care and skill.

31. *Question.* State care to be exercised in maintaining an arc transmitter for efficient operation.

Answer. The main points in caring for an arc converter are:

1. The chamber should be kept reasonably clean of soot and carbon deposits.
2. No water leaks, however slight, should be permitted inside the chamber. The anode tip connection and gasket should be tested whenever a new tip is installed.
3. The chamber should be kept air-tight. The surfaces of the upper and lower chamber sections should always be clean and the gasket kept in good condition.
4. The bakelite anode insulating disk and its gasket should be kept clean.
5. The moving parts should be cleaned and oiled occasionally.
6. Inspect all of the electrical connections, especially those in the high-frequency circuits and keep them clean and making firm connection.
7. Keep the alcohol cup filled with clean alcohol and see that it feeds properly.
8. Keep the water tank filled to about three-quarters full with fresh water only. Never use salt water. See that no kinks or sharp bends are allowed to develop in the water hose and also that the interior of the hose does not become partially clogged with torn pieces of the hose lining, which usually happens when the hose has been in use for a very long period.
9. See that the valves of the water tank are open and that the flow indicates a circulation of water when the pump is started.
10. See that the commutator and the brushes on the motor and generator, and carbon drive motor are kept in good condition and that all moving parts are properly lubricated.
11. Care should be taken to see that the anode tip is always properly aligned midway between the magnet poles. The copper tip of the anode is brazed to a short piece of brass tubing; this tip should be examined frequently for it will become worn after a long period of operation and in this circumstance it must be renewed. The surface of the tip should be smooth and not allowed to become dented by careless adjustment, as when striking the arc.
12. The carbon should always be held securely in its holder and the proper amount of projecting carbon for the most convenient operation should be maintained. The carbon deposit on the cathode must be deposited evenly as it rotates.

If the deposit builds up in an irregular or uneven form then a new carbon stick must be installed.

13. Keep the chopper commutator wheel clean and bright by rubbing with a fine grade of sandpaper or crocus cloth.

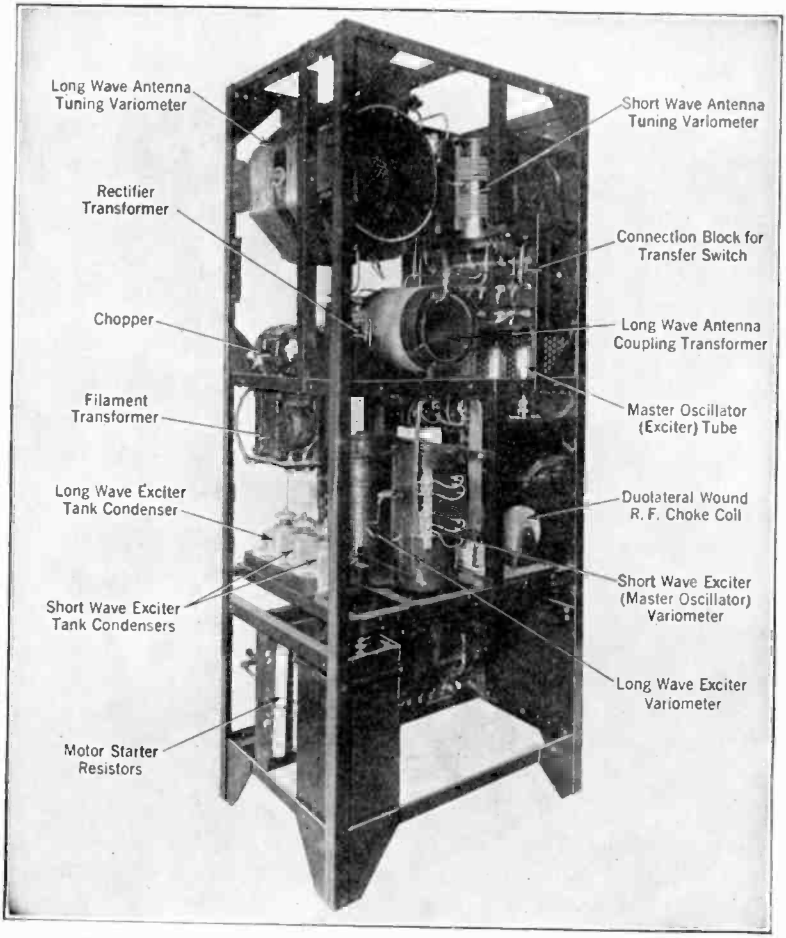


FIG. 27.—Rear view of RCA vacuum tube transmitter type ET-3626.

32. *Question.* If you were operating a vacuum tube transmitter and it suddenly stopped operating what would be the order in which you would look for the trouble and what steps would you take to correct it?

Answer. Tubes. Should any tube become inoperative in the average multi-stage set, and if no spares are available, the set may be operated with less than the usual number of amplifier tubes in place. Tube troubles in general are:

Filament wire burned out.
Grid touches the filament.
A soft tube, or one with a low emission.
A tube having poor oscillating characteristics.

Look at all wiring in the tube sockets for poor connections or loose wiring and be sure the pins in the tube base make good electrical contact with the springs in the socket.

Motor-generator: If the machine stopped running, with the "start" button pressed, look for a defective main fuse. A blown fuse should be replaced with a new one of similar rating. The operator should ascertain if there is line voltage at the main switch and if it is of the correct value. A test for line voltage can be easily made in most transmitters by depressing the telegraph key, which should cause the relay key to work, providing the ship's power is on. Examine the contactors in the starter. If circuit breakers are employed see if they have tripped and ascertain the cause if possible. The trouble might be due to a loose connection.

Filament voltage may be too low. Observe the filament voltmeter for a possible discontinuance of this supply.

Tube filaments do not light. If the motor-generator operates satisfactorily but the filaments suddenly fail to light, look for blown fuses, which might happen due to an accidental short-circuit. Also look for defective brush or insufficient brush tension on the slip rings on the machine supplying the filament e.m.f. If the trouble has not been located, then look for defective filament transformer, filament rheostat, or for the discontinuance of the a-c. supplied from the source.

A storage battery can be used to supply the requisite terminal e.m.f. to the filaments as follows: For example, if 10-volt tubes are used, then connect five cells in series to obtain 10 volts and attach the filament terminals across the five cells. If the motor-generator continues operating and filaments are O. K. then observe the plate voltmeter, plate ammeter and antenna ammeter for normal indications. No reading on any of these meters will assist one in isolating the trouble.

No indication on the antenna ammeter. The antenna circuit may not be in resonance with the transmitter circuit or the trouble may be due to loose connections, or the antenna or ground circuits may be open. Although the tuning adjustments are not apt to become disarranged during transmission yet it is advisable to try adjusting the tuning controls if antenna current suddenly drops to zero. Also, look for open or spread switch blades. If lack of antenna current is thought to be due to a burned-out ammeter, place a wire jumper between the meter terminals and note the results. If this is found to be the seat of the trouble then adjust the circuits in accordance with the tuning card and observe the plate current ammeter for final resonance.

No temporary repair is possible for a burned-out plate voltmeter. In this circumstance it is suggested that the generator field rheostat be adjusted to its usual position and the tubes watched closely to prevent overheating of the plates. In the case of a burned-out plate ammeter in some equipment a 150-watt lamp can be connected to the meter terminals and for normal operation the lamp should not exceed full brilliancy.

Examine all connections and look for loose wiring especially in the radio-frequency portions of the transmitter. The plate and grid leads may be found improperly connected to the oscillatory circuit inductance.

Burned-out grid leak. Should the grid leak of a power amplifier burn out or prove defective otherwise it may be replaced by an equal value of resistance. A satisfactory substitute may be made up with a rubber hose. A resistance of approximately 4000 to 10,000 ohms may be obtained from the use of a rubber hose about 10 in. long filled with water and plugged at each end with a connecting wire passing through each plug and protruding a short distance in the water to form suitable electrodes. A small amount of salt or washing soda should be added if the resistance seems too high.

If a plate r-f. choke is found to be defective it may often be replaced by a grid choke, but after removing the grid choke be careful to put in a temporary wire jumper to close the grid circuit. Although the efficiency of the transmitter will be somewhat impaired, this provides immediate remedy. A 400-turn honeycomb or duolateral coil, if one is available, can be used in most cases as a plate or grid choke.

A frozen bearing will cause the armature to stop rotating. To ascertain this condition, first open the main switch and with the power off turn the armature over by hand and at the same time inspect the oil wells and oil rings to see that they have plenty of oil.

33. *Question.* How would you proceed to place a tube transmitter in operation?

Answer. Placing the E.T. 3626-B into operation. (Refer to the frontispiece photograph.)

(1) Before starting the motor-generator set, turn the filament and generator field rheostats to minimum voltage positions and close the main line switch if it has been opened.

(2) To start the motor-generator set press the "start" button located on the operator's control unit, which closes the first contactor on the motor starter and from one to two seconds later the running contactor closes and the machine comes up to full speed. Now adjust the filament voltage to read 10 on the voltmeter by means of the rheostat, which is also mounted on the operator's control unit.

(3) The plate voltmeter should be observed while making adjustment of the generator field rheostat until a reading of 1000 volts is obtained. The plate current ammeter should read about 1.2 to 1.4 amperes for this transmitter.

(4) The transfer switch should be thrown up if transmission is desired on the long-wave range between 1250 and 2500 meters, or down for the short-wave range between 600 and 1250 meters.

(5) The exciter (master oscillator) tuning and range switch on the lower part of the panel is next placed in the wavelength position desired, the short-wave range being on the left and the long-wave range on the right.

(6) The above wavelength adjustments are followed by placing either one of the antenna tuning switches in its proper position, according to the range desired, the short-wave range switch is on the left and the long-wave switch on the right. The operator must be careful to place the exciter range switch in the correct position corresponding to the exciter range switch for a given wavelength.

(7) The "test" button on the panel may be depressed in order to ascertain if maximum antenna current will be obtained for a certain wavelength which

will be observed on the antenna ammeter. To obtain the best adjustment, turn the antenna tuning control until the antenna ammeter indicates a maximum current reading. This tuning adjustment is attached to the variometer rotor coil and consequently it may be manipulated for any particular wavelength; it resonates the radiating or open circuit with the transmitter or closed circuit.

(8) When a satisfactory antenna current indication is obtained after tuning the set as outlined above, the sending key may be operated for the transmission of messages.

(9) Before sending a message be sure the "CW-ICW" switch is in proper position, which, of course, is governed by the type of receiver employed at the station with which communication is to be established. When the sending key is closed and with the "CW-ICW" switch thrown to the "ICW" position the audio oscillator will generate one of three tone frequencies and operate in conjunction with the master oscillator and radio amplifiers. The tone frequency switch is located within the transmitter frame on the right-hand side and should not be touched while the motor-generator set is running, as the d-c. voltage is on the circuits. In certain other types of transmitters a motor-driven chopper is used to effect I.C.W. operation.

(10) When communication is completed the set is shut down by pressing the "Stop" button on the operator's control panel.

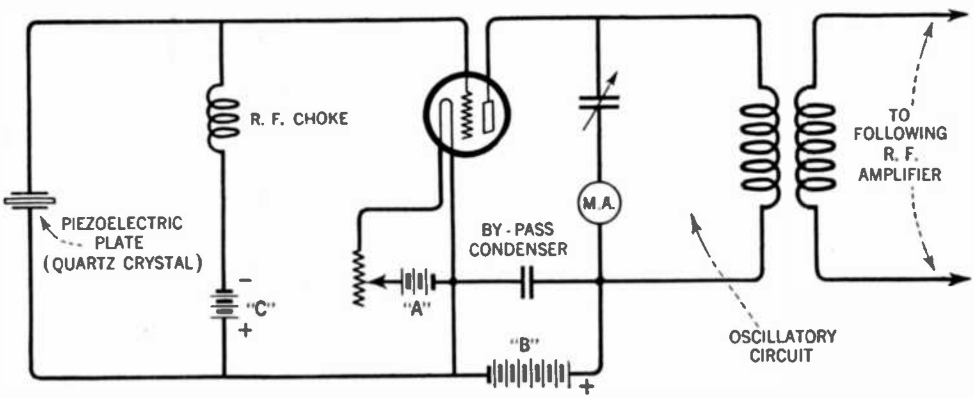


FIG. 28.—Showing one method of connecting a quartz crystal to an oscillating tube circuit for the frequency control of a transmitter.

34. *Question.* What is meant by the "piezo" effect of a quartz crystal or other crystal?

Answer. When an electric circuit is formed by a conductor connecting two metal plates between which a crystal is placed, and the plates are subjected to alternating mechanical impulses, the crystal will generate corresponding alternating currents. It is known that the opposite effect will also be produced by the crystal, for if an electrical pressure (e.m.f.) of an alternating nature is impressed between the plates, it will cause a similar mechanical vibration in the crystal. A quartz crystal, then, is capable of converting mechanical vibrations into electrical oscillations and vice versa. This peculiar property which a crystal exhibits has been given the name "piezoelectric." Different kinds of crystals have piezoelectric properties, but they are not all suited mechanically for practical uses and, furthermore, they do not all have the same pronounced electrical properties as does the quartz crystal. Crystals often chip or crack due to the intense molecular strain they are under when vibrating at very high-frequencies.

One method of connecting a piezoelectric oscillator (quartz crystal) to an oscillating tube circuit is shown in the diagram in Figure 28. Thus, it is pos-

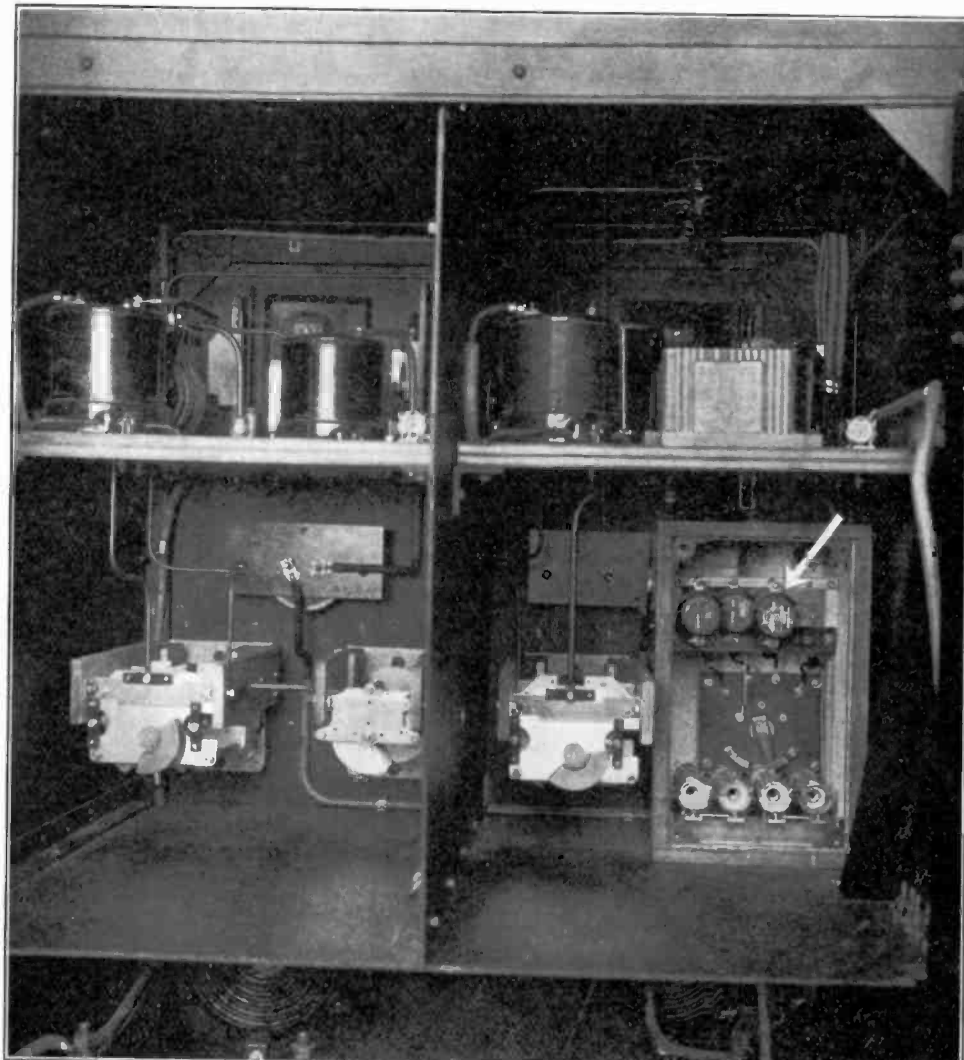


FIG. 29.—A view of the quartz crystals installed at WEAF to maintain stabilized frequency. Three crystals are shown above, as indicated by the white arrow, although only one is used at a time—the remaining two being held for emergency.

sible to connect a vacuum tube oscillatory circuit to a quartz crystal and control the frequency of the current circulating through the system. Every piezoelectric crystal has a natural mechanical vibration peculiar to itself, determined chiefly by its thickness, and the effects are strongest when an electrical oscillation is adjusted closely to the natural mechanical period of the crystal.

35. *Question.* Assume that the open and closed circuits of a transmitter are adjusted to 600 meters and through an accident the closed circuit is thrown out of resonance with the open circuit. How can you retune the closed circuit to resonance with the open circuit without the use of a wavemeter?

Answer. In this circumstance it is assumed that the secondary or open circuit is properly adjusted to the 600-meter wave. The closed circuit is retuned according to the following procedure:

Place the wavechanger switch in the 600-meter position and then attach the primary tuning lead or clip at some location on the turns of the primary or tank inductance as suggested by the location of the other wavelength adjustments. This is simply a preliminary or rough adjustment. Now start the set and close the key, at the same time observing the antenna ammeter. If a low current is indicated, which is the usual experience for initial adjustments of this kind, then make several widely varying adjustments on the inductance turns, noting each time whether the ammeter reading increases or decreases. As many trials as found necessary are made by attaching the lead at different locations on the primary turns until a certain place is found where maximum reading is obtained and this will be the resonant point. Our only means of ascertaining the best adjustment in the absence of a wavemeter is to utilize the antenna ammeter as a resonant indicating device. What we do is simply to resonate the primary or closed circuit with the secondary or open circuit, which is a reversal of the process when tuning in accordance with the customary manner.

If adjustable capacitors are included in the primary these may require adjusting in addition to altering the amount of inductance used to secure resonant conditions. It is to be understood that the coupling at the transformer may be slightly changed if the original factory adjustments are not duplicated and it would be desirable to secure again the proportion of inductance and capacitance values formerly used. If less capacity and more inductance is used in the new adjustment then the coupling will be increased, and vice versa. In any given oscillatory circuit an increase in inductance or capacitance decreases the oscillation frequency, that is, increases wavelength, and vice versa a decrease in inductance or capacitance increases the frequency, or lowers the wavelength.

When making adjustments of this kind care must be exercised to prevent abnormal plate current or grid current flow, or excessive heating of the tubes, since alterations of the oscillatory circuit constants affect the currents handled by the tube. A slight reduction of plate voltage when making initial adjustments should preclude the possibility of overloading the tubes.

36. *Question.* (a) Describe the motor-generator used with an arc transmitter. (b) Compare it with the motor-generator used with a spark transmitter.

Answer. (*a*) *Motor-generator for a 2-kw. arc transmitter.* The arc of a 2-kw. transmitter requires direct current power. In one type this is furnished by a two-bearing motor-generator set, which consists of a 100 to 120-volt d-c. shunt-wound motor, directly connected to a shunt-wound separately excited d-c. generator. The generator will deliver 2 kw/s. at 250 to 400 volts, and is wound for separate excitation from the 120-volt d-c. supply. All terminals for both the motor and generator are located on an enclosed terminal board on top of the frame. Protective devices for the windings of the motor and generator are mounted inside the molded insulating cover which protects the terminal board. The machine is equipped with two commutators; one is the motor end of the machine and the other is the generator end. The armature shaft runs on ball bearings and care should be taken to insure proper lubrication. A rheostat in the generator field is used to regulate the d-c. voltage supplied to the arc.

(*b*) *Motor-generator for a spark transmitter.* In general the motor-generator operating a spark transmitter consists of a compound-wound d-c. motor, with an input of 110-volts direct current, coupled to an alternating current generator. The field of the generator receives its excitation from the 110-volt d-c. source which supplies the motor. The standard frequency of a modern spark set is 500 cycles, and the generator is equipped with the proper number of field poles and driven by the motor at the requisite speed to produce this frequency. The motor end employs a commutator while the generator end is equipped with two slip rings. Thus the d-c. and a-c. parts of the machine are easily identified. The motor field is equipped with a rheostat to control its speed and in turn the frequency of the alternating current. The a-c. voltage is controlled by a rheostat in the generator field.

37. *Question.* If a spark transmitter suddenly stopped while you were operating what step by step procedure would you follow?

Answer. If the motor-generator continues to operate then the trouble is not anywhere in the main d-c. supply but possibly the fuses in the a-c. output of the generator may have blown or the generator field windings may have opened at some point. If no wattmeter reading is indicated when the sending key is depressed, ascertain if there is voltage at the a-c. main-line switch, for the current coil in the ammeter may have burned out or opened, or trouble may have occurred at the changeover switch due perhaps to a loose connection. Or the primary winding of the power transformer may be opened or the secondary may prove to be defective, being either open or short-circuited. One of the high potential condensers may have broken down or some flexible lead may have broken loose from its terminal connection. If it is apparent that all circuits up to and including the closed oscillation circuit are functioning O. K. but no antenna current is indicated, then there is a possibility the meter has burned out or the antenna or ground leads have for some reason become disarranged. If a blown fuse is encountered it need only be replaced with one of similar rating. A battery and headset may be used to test for a complete generator field circuit and if this proves to be open somewhere the trouble may be that the generator field rheostat has burned out. After a defective section of the rheostat is found by testing with the headset it may be shunted out by connecting a short wire jumper across it in the most convenient manner. Should a test indicate a short-circuit in the transformer primary then the winding must be removed from the case and a replacement made. A burned-out secondary is repaired by locating the defective pie section, and if no spares are available the damaged pie section is removed and the remaining pie sections are again connected in series and the transformer operated at reduced voltage. A punctured condenser must be replaced by one of similar electrical characteristics. If no spares are on hand a parallel connection of the remaining condensers should be made to provide the same capacity as that originally used. Before operating the transmitter the input voltage to the transformer is reduced by adjusting the generator field rheostat. The spark gap should be inspected; also it should be ascertained if all switch blades are making good connections.

38. *Question.* **Draw a diagram of the arc water supply system:**

Answer. The diagram in Figure 30 shows the general arrangement of the water circulating system and also a plan view of the arc converter.

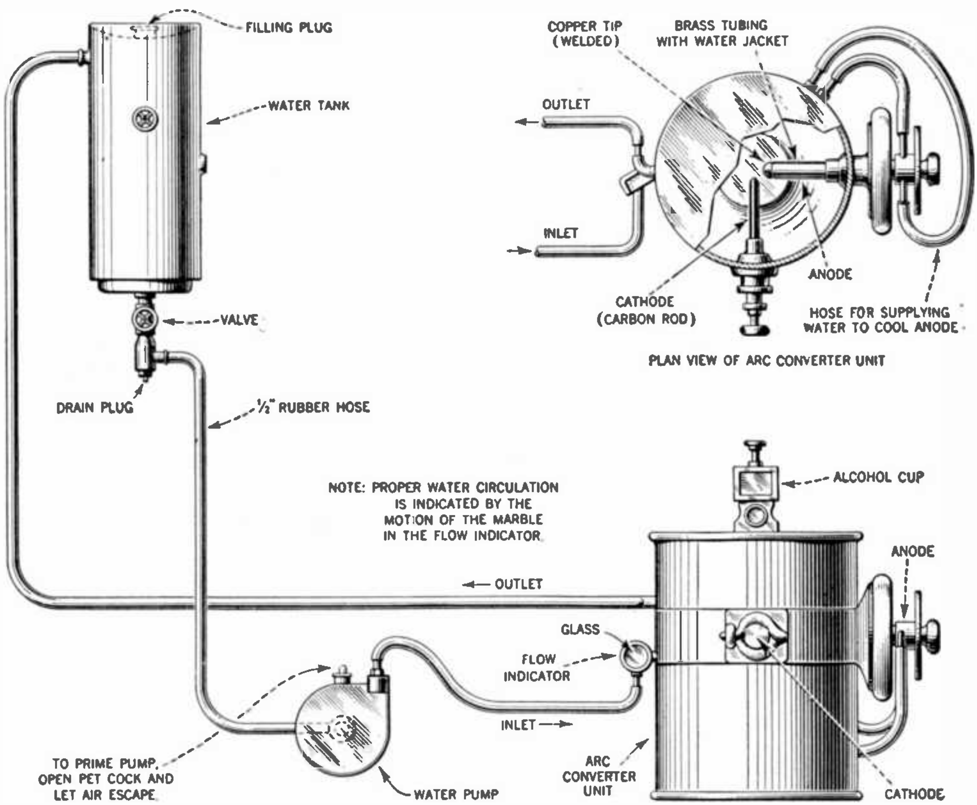


FIG. 30.—An illustration of the circulating system of the Federal arc transmitter.

39. *Question.* **At what point in the antenna is the electrical strain the greatest?**

Answer. The highest potential is built up at the free or far end of the elevated portion of any active antenna system, hence the greatest strain exists at this point.

40. *Question.* **How does the water acting as a conductor enable the arc to function?**

Answer. The water in the arc system should not act as a conductor. It is essential that only fresh water be used in the circulation system of the arc converter in order that the anode may be well insulated from the earth. If salt water is used, its presence in the rubber hose through which cooling water is supplied to the anode would furnish a relatively good conducting path from the anode to the chamber and the electrodes therefore would be short-circuited.

41. *Question.* Draw diagram showing three ways of furnishing plate supply to a vacuum tube transmitter.

Answer. Refer to Figure 31.

1. Plate potential may be supplied by a direct-current generator in conjunction with a suitable filter system, as shown in drawing *A*.

2. Direct current may be obtained through the use of one or more rectifiers operating from an alternating current source through a step-up transformer. One method is illustrated in drawing *B*.

3. Alternating current at a high voltage may be supplied to tubes through a power transformer without the use of rectifiers. In this case the plates are energized with raw a-c. One type of circuit arrangement is shown in drawing *C*.

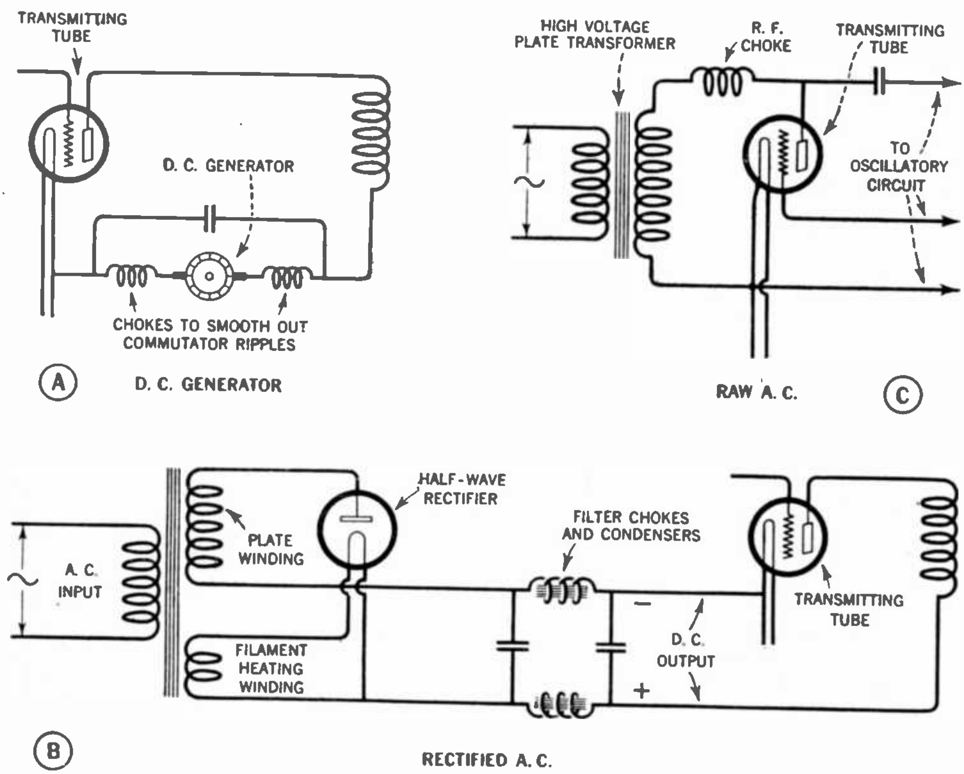


FIG. 31.—Three methods of supplying potential to the plates of transmitting vacuum tubes.

42. *Question.* Draw a diagram and explain a self-rectified transmitter. (Fundamental drawing.)

Answer. A schematic diagram of a self-rectifying tube transmitter utilizing two oscillator tubes is shown in Figure 32. This circuit operates during both alternations of the a-c. cycle. Notice that the two tubes are arranged symmetrically so that each one in turn becomes active during successive alternations of the a-c. cycle. This is generally known as a back-to-back arrangement, and provides full wave ACCW transmission, that is, the antenna sends out a signal wave of the tone-modulated variety.

In our diagram an oscillator circuit of the Colpitts type is used consisting of the tank inductance, the plate coupling condenser, and the grid excitation condenser. The plates of the tubes are energized by the high voltage a-c. output of the mid-tapped power transformer. In one type of transmitter the plate transformer receives a low voltage 500-cycle current in the primary and delivers a high voltage 500-cycle current from its secondary, the opposite ends of which are connected to the plates of the oscillator tubes. During successive cycles each tube alternately receives a positive and negative voltage but only the tube receiving a positive potential on its plate at any particular time becomes active and permits the flow of plate current. Since the plate voltage must continually change in value according to the a-c. cycle, that is, rising and falling with the 500-cycle frequency, then it follows that the amplitudes of the radio-frequency oscillations generated in this circuit will also vary in like manner.

Transmission of messages is accomplished by inserting the transmitting key in the transformer primary, thus the key contacts open and close the a-c. genera-

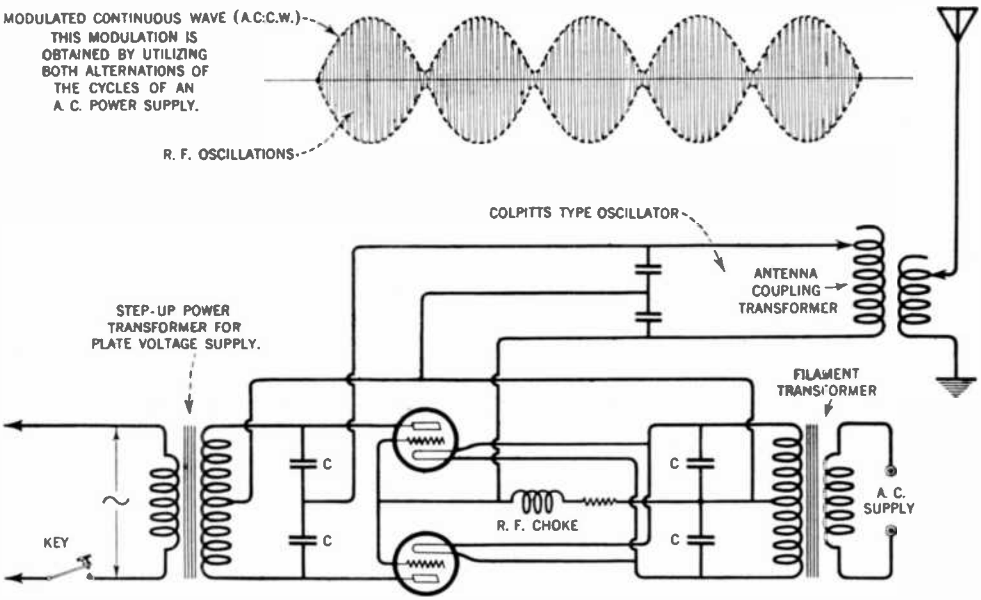


FIG. 32.—Oscillator tubes working in a full-wave self-rectified transmitter. C, C, C, C are r.f. by-pass condensers. The curves at the top depict the type of wave emitted by this transmitter.

tor circuit. The plate blocking condensers offer a low reactance path for the radio-frequency component of the plate current; this component represents the oscillating energy which passes from the plate or output of the tube to the tank or oscillatory circuit. The grid excitation condenser supplies the grids of the tubes with a radio-frequency voltage whenever oscillations circulate through the tank circuit. This is the feedback voltage impressed between grid and filament necessary to maintain the circuit in a state capable of generating oscillations. In the Colpitts type circuit the grid excitation condenser from which the feedback voltage is obtained is part of the total capacitance of the tank circuit. The total capacitance includes both the grid and plate condensers in series.

The characteristics of an ACCW signal wave, or r-f. oscillations modulated by a low frequency alternating current, is shown in the curves in Figure 32.

43. ***Question.*** **What are the principal losses in a condenser?**

Answer. The losses in a condenser are due mainly to the following causes:

(1) Whenever a condenser is charged and discharged at a fast rate, as in a radio-frequency circuit, energy is expended in the form of heat due to what is known as molecular friction in the dielectric. This waste of energy is known as the dielectric hysteresis loss.

(2) Losses also occur due to brush discharge. This effect is quite pronounced at all sharp edges and corners of conducting plates and particularly so if they are dirty or greasy. This is known as the corona effect.

(3) There is always a very small amount of leakage current passing through a dielectric material when subjected to an e.m.f. since no dielectric is an absolutely perfect insulator. This creepage is usually infinitesimal and takes place through the dielectric from plate to plate of the condenser, thus tending to equalize any difference of potential between the plates.

(4) Dielectric absorption occurs whenever an electrostatic field is set up between a charged condenser and some nearby object.

44. ***Question.*** **State two ways of obtaining I.C.W. signals.**

Answer. 1. One method is by the use of a chopper driven by a motor; the chopper commutator interrupts the high-frequency oscillations, breaking them up into audible group frequencies.

2. A second method is by the use of an audio oscillator. The output of an audio oscillator tube circuit is delivered to the transmitter circuits in which radio oscillations are generated. This causes the r-f. oscillations to vary in amplitude according to the wave form of the audio-frequency current. This type of signal is known as tone modulation.

45. ***Question.*** **What does an overheated plate indicate?**

Answer. If the plate of a transmitting tube exceeds a dull cherry red color it indicates that either the plate voltage is too high, the filament voltage is too high, or the tuned oscillatory circuit is thrown out of adjustment and the tube is not oscillating normally. In most cases where improper amounts of either plate or grid inductance or capacitance are used in the oscillation circuit the tube will heat up and the plate ammeter will indicate excessive plate current. Under such conditions the circuit must be recalibrated. Undue heating of the plate may also result if for any reason the normal negative grid bias has been removed. The trouble might be due to a defective tube—one which is said to be "soft."

46. ***Question.*** **Why is a speech amplifier used?**

Answer. The output current of a microphone circuit is necessarily very feeble and therefore will not provide sufficient voltage to operate with effectiveness the grid of a large modulator tube. It becomes necessary then to pass the speech frequencies from the microphone through a vacuum tube amplifier, called a speech amplifier, to build up the speech voltages to a level as determined by the power of the tube used. In most broadcasting equipment the speech amplifier is followed by several stages of amplification which further build up the strength of the audio-frequencies until a suitable voltage is obtained for exciting the grid of a high power modulator tube. A speech amplifier panel is shown in Figure 33.

47. *Question.* Explain how you would effect short distance communication if the radio transmitter on shipboard were disabled beyond repair.

Answer. In the majority of shipboard installations the receiving set is one of the regenerative type which may be set into oscillation by closely coupling the plate coil to the grid circuit. The key should be connected in series with the plate supply lead for signaling purposes and the circuit adjusted to 600 meters. This expediency is only to be used in the event that the ship's power fails or in case of a complete breakdown of the transmitter.

FIG. 33.—Speech amplifier panel and control permits uniform amplification of all audible frequencies. The monitoring control (volume level control), amplifier tubes, and output jacks for connecting a volume indicator (sensitive quick-acting milliammeter) and loudspeaker, are clearly shown. This panel is part of a 5-kw. broadcast transmitter.

48. *Question.* What is the purpose of the transverse magnetic field in an arc transmitter?

Answer. The field coils used in an arc chamber are connected in series and serve both as magnetizing windings and choke coils to prevent the flow of radio-frequency current back into the d-c. generator. The strong transverse magnetic field produced by the coils must be in such a direction that it will blow the arc flame toward the exhaust opening in the back of the chamber and remove the ionized condition resulting from the burning arc flame. The purpose of providing a transverse magnetic field is to insure a steady operating arc. The principle of operation is that the magnetic field acts upon the arc flame to blow it out periodically which tends to restore the gap resistance to normal. This is another way of stating that the gap is partly deionized by the action and at such moments it is not a good electrical conductor. A very high voltage, produced by the self-inductance of the oscillatory circuit, breaks down the high gap resistance and it is these combined effects that permit the generation of continuous oscillations. If the gap resistance were not increased periodically and remained practically constant a strong ionized condition would remain between the arc electrodes, and current would flow across the gap continuously from the generator and the circuit would not oscillate.

49. *Question.* How would you maintain a clean and steady note in a transmitter utilizing the quenched spark gap?

Answer. Proper selection of inductance values in the closed and open circuits must be made in order to secure maximum efficiency from a quenched spark transmitter circuit. The degree of coupling between the oscillatory circuits is also very critical. The correct values of the self-inductance of the open and closed circuits (as determined by the number of turns used on the respective inductances and the degree of coupling used) are indicated when maximum deflection is obtained on the antenna ammeter. The note of the transmitter signal is determined by the frequency and voltage of the a-c. output of the power transformer, hence the generator voltage must be carefully regulated by the generator field rheostat according to the number of gaps used for the power required. By listening-in on the station's own receiver, which will pick up the signal through induction, the quality of the note may be ascertained. If too few gaps are used the note is very apt to be rough even when normal or reduced current is flowing in the primary circuit. Then by the addition of gaps and increasing the a-c. voltage accordingly a clear note may be obtained. An irregular note will be heard if the open and closed circuits are not in resonance. Keep the sparking surfaces of the gap clean and the gap air-tight by using perfect fitting gaskets in order to maintain a good steady note.

50. *Question.* What causes a vacuum tube to overheat?

Answer. Some of the principal causes are:

Improper grid bias voltage, defective bias resistance or defective grid leak.

Defective tube; soft tube.

Improper adjustment of the oscillation circuit, or the circuit not in an oscillating condition.

Excessive operating voltage on the plate or filament.

51. *Question.* Of what use is the plate milliammeter in a vacuum tube transmitter?

Answer. The plate milliammeter is used primarily to indicate whether the plate circuit of a tube is passing normal current as recommended by the manufacturer. Excessive plate current indicates that the tube is overloaded and in this event steps should be taken to correct the difficulty. By observing the plate current ammeter and the plates of the tubes themselves for signs of color in excess of the permissible dull cherry red the operator may easily tell if a tube is overloaded. Overloading may be caused by improper grid bias voltage, a soft tube, or the oscillatory circuit may be in an unstable oscillating condition.

52. *Question.* **How can you tell when a vacuum tube transmitter is functioning properly?**

Answer. When all of the readings on the meters are indicating normal values it may be assumed that the transmitter is performing satisfactorily. For example: Proper reading on the antenna ammeter suggests that the normal power is supplied to the transmitter circuits and resonance is established between the closed and open circuits. Proper plate voltage, plate current, and filament voltage readings show that the tubes are functioning normally. In certain types of high

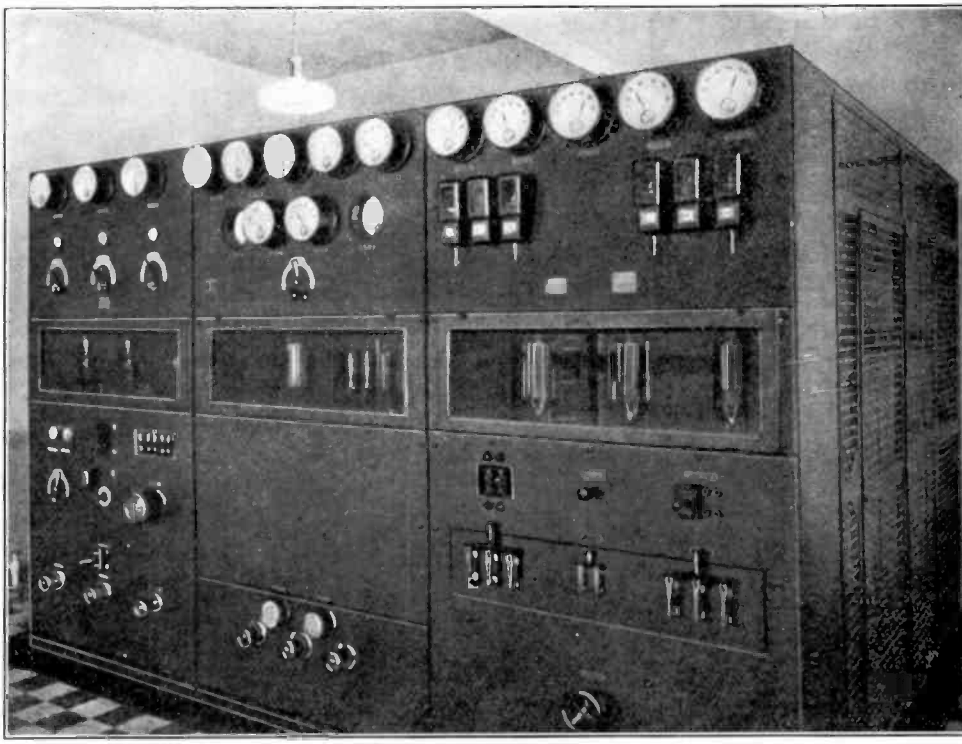


FIG. 34.—The main unit of the 1005-A 5-kw. broadcast transmitter equipment manufactured by the RCA.

power transmitters the grid current may be easily read by plugging in a milliammeter in a jack provided for that purpose. It is to be remembered that the plates must never be allowed to heat excessively and show a color which appears more than a dull cherry red.

53. *Question.* **Describe how you would tune a modern vacuum tube transmitter to the various wavelengths used in commercial service.**

Answer. The following description deals with the calibration of the ET-3628 telegraph transmitter. Whenever calibration of this particular transmitter is performed the power should be adjusted to about ½ kw. and the tubes constantly observed during the process for heating and sparking. A rough tuning adjustment is first taken by placing the wave-changer switch on the lowest wavelength position, or 600 meters, and using a wavemeter held near the tank inductance to measure the wavelength. The wavemeter condenser should be moved very slowly in order to obtain the exact point of resonance or where the deflection of the needle is maximum at 600 meters. The tank inductance is provided with only one clip, which should be varied until the desired wavelength of 600 meters is obtained. This procedure is to be followed by resonating the antenna circuit to the primary or tank circuit. The adjustment is to be considered satisfactory when a maximum reading is obtained on the antenna ammeter and the wavemeter indicates maximum current when adjusted to 600 meters. When tuning the antenna circuit care must be taken not to include too many turns on the secondary coil. It will be found that for this transmitter about two turns gives a sufficient amount of inductance for the proper transfer of power, and will not result in too close coupling between the primary and secondary circuits, a condition that usually produces an effect called "split tuning." It is essential that a transmitter be cleared of such an undesirable condition, providing it exists, because the frequency of the emitted signal will "swing" sharply from one frequency to another. The operator at the distant receiving station could only intercept the signals upon the frequency to which his receiver circuit is tuned, and the other frequency when the signal swings could not be heard.

In order to detect the presence of split tuning the following indications should be noted while performing the two tests.

First test. The transmitter is in correct adjustment (that is, only one frequency or wave is being radiated) when the antenna ammeter reading increases steadily while the open circuit is brought to resonance by carefully making adjustments in the loading inductance used for fine tuning and, if after the resonance point is passed, the ammeter reading is again seen to decrease steadily. On the other hand, it may be accepted that two frequencies or waves are being radiated (that is, the split tuning effect is present) if the ammeter reading drops suddenly after the critical point or highest reading is passed. It can be assumed also that the split tuning effect is due to tight coupling and this trouble may be corrected by changing the coupling. This is accomplished by altering the amount of secondary inductance used, by very carefully going over the wire inch by inch with the clip until a suitable point is found. Coupling cannot be changed by varying the distance between the two coils, as they are in fixed mechanical relation to each other. The person performing the calibration must not touch any wiring or clips when the transmitting circuit is active. When making adjustments it is advisable either to stop the motor-generator or to open the switch marked "Generator Field."

Second test. Another test for determining split tuning is to mark the resonant point on the antenna inductance scale on the panel while the handle is turned in one direction, and after passing the resonant point by two or three turns of the handle, reverse the direction and return to resonance and again mark the scale. If the two marks do not coincide the coupling should be reduced until they do.

After the calibration is completed on low power, the power can then be increased to normal and in this transmitter an antenna current of about 10 amperes is usually obtainable. A similar procedure is carried out for each one of the other wavelengths provided by the transmitter.

54. *Question.* How can you tell when a vacuum tube is soft?

Answer. This condition is generally evidenced by the defective tube showing a blue haze between the filament and plate and heating more than the other tubes.

Although the plate current through a soft tube will rise beyond normal values yet this can be determined sometimes only by careful observation of the plate current ammeter in a multi-tube transmitter because the total plate current of all tubes is read on the same meter.

55. *Question.* What is meant by the term "break-in"?

Answer. The term "break-in" indicates that the transmitter is equipped with a key relay having suitably arranged contacts which permit rapid changeover from send to receive and vice versa, the relay being operated magnetically by the hand key. Modern traffic conditions require this feature to be provided so that even while sending a message an operator's attention may be attracted by a signal sent out by the operator of the distant station with which communication is established.

It is possible to receive a signal in this way because of the series of rapidly occurring silent intervals between dots and dashes of the code characters. Valuable time can be saved by the use of the break-in system as, for example, a repeat signal can be sent at any opportune moment in which event parts of a message could be repeated before completing an entire series of messages as under the old system, or for that matter an operator may be interrupted during the transmission period to execute any urgent business transaction. The break-in relay also controls the transmitter proper through one pair of contacts while the low side of the antenna contains a second pair of contacts connected in series, which during the transmitting periods serve to disconnect the antenna from the input to the radio receiver. In order to prevent sparking at the antenna contacts and also to reduce the disturbances from key clicks in the radio receiver, one pair of contacts which key the transmitter proper are adjusted to close slightly after and open slightly before the antenna circuit contacts. The key relay is equivalent to a double-pole single-throw relay.

Break-in operation may be provided if a relay key is not included in the equipment by arranging a separate antenna for the receiving set.

56. *Question.* Name several ways of suppressing harmonics in a broadcast transmitter.

Answer. Harmonic radiation may be suppressed by employing a radio-frequency choke coil having a suitable value of inductance so as not to interfere with the carrier frequency of the transmitter. The chokes are usually inserted in the grid circuits or sometimes in the plate circuit. In certain installations a resistor is inserted in series with the high voltage plate lead or in series with the grid to accomplish this purpose. Also, a trap circuit may be included in the transmitter and tuned to absorb any harmonic frequencies which might be generated. Transformer coupling between the transmitter and the radiating circuits and proper adjustment of these circuits will do much to lessen these troublesome high frequencies.

The voltage or current-feed type antenna also tends to lessen this trouble. A special radio-frequency choke coil may be inserted in the feed line which supplies the antenna with the high-frequency voltage.

57. *Question.* Where and why are radio-frequency choke coils used?

Answer. Radio-frequency choke coils are used wherever it is desired to block the passage of a high-frequency current and at the same time not interfere with the flow of some lower frequency in the circuit.

Refer to the diagram in view *B,* Figure 35, showing a transformer and radio-frequency choke inserted in the plate circuit. The r-f. component of the plate current can not pass through the primary of the transformer because it is blocked out by the choke and therefore this component is forced through the fixed condenser path to the filament circuit. This condenser provides a low reactance path whereas the r-f. choke is an obstacle to the high-frequency. However, the d-c. component of the plate current does pass through the r-f. choke to the plate supply source, which may be a "B" battery, generator, or other source.

Another location for a radio-frequency choke is shown in the circuit illustrated in view *A,* Figure 35. Again the r-f. choke is employed to separate the r-f. component of the plate current from the d-c. component.

Radio-frequency choke coils are usually inserted in the grid circuits of oscillator and power amplifier tubes to prevent losses of radio-frequency energy, as shown in view *C,* Figure 35.

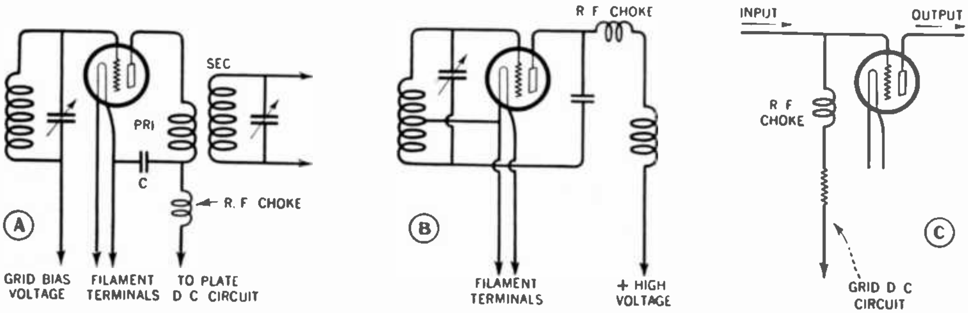


FIG. 35.—Illustrating three ways in which r-f. choke coils may be advantageously used.

58. *Question.* Where and why are blocking condensers used?

Answer. Blocking condensers are used whenever it is desired to exclude the flow of direct current from a certain part of a circuit and at the same time provide an easy path for the passage of alternating current, or the alternating component of a plate current acting under the influence of the particular current circulating in the grid circuit of a vacuum tube.

Thus a blocking condenser may be used to advantage in certain types of feedback circuits associated with oscillator tubes to allow the radio-frequency voltage to pass through readily but act as an obstacle to the passage of the plate direct current. A condenser used for this purpose is inserted in the lead which connects the plate to the inductance of the oscillatory circuit, as, for example, in the Hartley shunt feed type or the Colpitts capacitive coupled type.

Another use for a blocking condenser is in series with the grid of a tube which is employed in a resistance or impedance coupled amplifier circuit. The condenser will allow the fluctuating voltage for grid excitation to pass but it will isolate the grid from the plate d-c. circuit of the preceding tube.

A condenser can be inserted in the grid of any vacuum tube to block the flow of electrons away from the grid, that is, to block the flow of grid current. In conjunction with the use of a grid leak resistance of proper value, the grid will be charged constantly with a negative bias voltage to give the tube a certain operating characteristic. When used for the latter purpose the condenser is simply called a grid condenser and the circuit requires the use of a grid resistor to pass the grid direct current.

59. *Question.* Why is a speech amplifier used in conjunction with a microphone?

Answer. A speech amplifier is required in order to build up the necessarily weak speech frequency current received from the microphone and thus supply sufficient excitation voltage to the modulator grid for efficient operation. In this way complete modulation may be obtained, that is, the fundamentals and harmonics of the sounds directed toward the microphone are repeated in complete form to give fidelity and naturalness to the broadcast program being reproduced.

60. *Question.* Name two or more sources for plate potential on transmitter tubes.

Answer. One of the sources of plate potential is the generator, either a-c. or d-c. type. A transmitter employing an a-c. generator is equipped with a power transformer of the step-up voltage type; the transformer output feeds raw a-c. to the tube plates. When a d-c. generator is used its output feeds directly to the plate circuits through a suitable filter system.

Direct current for plate excitation may be obtained from the output of vacuum tube rectifiers operating in conjunction with transformers which are supplied with alternating current. This is rectified alternating current.

Some of the lower power tubes in transmitters receive their plate power supply from dry batteries or storage batteries.

61. *Question.* What effect does an audio-frequency have upon the carrier frequencies?

Answer. An audio-frequency superimposed upon r-f. oscillations or carrier frequency will cause the amplitudes of the r-f. oscillations to be varied in exact accordance with the wave form and frequency of the audio energy. The audio-frequency may originate either in a microphone circuit or an audio oscillator circuit. The r-f. oscillations (carrier frequency) continually rise and fall in value or are modulated; thus they possess two frequency characteristics—one is the carrier frequency or rate at which the oscillations are generated and the second is the modulation component represented by the amplitude variations.

62. *Question.* How do you measure the input of a vacuum tube oscillator?

Answer. The watts input to a vacuum tube is calculated according to the watt formula

$$W = E \times I$$

To apply this formula consider a certain power tube rated at 50 watts, drawing 125 milliamperes of plate current with the plate potential regulated at 1000 volts. By substituting these known values in the watts formula, after first converting milliamperes into amperes (or 125 m.a. equals .125 amps.) and solving, we have

$$W = 1000 \times .125$$

$$\text{or Watt input} = 125 \text{ watts.}$$

63. *Question.* **Explain the theory of a vacuum tube used as an oscillator.**

Answer. The theory of a vacuum tube oscillator is explained with references applied to the simple inductively coupled feed-back circuit of the type shown in Figure 36. There it will be observed that a small coil inserted in series with the plate circuit is closely coupled mechanically with the grid coil of the tube circuit. It is evident that all of the plate current passes through the plate coil and accordingly magnetic lines will encircle its turns and also encompass the turns of the grid coil.

If for any reason the plate current changes in value then the magnetic lines also will change and by the laws of electromagnetic induction these changing lines acting upon the grid coil will induce an electromotive force (voltage) in the latter coil.

When two circuits (the plate and grid in this case) are so related to one another that a disturbance in one of them will produce an effect in the other there is said to be mutual inductance between them.

To begin the explanation let us assume that the plate current undergoes its first change or rise in value upon placing the circuit in an operating condition.

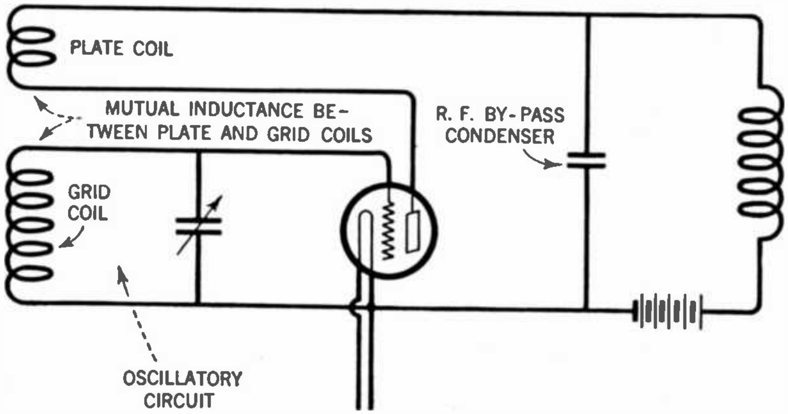


FIG. 36.—A fundamental drawing of the inductive feed-back type oscillator.

This is done by closing the filament switch which causes the filament to heat and emit electrons. The electrons constitute the plate current. There is a short interval of time at the initial start when electron emission is increasing or the plate current rises. Other important points to consider are that the grid receives the e.m.f.'s induced in the grid coil and the grid in becoming charged in this manner exercises its control over the electron flow in the tube, thus causing corresponding changes in the plate current. Positive voltages on the grid increase the plate current and negative voltages decrease the current. Hence, the system works on the principle that changes in plate current will in turn excite the grid with a varying potential and produce further changes in plate current, and so on. A continuation of this action is based on the theory that the induced voltage in the grid coil must be in correct phase with the current in the grid circuit. That is to say, the grid must receive a potential of the proper polarity or sign; for example, a positive charge at some instant so that it will exert a greater attractive force for the electrons emitted by the filament, thus providing an increase in the flow of current in the plate circuit. A positive grid acts to neutralize, partly, the space charge in the vacuum tube. The positively charged grid forces the plate current to rise above a certain steady value wherein it would have remained had not this feed-back action taken place. The steady value referred to may be called the normal value. When the plate current finally ceases its increase the voltage induced in the grid coil drops to zero. What occurs next is that the plate current begins to decrease and it follows that the magnetic lines encircling the plate coil will begin to diminish and in their movement inward toward the plate coil they cut through the turns of the grid coil in a direction opposite to their previous action, as for instance when they were expanding and building up due to the rise in plate current. This plate current

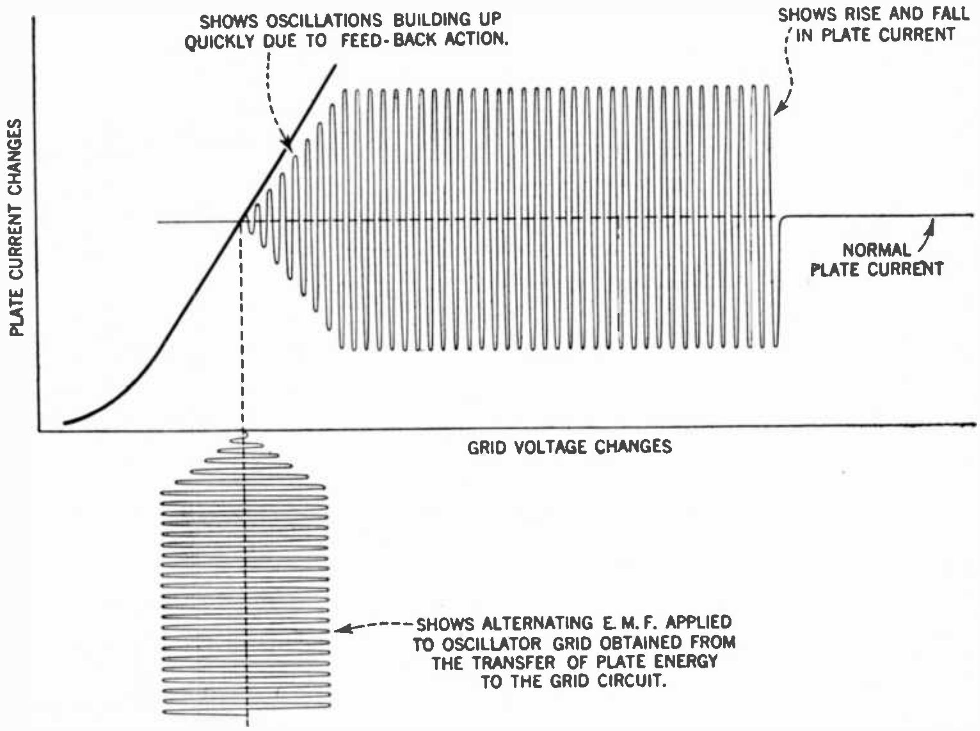


FIG. 37.—Curves depicting how high-frequency alternating current is generated by an oscillator tube and its associated circuits.

decrease causes the induced e.m.f. in the grid coil to be reversed in sign or polarity and hence the grid receives a negative charge this time. Electrons in certain quantities will be turned back or repelled by the negative grid and thus electrons in lesser quantities than previously will reach the plate. In a few words, this means that a negatively charged grid will force the plate current to drop to some value less than normal.

When the fall in plate current finally ceases, the magnetic field about the plate coil stops changing and at this period in the action the induced voltage in the grid coil drops to zero. This discontinuation of the negative charge on the grid permits the plate current to rise again to normal and, furthermore, it will continue rising above normal for reasons already outlined and the cycle of events will be repeated.

Noting how energy is transferred from one circuit to the other it is seen that each rise and fall of plate current induces an e.m.f. in the grid coil which charges the grid alternately with a positive and negative potential, and the fluctuations in grid voltage in turn cause further changes in plate current. In other words, a rise and fall of plate current produces one cycle of alternating e.m.f. in the grid circuit. This cycle of alternating current may be called an oscillation. By proper selection of the inductance and capacitance values in the grid circuit the frequency of the alternating current generated by the vacuum tube and its associated circuits may be controlled.

In this system d-c. power furnished by the "B" battery is converted into a-c. power. After once starting this process of transferring power from the plate to the grid circuit by the phenomenon of electromagnetic induction and regardless of how small the initial grid excitation voltage might be, the action will persist and oscillations will build up in amplitude until a distinct upper limit is reached as governed by the characteristics of the tube and the resistance of the circuit. The plate r-f. component passes through the by-pass condenser.

The continuous form and constant amplitude of the oscillations produced by a vacuum tube oscillator is shown in Figure 37.

64. *Question.* (a) Why should the antenna be rigid? (b) What effect does a swinging antenna have on the frequency?

Answer. (*a*) An antenna should be rigid so that it will not come in contact with rigging or other objects and to prevent changes in the distributed capacitance of the radiating system which would have the effect of altering the transmitter's communication frequency.

(*b*) A swinging antenna will cause changes in the transmitted frequency resulting in the signal fading in and out in the distant receiver.

65. *Question.* What is done to alternating current before it is applied to the plates of transmitting tubes?

Answer. In certain types of transmitters the alternating current is passed through a step-up power transformer and raw alternating current at a high voltage is impressed upon the plates. On the other hand, in other types of transmitters the alternating current is passed through a rectifying device, which consists of one or more vacuum tube rectifiers, to be converted into a uni-directional current, or direct current. The d-c. output of the rectifier is unsuited for plate excitation because it is continually fluctuating in value according to the a-c. cycle and hence the direct current must be passed through a suitable filter system consisting of choke coils and condensers to smooth out ripples or pulses that are present. Any slight fluctuation in the plate voltage due to inefficient filtering would be present in the output of the transmitter and consequently would be heard in the distant receiving set as a purring sound.

66. *Question.* How would you adjust a vacuum tube transmitter to a definite wavelength?

Answer. Refer to the answer to Question 53.

67. *Question.* How would you keep a radiotelephone transmitter on its assigned frequency?

Answer. This is done by careful adjustment of the variable elements forming the oscillatory circuit associated with a piezoelectric oscillator, or master oscil-

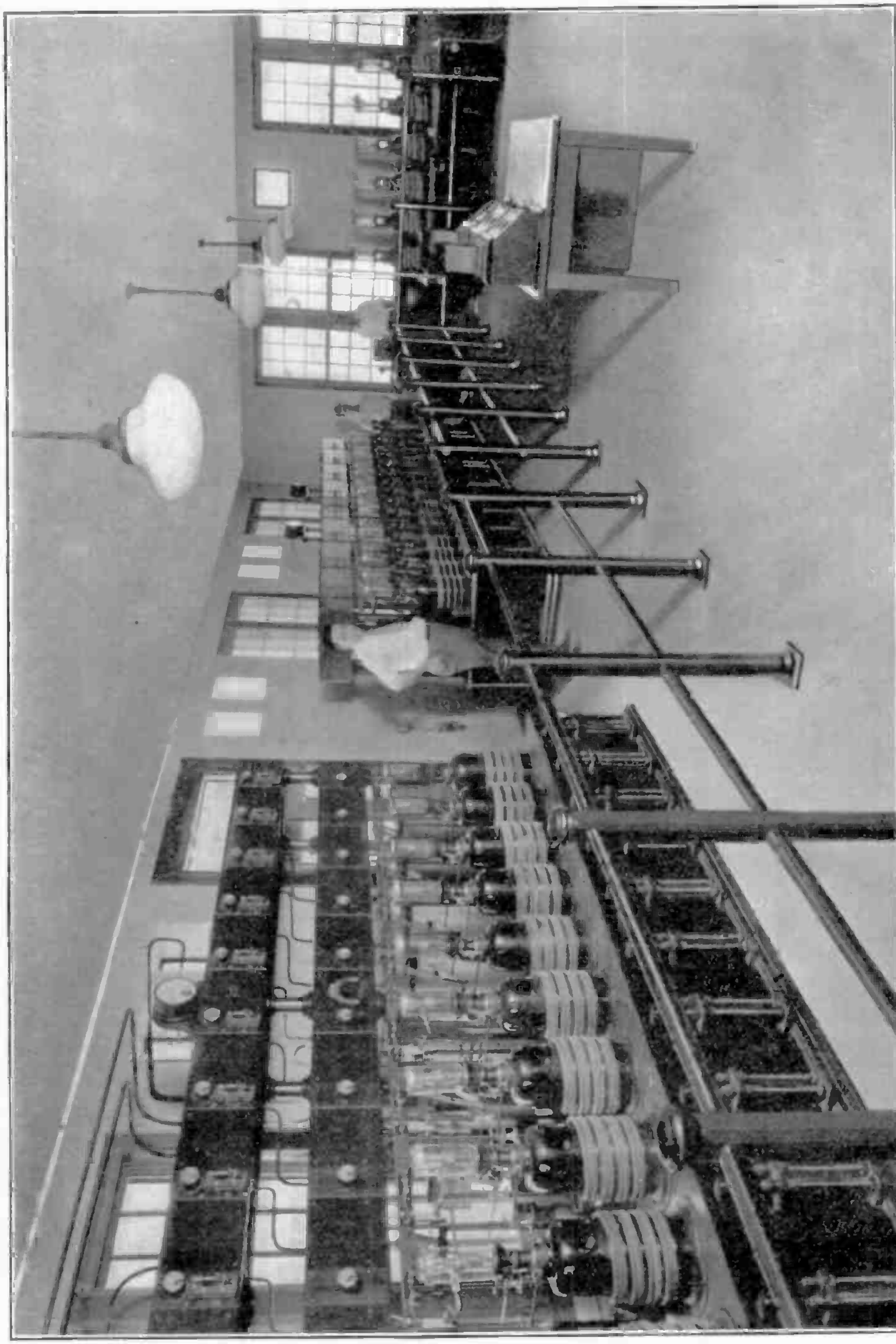


FIG. 38.—A general view of the thirty-two water-cooled tubes with which the WEAF transmitter of the National Broadcasting Company is equipped. Pure water from cooling tanks circulates through the coils of rubber hose at the base of the tubes. Each tube is equipped with a relay which drops and displays a small white disk in case of tube trouble.

lator, depending upon which type of frequency generator is employed. A wave-meter previously calibrated from known standards is used to check the frequency. The correct adjustment is obtained by variation of the capacitance or inductance, or both, according to the design of the equipment. Close and accurate temperature regulation of the heated chamber holding the quartz crystal should be maintained inasmuch as slight changes in temperature markedly affect the frequency. The antenna system should also be examined periodically to see that it is fastened securely and does not swing in a heavy wind, for this condition would also alter the transmitted frequency.

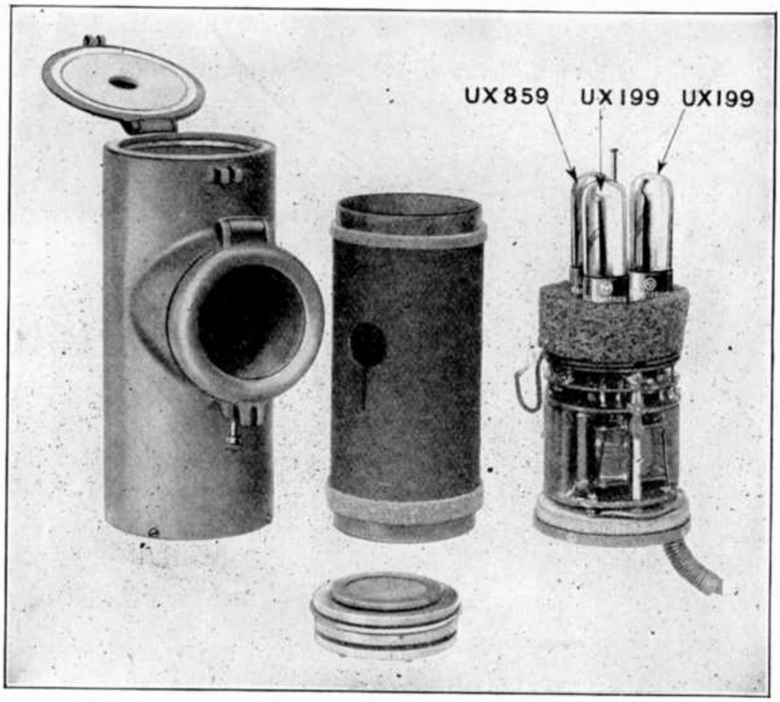


FIG. 39.—A condenser microphone disassembled, showing the microphone (lower center) and compact speech amplifier consisting of three tubes, required to build up the low output level of the microphone to provide proper grid voltages for operating the audio amplifiers.

68. ***Question.*** **Describe the condenser type microphone and its operation.**

Answer. The condenser type transmitter (microphone) converts sound into electrical impulses with practically no distortion, hissing or interfering noises. The condenser transmitter consists of a tightly stretched thin metal diaphragm mounted close to a heavy metal plate which serves as the second plate of the condenser. The air film separating the diaphragm from the metal plate is the dielectric and it acts to dampen the vibrations of the diaphragm so that it will not set up independent movements of its own and thus actuate certain frequencies more than others. One type of condenser microphone is shown in Figure 39.

The small plate area and general construction provide the condenser with a rather low capacitance, in the order of 400 micro-microfarads. A dry battery of a few hundred volts is used to set up the electrostatic capacity between the plates.

When in active use the sound pressure waves strike the diaphragm setting it into vibration, thus causing a continuous variation in the condenser's capacitance. These changes in capacitance set up feeble voltages which are applied to the grid of an amplifier tube. Hence, during the broadcasting of speech or music the complex sound waves are repeated as electrical impulses in the microphone output. The sound waves are varying continuously both in amplitude and frequency.

The diagram in Figure 40 shows one method of connecting a condenser microphone in a circuit and supplying a high e.m.f. to its plates. A microphone of this type requires more stages of amplification to reach a satisfactory volume level in the output of the transmitter when compared to the operation of the carbon-button type transmitter.

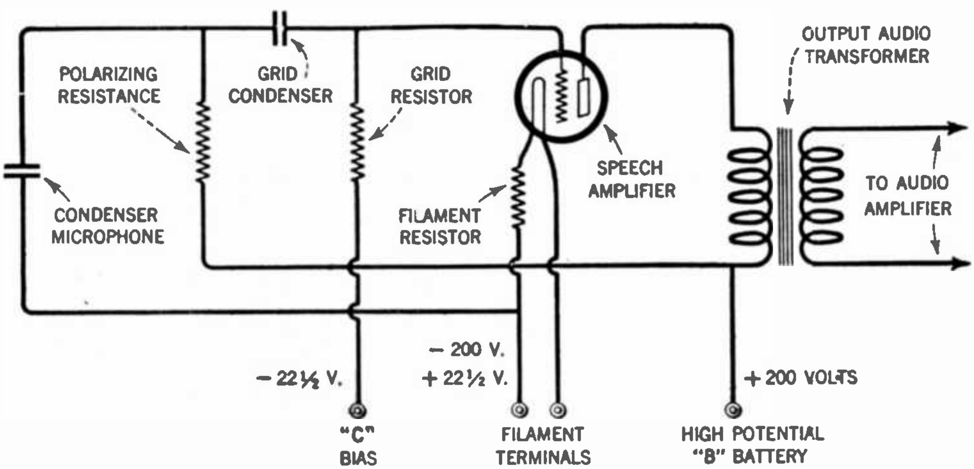


FIG. 40.—Showing how the electrostatic field is set up in the condenser type microphone by connecting a high potential "B" battery across its plates through a polarizing resistance.

69. *Question.* **Draw three elementary diagrams of vacuum tube transmitting circuits.**

Answer. (1) A Hartley type oscillator is shown in the circuit arrangement in views *A* and *B*, Figure 41. By utilizing this method the requisite feed-back voltage is obtained from the voltage drop across a certain portion of the inductance, that is, from the turns included between the grid and filament leads, when current circulates through the system. View *A* shows a series-feed type and view *B* a shunt-feed type.

(2) A Colpitts type oscillator is illustrated in the diagram of view *C*, Figure 41. This circuit obtains the requisite feed-back voltage for maintaining the circuit in a state capable of generating continuous oscillations from the voltage drop across the condenser to which the grid and filament leads are attached. This condenser is called the grid input or grid excitation condenser.

(3) A typical tuned-plate tuned-grid oscillator system is shown in view *D*, Figure 41. The feed-back is provided through the internal capacity between

the tube electrodes, that is, the capacity between grid and plate as indicated by the dotted lines.

By careful adjustment of the inductance or capacitance elements forming the oscillatory circuits any desired frequency may be generated, but of course within certain limits as determined by the electrical values of these elements.

70. *Question.* How would you change a radiotelephone transmitter to a telegraph transmitter for c.w. and I.C.W. transmission?

Answer. To accomplish c.w. transmission in a radiotelephone transmitter first insert a sending key in series with the plate supply lead, preferably in the low potential side (negative side) of the plate circuit. With the transmitter in full

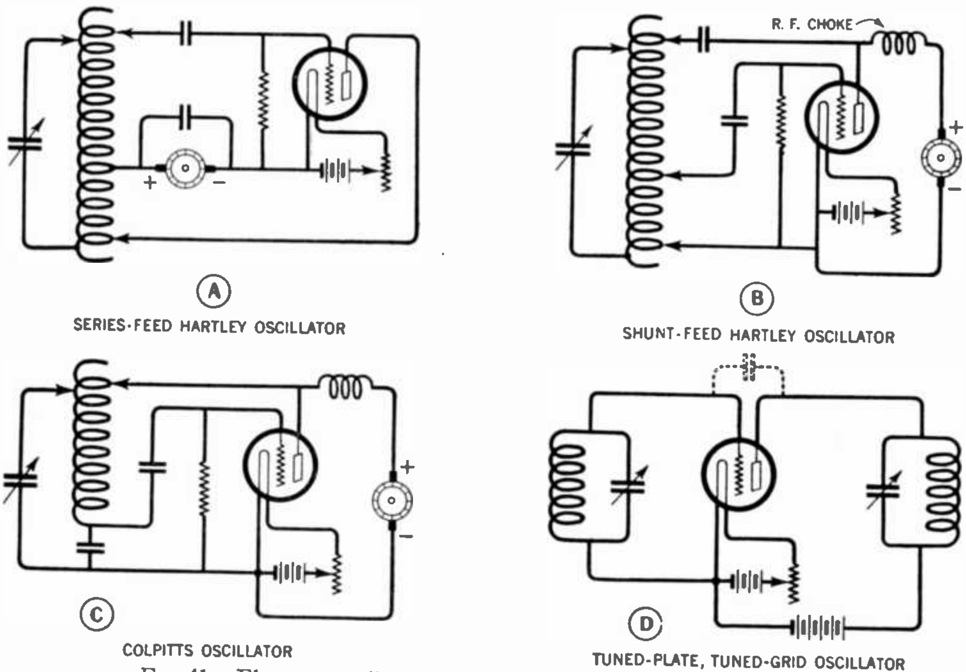


FIG. 41.—Elementary diagrams of vacuum tube oscillatory circuits.

operation and the microphone idle a continuous wave is radiated from the antenna which may be controlled by the sending key. This is simply straight c.w. transmission. The tuned circuit must be adjusted to the desired communicating frequency.

If I.C.W. transmission is desired the key should be removed from the plate circuit and the circuit closed for normal operation.

An ordinary buzzer circuit consisting of a high-frequency buzzer, key and battery, is now set up and placed close to the microphone so that the sound waves sent out by the buzzer will strike the microphone diaphragm. With the transmitter in full operation the c.w. carrier frequency generated by the transmitter will be modulated each time the key is depressed; thus, a signaling wave having the characteristics of an interrupted c.w. will be transmitted. This method is called tone modulation or I.C.W. The frequency of the buzzer armature determines the pitch of the note received.

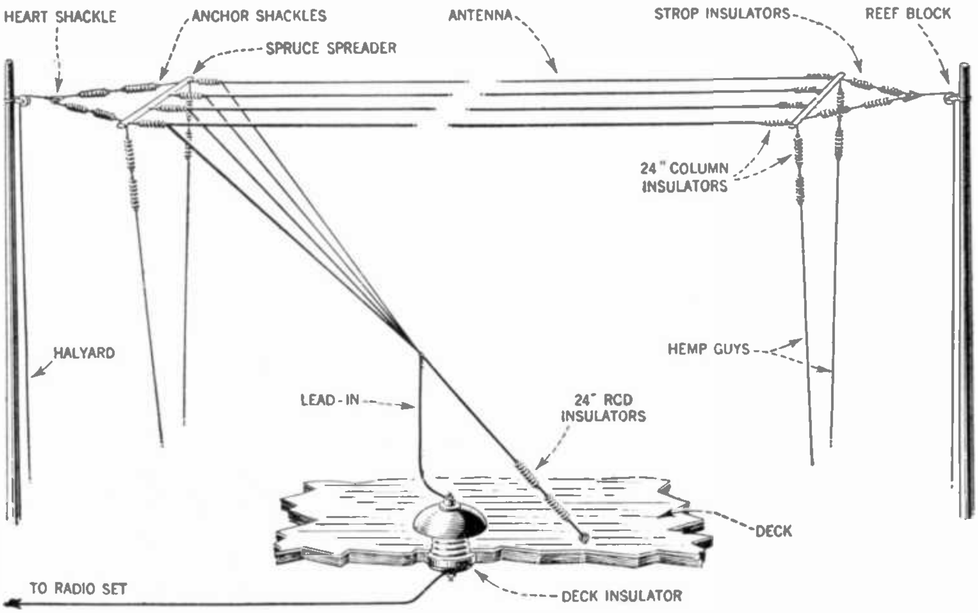


FIG. 42.—A detailed sketch of the flat-top inverted "L" antenna, lead-in and deck-insulator of the type commonly installed on shipboard.

71. *Question.* Describe several types of transmitting antennas.

Answer. (1) The inverted "L," or flat-top antenna, shown in Figures 42 and 43, consists usually of two to four equally spaced parallel wires secured at either end to insulators which are in turn fastened to spreaders. The spreaders are

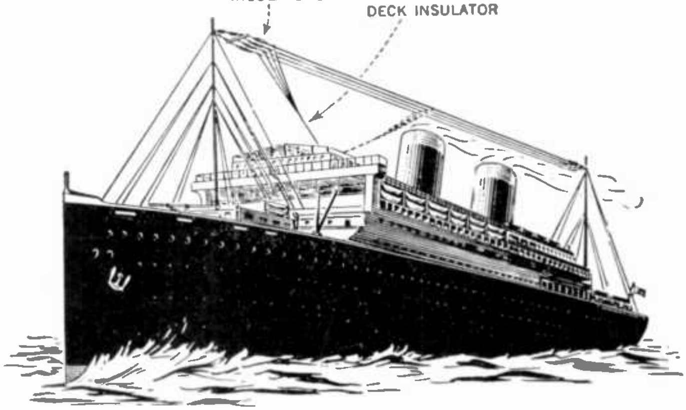


FIG. 43.—The inverted "L" type antenna. If the antenna lead-in is connected at the center of the antenna as shown by the dotted lines, the antenna then becomes the "T" type.

swung between the supporting masts by suitable lines. These horizontal conductors are known as the flat-top portion. Each horizontal wire is electrically connected to a vertical wire. The vertical wires are spliced together at their lower ends to form what is known as the lead-in. Numerous transmitter installations employ only a single long wire for the horizontal conductor. The inverted "L" type antenna is to some degree a directive antenna because it radiates a greater amount of energy in the direction opposite to the free end. This effect depends greatly upon the ratio of the horizontal length to the height of the vertical portion. The relation of the antenna's fundamental (natural) wavelength to its physical size is as follows: The fundamental wavelength is approximately 4.4 to 4.8 times the total length of the antenna in meters, the total length of the antenna being the distance measured from the extreme end of the elevated portion down to the apparatus at the transmitter.

(2) "T" *type.* When the lead-ins of a given antenna are removed from the free end of the flat portion and attached to the center, the antenna is then known as the "T" type. By moving the lead-in wires to the middle as shown in Figure 43, the distributed capacity of the antenna system remains practically the same

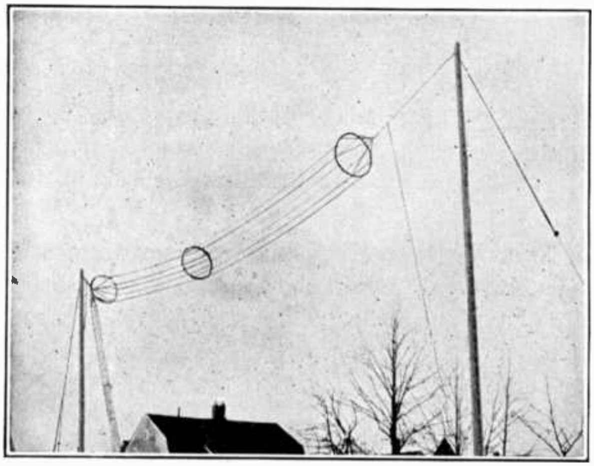


FIG. 44.—Cage type antenna with cage lead-in.

whereas the total inductance will be less. This is due to the fact that the "T" type might be considered as comprising two antennas connected to a common lead-in wire and the whole arrangement is quite similar in effect to that obtained from any two parallel conductors, for in this case the total inductance is less than the inductance of either conductor taken separately. It radiates equally strong in opposite directions.

(3) *Cage type.* One type is shown in Figure 44. The cage antenna consists of a number of component wires spaced equidistant, held in position by hoop spreaders (insulated rings) forming a cylinder. The several antenna wires are brought together, or both ends may be closed in, with the lead-in conductor attached to either end, depending upon the installation. The diameter of the spacer ring is determined by the size of the cage desired. The spacing of wires in a cage form is useful in obtaining a maximum of capacitance in a limited space.

In many installations a cage form of lead-in is used, the diameter of the cage being made relatively small in order to decrease the capacity of the conducting leads to ground and in this manner the effective height and efficiency of the antenna are not materially lowered.

(4) *Fan type.* The harp or fan antenna shown in Figure 45 consists of a fan of copper or silicon bronze wires erected vertically in the same plane and supported at their free end by a wire attached to supporting towers. The free end of each vertical conductor may or may not be soldered or electrically connected to the supporting wire. All wires converge at the lower end and are attached to a lead-in which passes through a large insulator where it enters the transmitter building. Although this vertical type antenna is an efficient radiator of electromagnetic waves its construction prohibits its general use.

(5) *Umbrella type.* In the umbrella type antenna the conducting wires spread out radially in all directions from a common center at the top of the supporting mast. The conductors are generally about two-thirds the length of the mast with insulators connecting their lower ends to other wires

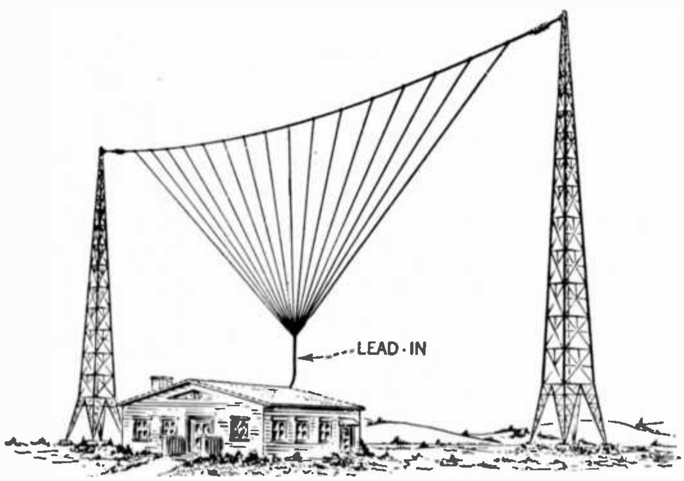


FIG. 45.—The vertical fan-type antenna.

or ropes which are fastened to ground stakes. The wires form a cone-shaped antenna with the lead-in connected at the apex. This type may be used to advantage in a temporary condition where the erection of an antenna must be made in several minutes.

(6) *Condenser antenna.* An antenna of this type utilizes a counterpoise (or earth screen) to reduce soil resistance. The counterpoise increases the distributed capacity between antenna and ground and, in general, where surrounding conditions permit, the wires forming the counterpoise are elevated above the ground covering about the same area as the antenna itself. The counterpoise forms a lower capacity area, and the antenna itself the upper capacity area; together they form two capacity areas, with the space between acting as a dielectric, the whole system being known as a condenser antenna. To reduce soil resistance in some installations a number of copper or zinc plates are buried in moist earth, or a buried ground wire or wires are used in combination with the counterpoise. All wires used in a counterpoise, or buried ground system, are joined to a common terminal and connected to the ground post of the transmitting apparatus.

72. *Question.* What is the transmission feed-line at the transmitter?

Answer. The construction of a suitable ground network is often obstructed by a transmitter building erected beneath the antenna and moreover the presence of a building may cause considerable radiation loss.

Therefore in some installations a transmission-line antenna-feed system is installed. This permits the transmitter building to be located a hundred feet or more from the antenna, which allows the construction of the type of ground network necessary to a powerful station. The coupling between the transmitter and the antenna is made with a long conductor called the feeder line. The radio-frequency energy is transferred with high efficiency over the wire and, in addition, this transmission line system provides an effective suppressor of any existing harmonics. Antenna coupling and tuning equipment is required to couple the transmission line to the antenna system, this apparatus being usually housed in a small shed located near the antenna structure as illustrated by the photograph, Figure 46.

FIG. 46.—Transmission-line antenna coupling. Radio-frequency power is carried over a long transmission feed-line from the transmitter to the main antenna system when the latter is located several hundred feet or more from the transmitter building. This system provides an effective suppressor of existing harmonics. The antenna coupling and tuning equipment required to couple the transmission line to the antenna system is housed in the small shed.

73. *Question.* How would you cause a tube to oscillate?

Answer. If oscillations in a vacuum tube oscillator cannot be obtained the trouble may be due to any of these causes and the remedy in each is suggested by the cause:

1. Plate voltage below operating value.
2. Filament voltage low.
3. A low emission tube used, or the tube otherwise subnormal.
4. By-pass condenser may be open.
5. If an inductively coupled type oscillator circuit is used the leads on the plate coil may have been reversed or turns in this coil may be shorted.

6. If a capacitively coupled oscillator circuit is used a condenser might be broken down or open.
7. A high resistance connection caused by salt air or corrosion in the high frequency portions of the transmitter will sometimes place the set in a non-oscillating condition.

When a circuit is apparently in normal condition, but not oscillating, a slight change in one of the circuit constants will in some cases prove sufficient to start oscillation. This may be done, for example, by varying the capacitance of a

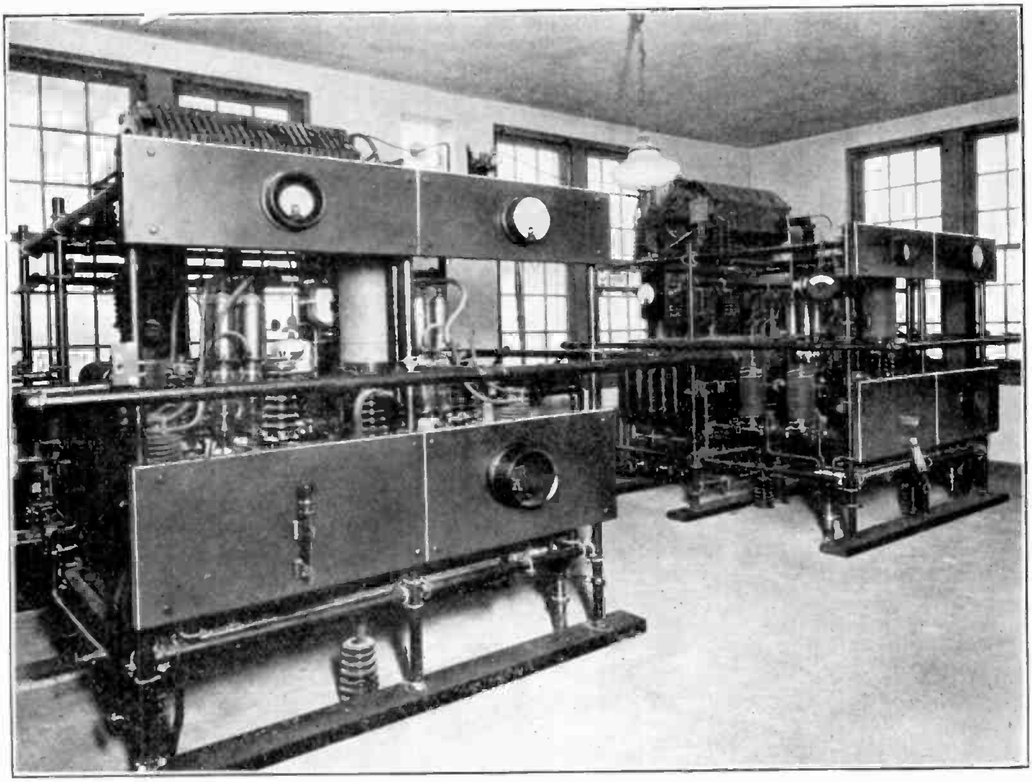


FIG. 47.—The oscillators at WJZ.

condenser in the oscillatory circuit, provided of course that a variable condenser is employed.

If the coupling between the plate and grid circuits is adjustable, the coupling should be increased. Also, try changing the filament voltage, increasing it very slightly and then return to normal. This tests whether the tube has a low electron emission. If it oscillates at the higher voltage but not at normal value then the tube should be replaced with a perfect one.

Be sure that the connecting leads are attached to the correct locations on the turns of the circuit inductance to obtain the requisite voltage-drop for grid excitation. If the observer suspects that the original factory adjustments have been altered, then a few trial adjustments should be made by moving the clips or leads provided for this purpose, at the same time observing the various meters for normal indications. This procedure will often prove sufficient to start a circuit oscillating.

If the feed-back energy is obtained from the voltage drop across a condenser, and if the condenser is adjustable, try several different adjustments and again observe the meters. It would be advisable in all cases before changing any circuit connections on an inductance, or varying the capacitance of a condenser, first to mark the position of the original adjustment so that if found necessary the circuit could be easily returned to its former condition.

74. *Question.* **(a) Give the various operating values of a 250-watt tube. (b) Name other types of transmitting tubes and give their values.**

Answer. (a) *UV204-A, 250-watt tube.* This tube has an output rating of 250 watts and a safe plate dissipation of 200 watts. The normal plate e.m.f. is

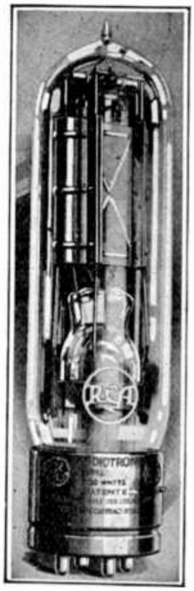


FIG. 48.—A 50-watt transmitting tube.

FIG. 49.—A 1000-watt transmitting tube.

2000 volts and the filament requires 11 volts and 3.85 amperes, or 42.5 watts. The emission of the thoriated (*X-L*) filament is very high, reaching approximately 5 amperes at the rated terminal e.m.f. of 11 volts.

(b) *UV211 and UV203-A, 50-watt tubes.* These tubes are designed for use as an oscillator, amplifier or modulator. The filament is of the *X-L* thoriated type and normally draws 3.25 amperes at 10 volts. The plate power dissipation is 100 watts at a normal plate voltage of 1000 volts when either tube is used as an oscillator. A 50-watt tube is shown in Figure 48.

UV851, 1000-watt tube. The normal plate potential for this tube is 2000 volts; the filament draws 15.5 amperes at an input e.m.f. of 11 volts, equaling a power consumption of 170 watts. The electron emission is approximately 20 amperes. The maximum plate power dissipation is approximately 750-watts when the tube is employed as an oscillator. A 1000-watt tube is shown in Figure 49.

75. *Question.* Explain how a high-power tube is cooled.

Answer. High power tubes are cooled by means of water circulation. The anode (plate) of the tube is inserted in a water-cooled jacket so that heat generated at the plate will be quickly extracted. A complete water jacket assembly is illustrated in the photograph, Figure 50; the tube itself is shown in Figure 51. The tube is supported only by the water jacket and special precautions are taken to insure a water-tight joint by the use of a suitable gasket between

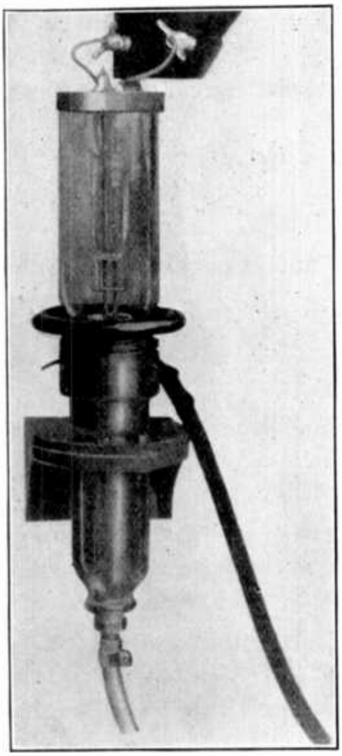


FIG. 50.—A water-cooled tube mounted in its water jacket.

FIG. 51.—A view of a water-cooled tube showing filament leads at the top, grid connection at the right and the cylindrically shaped plate at the bottom. The plate is inserted in the water jacket.

a metal flange and the jacket. Sufficient space is provided between the inside of the jacket and the copper cylinder, or plate, to permit a column of water to circulate freely around the plate for the extraction of heat generated at this point. In the large tubes about two or three gallons of water per minute is pumped past the surface of the anode and through the system from cooling coils. The water circulation is maintained by electrically driven centrifugal pumps. An interlock or circuit breaker is installed between the water circulating system and the electrical circuits and it is set to open if the water supply fails for any reason.

The temperature of water is usually measured after it has passed the hot anode, this being called the outlet temperature, which seldom is permitted to exceed 70 degrees Centigrade. Because of the high plate potential required by such tubes, the plate is carefully insulated from the water tank and the metal tubing, which is normally grounded. By using a fairly long length of rubber hose to connect the water jacket to the water source and, also, by using pure water in the circulatory system the insulation resistance is built up to the order of several hundreds of thousands of ohms. This resistance is between the high potential anode, which is in direct contact with the water, and the cooling system and, in turn, the ground. The photograph in Figure 38 shows a number of the water-cooled tubes used in WEAF's new 50 kw. broadcast transmitter at Bellemore, Long Island.

76. *Question.* What is meant by the term "transformation" as applied to a power transformer?

Answer. The meaning of this term is the transformation of alternating current of comparatively high amperage and low voltage to an alternating current of less amperage and higher voltage.

77. *Question.* (a) Define inductance and capacity. (b) What is resonance?

Answer. (*a*) Inductance is the ability of a circuit to store up energy in electromagnetic form, whereas capacity is the ability of a circuit to store up energy in electrostatic form.

(*b*) Resonance is an adjustment of the quality of inductance and capacity—one balancing or equaling the other for a given frequency, thus giving the circuit the lowest opposition possible for that frequency.

78. *Question.* What would be the effect of putting a quenched or rotary spark gap in parallel with the secondary of the power transformer?

Answer. It would short-circuit the power transformer.

79. *Question.* What causes a spark transmitter to emit more than one wave?

Answer. A spark transmitter will emit more than one wave if tight coupling and improper quenching exist, which cause a re-transference of energy from the open to the closed circuit.

80. *Question.* What effect has the transformation of power upon the impressed frequency.

Answer. No effect.

81. *Question.* What determines the capacitance of a condenser?

Answer. The capacitance of a condenser is determined by the area of the plates, the distance they are spaced, and the specific inductive capacitance of the dielectric separating them.

82. *Question.* Why is the negative electrode made to revolve when an arc transmitter is in operation?

Answer. Unless the negative (carbon) electrode revolves it will not burn evenly and steadily, and the result will be the emission of unsteady signals on different frequencies.

83. ***Question.*** **What is a counterpoise?**

Answer. A counterpoise is practically a second antenna spread under or near the main antenna to afford a systematic reduction of ohmic resistance. It may be used in place of a main ground, or in conjunction with the ground.

84. ***Question.*** **Does a radiotelephone transmitter radiate only on one wave when the wave is modulated?**

Answer. The carrier wave, if unmodulated, radiates on one wave but if modulated it radiates over a band which might be of the order of 5 kilocycles wide on each side of the main wave. This is due to the fact that when any modulation takes place there are not only the two frequencies but beat tones and hormonic frequencies produced by their action on each other. Modulation also introduces decrement, and the dying down of various voice harmonics and beat notes produce a disturbance which covers a band on each side of the original carrier wave.

CHAPTER III

RADIO RECEIVING APPARATUS

85. *Question.* How many pieces of apparatus are actually required to receive signals? Draw diagram.

Answer. A crystal detector connected in the antenna-ground circuit, and a pair of headphones, are the least number of pieces of apparatus that can be employed to receive signals. A diagram is shown in Figure 52.

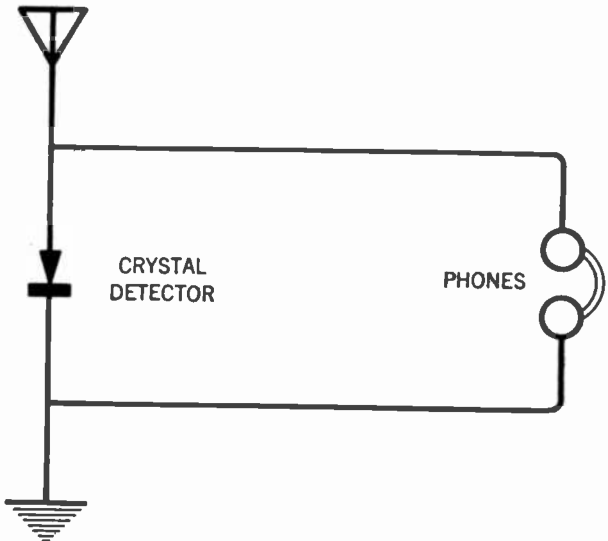


FIG. 52.—Showing the least number of pieces of radio apparatus that may be employed to receive radio signals.

86. *Question.* Explain several causes and methods by which you can determine the location of an audio squeal.

Answer. A defective transformer will cause squeals and howls and if the transformer is suspected it should be tested as explained in the answer to Question 96. Overloading the tubes will also produce a squealing noise as will weak or defective "C" and "B" batteries. The by-pass condenser across the phones will cause a squeal if it should become defective; it may be tested by the "click" test as explained in the answer to Question 102. Defective or microphonic tubes will cause a squeal or howl; new tubes should be tried and if the squeal persists it may be overcome by interchanging the tubes in the sockets.

87. *Question.* (a) What would be the effect if the tube filaments are burned at excess voltage? (b) At too low a voltage?

Answer. (*a*) If the voltage of the filament is above the designated "working" voltage the filament will soon become deactivated, thereby resulting in a decrease in the electron emission. In other words the life of the tube will be materially shortened if excessive voltages are applied to the filament.

(*b*) If the voltage applied to the filament is too low there will not be sufficient electron emission, the "space charge" will be reduced and the signal intensity lowered.

88. *Question.* How are c.w. signals rendered audible at the receiving station?

Answer. In modern practice c.w. signals are rendered audible at the receiving station by the "self-heterodyne" (also known as "autodyne") method. The self-heterodyne effect is utilized in vacuum tube receiving circuits by adjusting the coupling between the plate and grid close enough to

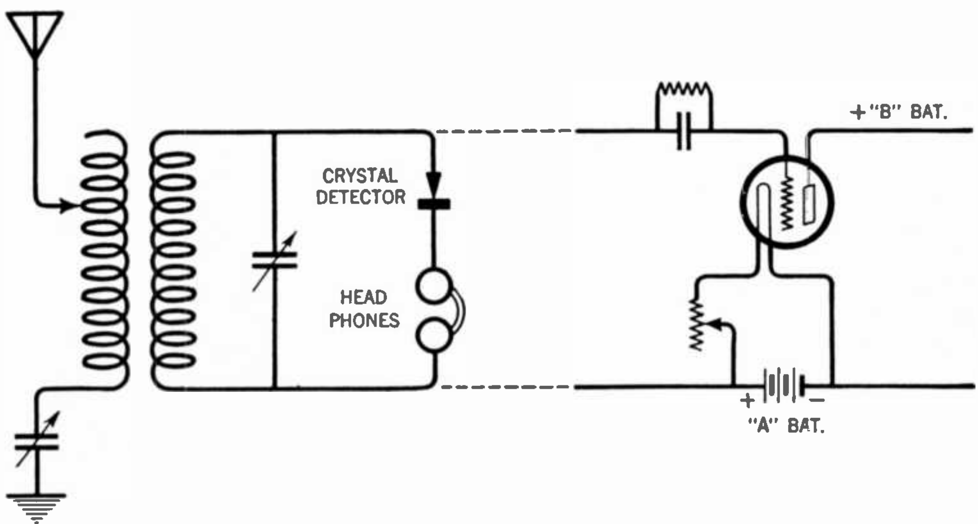


FIG. 53.—Showing how a crystal detector and headphones may be connected in a receiving circuit to receive radio signals in case all tubes become inoperative.

produce a *beat* effect. These locally generated oscillations combine with the incoming signal frequency resulting in a third frequency being set up which is the numerical difference between the incoming and the locally generated frequencies. That is to say, if the frequency of the incoming signal is 500,000 cycles per second and the locally generated frequency is 499,000 cycles per second, the resultant or beat frequency (audio-frequency) produced by this action is the difference between the two; namely 1000 cycles per second. The "chopper" and "tikker" methods, now obsolete in modern equipment, may be employed to convert radio-frequency currents into audio-frequency in a receiving set.

89. *Question.* In the event that all the vacuum tubes on board ship were burned out how would you connect a crystal to the receiver in order to receive signals? Answer by diagram.

Answer. The crystal and headphones would first be connected in series and these in turn connected across the secondary as shown in Figure 53.

90. *Question.* **How would you adjust your receiver to copy a desired signal through heavy interference?**

Answer. By using loose coupling, thereby sharpening the tuning.

91. *Question.* **Why is it necessary to employ a current regulating device in series with the filament?**

Answer. A current regulating device is employed in series with the filament to maintain the *normal flow of current* to the filament as specified by the manufacturer for the particular tube or tubes. The electron emission of the filament is dependent upon the amount of heating current applied to it.

92. *Question.* **Draw a diagram of a regenerative receiver with a resistance control of regeneration.**

Answer. The diagram is shown in Figure 54.

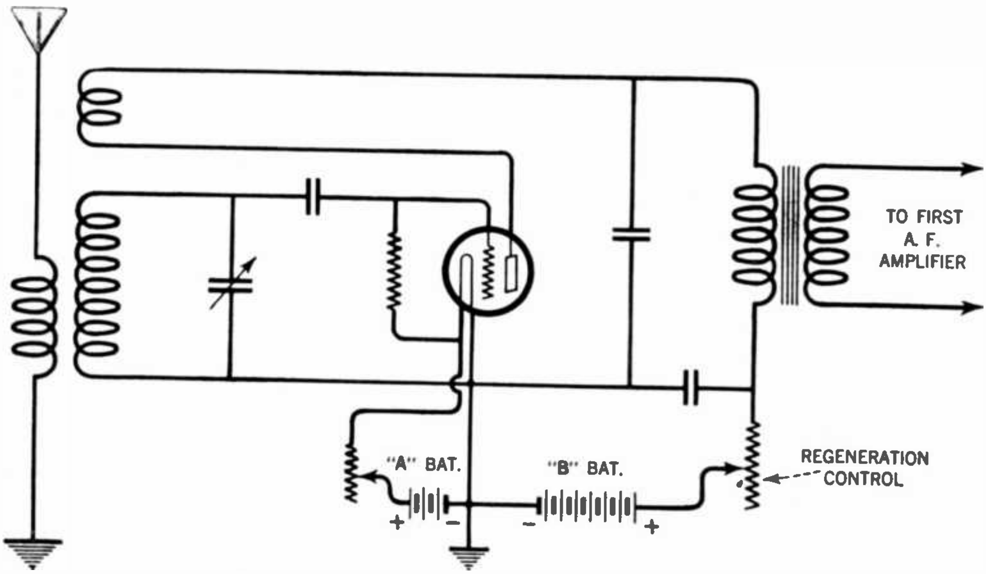


FIG. 54.—Regenerative receiver employing variable resistance to control regeneration.

93. *Question.* **Explain how to reactivate a 201-A tube.**

Answer. The plate and grid potentials are removed, after which 15 volts are applied to the filament for a period of from 10 to 20 seconds. This is called "flashing" the tube. After "flashing" the filament it should be subjected to a potential of 7.5 volts for a period of 10 minutes. It is essential to have a reliable voltmeter and a watch when reactivating a tube. Either alternating or direct current may be used for heating the filament.

94. *Question.* **(a) What would be the effect on a tube by reversing the "A" battery connections? (b) By reversing the "B" battery connections?**

Answer. (*a*) If the "A" battery connection were reversed it would affect the signal strength slightly, that is, increase or decrease it slightly, depending upon the adjustments of the tube.

(*b*) If the "B" battery connections were reversed the tube would cease to function because a negative plate would repel the electron stream and, therefore, plate current would not flow.

95. *Question.* **Explain briefly the theory of regeneration.**

Answer. Regeneration is employed in a receiving circuit for the express purpose of obtaining large signal amplification. This is accomplished by inserting a "tickler" or "feed-back" coil in the detector plate circuit to divert a part of the detector tube output in the plate circuit back to the detector grid circuit for re-amplification. Since slight changes in grid voltage cause considerably large fluctuations in plate current, such coupling brings about relatively enormous amplification.

96. *Question.* **How would you test for an open circuit or "burn-out" in an audio-frequency transformer?**

Answer. By employing a pair of headphones and a 4.5 volt battery as shown in Figure 55, or a voltmeter and battery as shown in Figure 56, the voltmeter being provided with a scale of sufficient size to give a readable deflection when connected to the battery terminals. In testing a transformer which is closed or

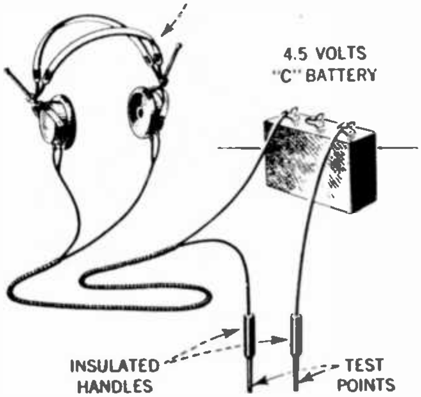


Fig. 55.—Headphones and battery for testing transformers, condensers, grid leaks, circuit continuity, etc.

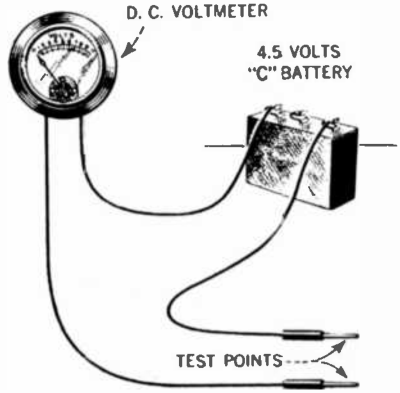


Fig. 56.—Voltmeter and battery for testing transformers, condensers, grid leaks, circuit continuity, etc.

complete, a click will be heard in the headphones if they are used, or by employing the visual method the voltmeter will read when the test leads are connected to the transformer under examination, providing the transformer windings are continuous or closed. An open or burned-out coil will give no indications in the test circuit.

97. *Question.* **Can a modulated wave be received on a crystal?**

Answer. Yes.

98. *Question.* **(a) Explain magnetic coupling. (b) Explain electrostatic coupling.**

Answer. (*a*) A diagram of magnetic coupling is shown in Figure 57. There is no metallic connection between the primary and secondary circuits. All of the energy is transferred from the primary to the secondary circuits by electromagnetic induction. Magnetic, electromagnetic and inductive coupling are identically the same.

(*b*) A diagram of electrostatic coupling is shown in Figure 58. In this system energy is transferred from the primary to the secondary circuit through condensers $C1$ and $C2$ by electrostatic lines of force. Electrostatic, static and capacitive coupling are identically the same.

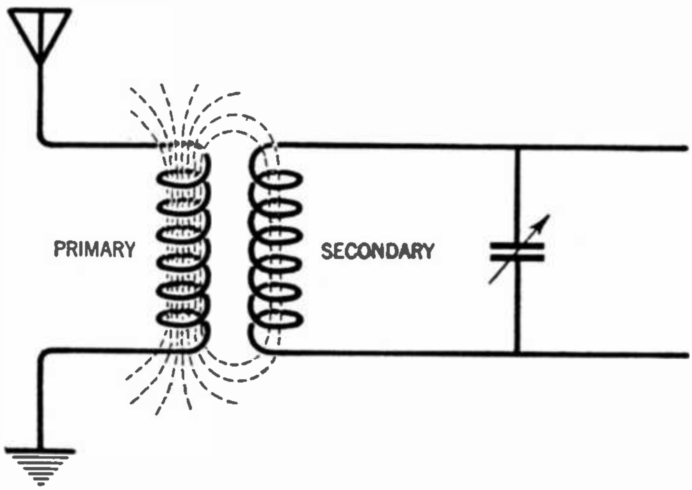


FIG. 57.—Magnetic or inductive coupling.

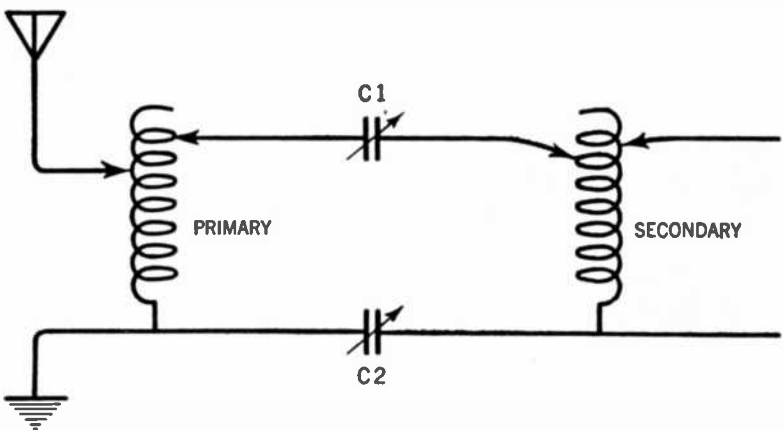


FIG. 58.—Electrostatic or capacitive coupling in a radio circuit.

99. ***Question.*** **Why are high resistance phones used in radio work?**

Answer. To have high impedance, which is necessary because of the low value of the incoming signal, phones must be wound with thousands of turns of wire which gives them a high resistance. A large number of turns are necessary to produce sufficient flux capable of influencing the diaphragms. High resistance telephones are more sensitive than the low resistance type.

100. ***Question.*** **Draw a wavemeter with current indicating device, crystal, phones, battery and buzzer.**

Answer. Refer to Figure 59.

101. ***Question.*** **Why is it necessary to have all connections in good condition?**

Answer. All connections should be in good condition to prevent high resistance in the circuits. The incoming pulses are so weak that the smallest leak in splices, connections, or insulation will cause inefficient reception.

102. *Question.* **(a) How would you test for a defective variable condenser? (b) A defective grid leak? (c) A burned-out telephone receiver?**

Answer. (*a*) In testing a variable condenser it should be removed entirely from the circuit, that is, all connecting leads should be removed from it. Then the headphones and battery test (see Figure 55), or the voltmeter and battery test (see Figure 56), as explained in answer to Question 96, may be made. If a click is heard in the headphones or the meter pointer is deflected, the condenser is defective. If no click is heard, or the meter pointer is not deflected, the condenser may be assumed to be in good condition.

(*b*) When testing a grid leak it should be removed from its mounting and subjected to a test with the battery and headphone test set. If a click is heard

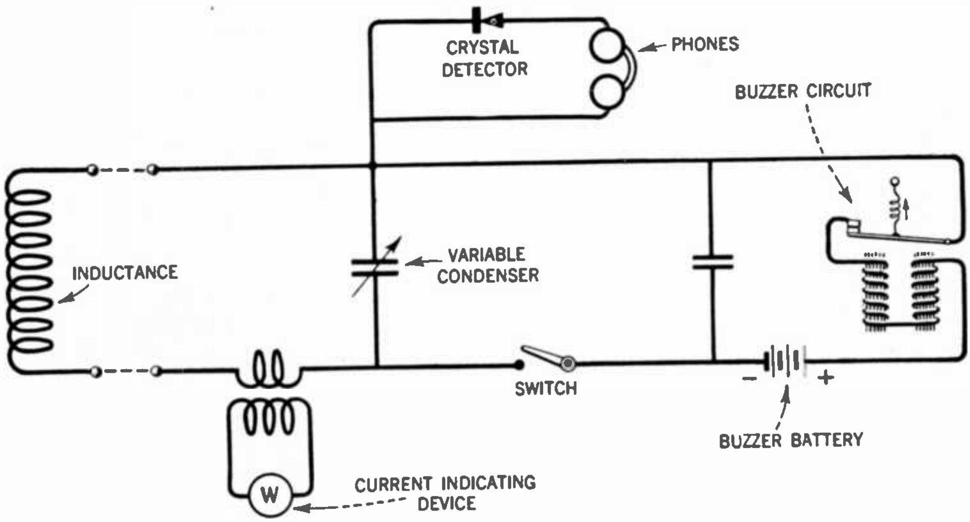


FIG. 59.—A wavemeter circuit with current indicating device, crystal detecter, phones, battery and buzzer.

the grid leak may be assumed to be in good condition. In making this test the hands should not come in contact with the leak or any exposed portion of the test leads.

(*c*) A telephone receiver may be tested by touching the tips of the phone cords across a 1.5-volt dry cell (or across only one cell of a storage battery). If a click is heard the receiver may be assumed to be in good condition.

103. *Question.* **Describe one method of heterodyne reception.**

Answer. One method of heterodyne reception consists chiefly of an external vacuum tube oscillator connected in inductive relation to the receiver. The frequency of the oscillator is varied by varying its inductance, or capacity, or both; and when its frequency is adjusted close to the frequency of the incoming signal a third frequency is created in the receiver, which is an audio-frequency. This third frequency is known as the *beat note*. For example, if the frequency of the incoming signal is 500,000 cycles and the external oscillator is adjusted to 499,500 cycles, a resultant beat note of 500 cycles would be obtained and, as it is at an audio-frequency, it would be heard in the headphones. The frequency of the oscillator may be either below or above the incoming frequency.

104. *Question.* Draw a diagram of a standard vacuum tube receiver employing two stages of low frequency (audio-frequency) amplification.

Answer. Refer to the receiving circuits in Figures 1 and 9.

105. *Question.* If your receiver stopped working where would you look for the trouble and how would you remedy it?

Answer. A commercial radio receiver may operate poorly or cease functioning altogether due to the following causes:

1. *Antenna or antenna insulator trouble.* The entire antenna system should be checked to ascertain that the antenna wires are not making contact with guys, halyards or other objects. Leaky insulators will cause trouble. If an insulator is broken and no spares are obtainable a short piece of marlin rope that has been thoroughly soaked in oil may be used temporarily.

2. *Poor ground connection.* On shipboard the ground itself (ship's hull) rarely gives trouble but the ground connection on the receiver may be faulty. This should be checked to ascertain that all connections make good metallic contact.

3. *The "A," "B," or "C" batteries may be exhausted.* The condition of the batteries may be tested by a good voltmeter and if the batteries are found to be discharged new ones should be substituted. If the "A" battery is a storage battery it should, of course, be put on charge. A partially run-down "B" battery will not always cause the receiver to cease functioning altogether but it will impair the quality of reception.

4. *Defective tubes.* A tube that is known to be good may be inserted in place of the other tubes, beginning with the detector tube. Often a tube will "light-up" and yet be defective and the operator should not assume that all tubes are satisfactory merely because their filaments light.

5. *Poor or loose connections in primary or secondary of receiving transformer, or in the tickler coil.* A loose connection may be observed by testing with a 22.5-volt battery, headphones and voltmeter. With this test circuit connected to the coil under test, that is, to primary, secondary, or tickler coil, the meter needle will flicker from zero to approximately 20 volts, when the coil under test is shaken, if there is a loose connection in the coil. If no reading at all is obtained the coil may be assumed to be open. In case of an "open" or a loose connection the operator should effect repair by soldering.

6. *The primary winding or secondary winding of one of the audio-frequency transformers may be open.* The primary of an a-f. transformer sometimes causes trouble and both primary and secondary may be tested separately for continuity, with the test circuit mentioned in the preceding paragraph. If no deflection of the needle is obtained the winding may be assumed to be defective and, in this case, a transformer of similar electrical characteristics known to be good should be connected in the receiver circuit.

7. *A defective grid leak, defective condensers or a defective headphone may cause trouble.* They may be tested in the manner explained in the answer to

Question 102 and if found defective they should be replaced with parts known to be good.

106. ***Question.*** **Draw a diagram showing how you would use the 110-volt d-c. ship supply for the plate voltage of receiving tubes.**

Answer. Refer to Figure 60.

107. ***Question.*** **How would you adjust a receiver for "stand-by" position?**

Answer. The primary and secondary of the receiver should be closely coupled. This permits the receiver to respond to a broad band of wavelengths and henceforth enables the receiving operator to hear the signals of a number of transmitting stations operating on different frequencies.

108. ***Question.*** **Explain one method of adjusting a receiver to the standard commercial frequencies.**

Answer. When tuning for c.w. signals with the IP-501 receiver the tickler coupling should be loosened as much as possible, and the primary and secondary circuits should also be loosely coupled. The antenna circuit should be adjusted

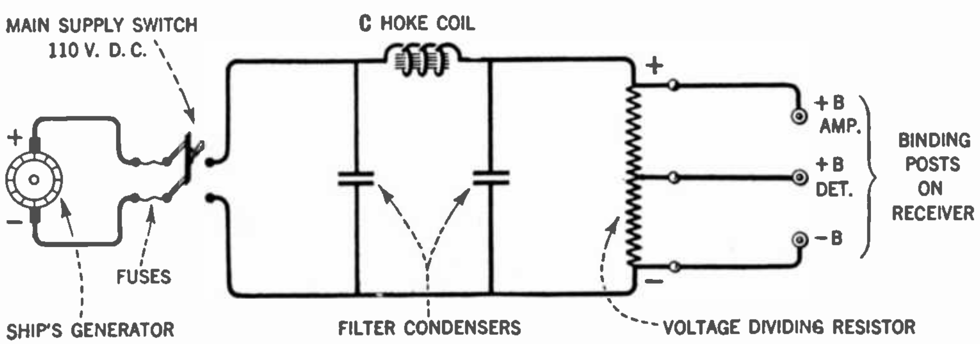


Fig. 60.—Diagram showing how the plate voltage for receiving tubes may be obtained from the d.c. ship supply.

to resonance with the received wave by varying the antenna inductance and antenna condenser. The secondary circuit is adjusted to resonance with the primary by slowly varying the secondary condenser and secondary inductance switch; when the primary and secondary are in resonance a slight click will be heard in the headphones. The best setting for a particular transmitter station is heard slightly below or above the resonance point.

When tuning for spark or modulated signals with the IP-501 receiver the tickler coupling should be loose. The antenna inductance and antenna condenser are varied until maximum signal is heard. The receiver should now be tuned to resonance by means of the secondary inductance switch and secondary condenser. Maximum selectivity on spark signals is obtained by using the loosest coupling consistent with an easily readable signal, and with the primary and secondary circuits tuned to resonance.

109. ***Question.*** **In brief what is the principle upon which telephone receivers operate?**

Answer. The diaphragms of telephone receivers are under a constant state of tension by the permanent magnets and when current passes through the windings on the poles of the magnets the diaphragms are pulled more or less strongly to the magnets, dependent upon the strength of the current passing through the pole windings. As the current varies with the incoming signal the diaphragms will vibrate accordingly, producing sounds of varying intensity and pitch.

110. *Question.* (a) In what places can blocking condensers be used advantageously in a receiver? (b) In what places can chokes be used advantageously in a receiver?

Answer. (*a*) A blocking condenser may be used advantageously in a receiving circuit connected across the head telephones, in series with the grid of a vacuum tube, and frequently between the positive and negative terminals of the "B"

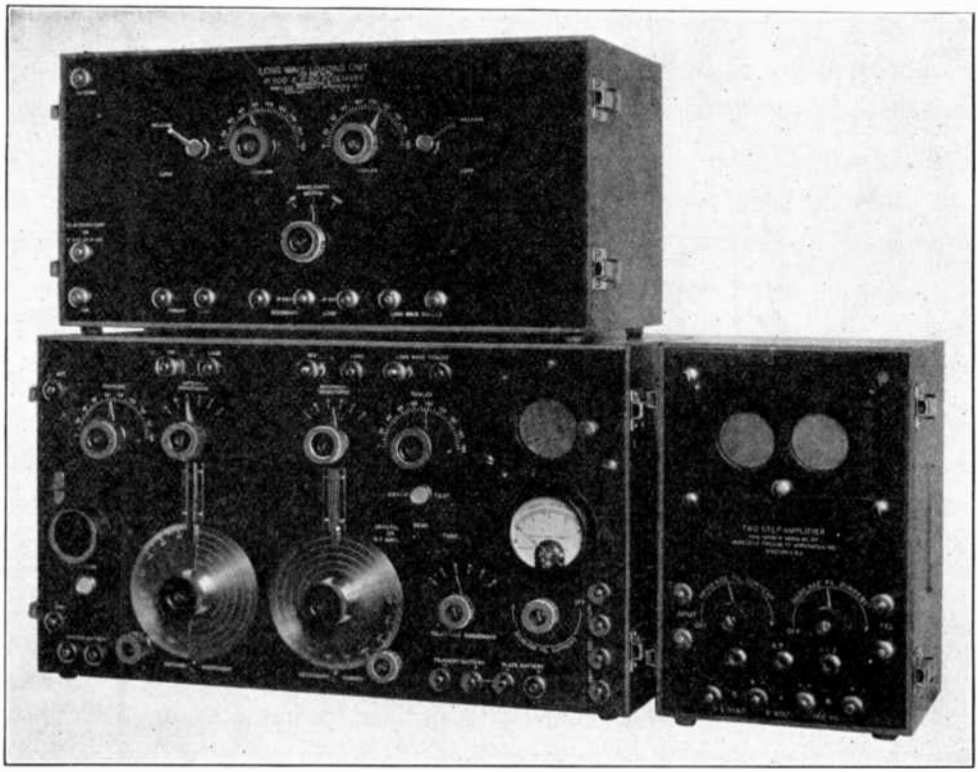


FIG. 61.—Type IP-501 commercial receiver with long-wave loading unit and two-stage audio-frequency amplifier unit.

battery. Blocking condensers may be employed in any part of a receiver where it is desired to exclude the flow of a direct current, but permits an alternating current to pass readily.

(*b*) A choke may be used advantageously in some receivers in series with the plate of the detector and in series with the plate of the last stage of a-f. amplification. In general, chokes are employed in receivers when it is desired to permit currents of certain frequencies to flow, but to present an opposition to currents of another order of frequencies.

111. *Question.* Why are filament voltage regulators used with vacuum tubes?

Answer. Refer to the answer to Question 91.

112. ***Question.*** **Why is it necessary to maintain proper vacuum tube voltage?**

Answer. It is necessary to maintain proper vacuum tube voltage in order that the tube may function normally. If the "A" battery voltage is too low, electron emission will be low; if too high, electron emission will be too high and the life of the filament will be materially shortened. If the "B" battery voltage is too high with respect to the grid potential the tube may set up a "howl"; if too low the signal volume will be reduced and a hissing or frying noise may result. If the "C" battery voltage is too high the tube action will be blocked; if too low it will cause a hissing sound and the signal strength will be considerably lowered.

113. ***Question.*** **How could you receive continuous-wave signals on a crystal?**

Answer. A crystal may be used with a "tikker" or chopper as shown in Figure 62 to receive c.w. signals. The tikker or chopper is rotated by a small

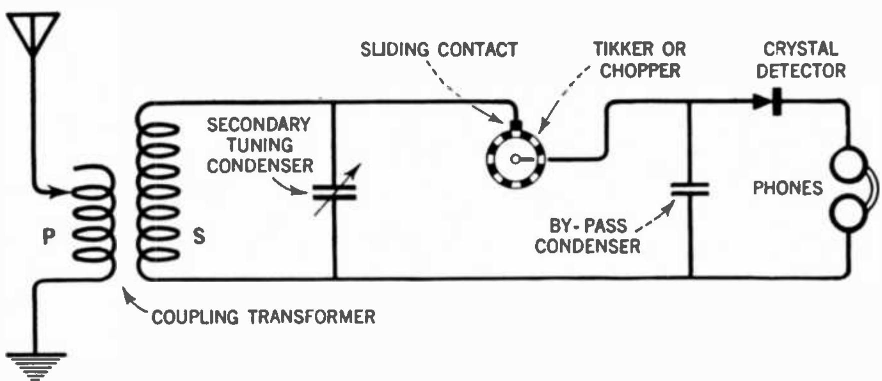


FIG. 62.—A crystal detecter may be used with a tikker or chopper to receive c.w. signals.

motor connected to the brass disk. Connection to the chopper from the crystal is made by means of a spring contact on the side of the chopper disk, whereas a brush rests on the outer surface which is fitted with alternate strips of metal and highly insulated material as shown in the diagram. When the disk is rotated the circuit to the crystal detector and headphones is closed and opened at regular intervals, usually from 500 to 1000 times per second, thereby producing currents of audio-frequency. The "tikker" method of reception has long been obsolete and it is doubtful if spare parts for such an arrangement could be found on shipboard. An emergency method of receiving c.w. signals with a crystal would be to utilize the transmitter chopper. The leads from the transmitter should be removed from the chopper and the chopper in turn connected to a receiving circuit as shown in Figure 62.

114. ***Question.*** **Show by diagram three different ways of using variable condensers in a receiving circuit. Explain their use.**

Answer. Three variable condensers are shown in the tuned-plate regenerative circuit in Figure 63.

Condenser C_1 is known as an antenna series condenser and it is used to vary the total effective capacity of the antenna circuit. More specifically C_1 and inductance L_1 serve to tune the primary (antenna) circuit to a given wavelength.

Condenser C_2 is the secondary tuning condenser. This condenser and inductance L_2 comprise the frequency determining elements of the secondary circuit. Specifically C_2 and L_2 serve the purpose of obtaining a condition of resonance between the primary and secondary circuits.

Condenser C_3 and inductance L_3 serve to tune the plate circuit to the same frequency as the secondary circuit L_2, C_2. When these two circuits are in resonance the tube capacity offers minimum opposition and, consequently, energy is transformed through the tube capacity. For every change in the frequency of circuit L_2 C_2 there will be a regenerative action provided L_3 C_3 is also adjusted to the same frequency to that of L_2 C_2, or nearly so.

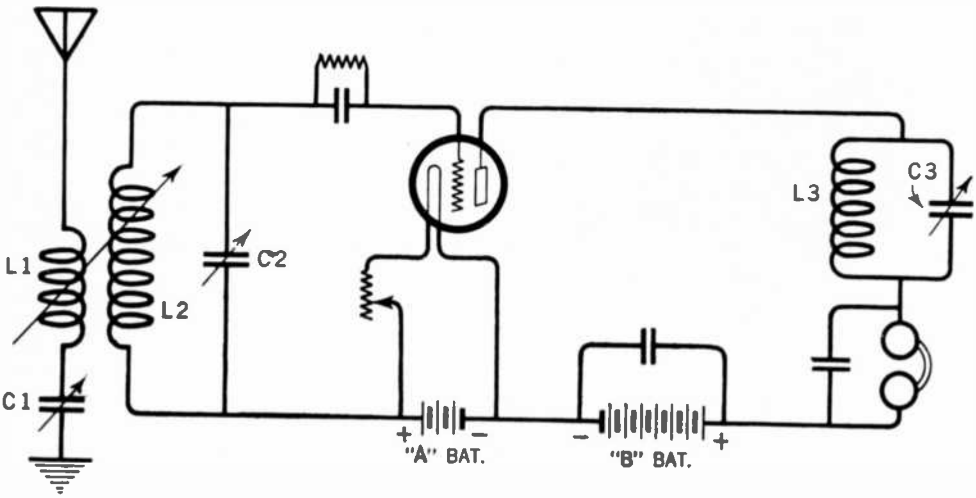


FIG. 63.—Showing various uses of variable condensers in a receiving circuit.

115. *Question.* In general, how would you test for trouble in a receiver, starting with the aerial circuit and continuing through to ear phones?

Answer. Refer to the answer to Question 105.

116. *Question.* Explain the purpose and action of a detector.

Answer. The express purpose of the detector is to convert incoming radio-frequency current into pulsating direct current. The high frequencies used in radio transmission will not flow to any appreciable extent through the windings of the receiver headphones; but, even if the current did flow, the diaphragms in the headphones could not vibrate at such high rates. Furthermore, if the diaphragms could vibrate at the high frequencies the signals would be inaudible because the human ear would be insensitive to the fast vibrations.

It should be understood that a detector does not, in reality, detect signals, but alters the high frequency into a varying current suitable for actuating the telephone diaphragms. The high frequency oscillations impress a varying voltage on the grid of the detector causing the plate current to vary from its usual steady flow when no signals are being received. The high frequency changes in the plate current are made to produce an average effect by the high impedance of the telephone windings. The average effect is the audio-frequency current which flows through the windings, thus actuating the diaphragms and reproducing the signal.

117. ***Question.*** **If your receiver oscillates too freely what would you do?**

Answer. Excessive oscillations in the receiver may be best controlled by the tickler coil. In commercial receivers the tickler coil is variable. Excessive oscillations may also be controlled by slightly decreasing the potential applied to the filament.

118. ***Question.*** **(a) What is the effect of coupling between primary and secondary? (b) What is the effect of coupling between secondary and tickler?**

Answer. (*a*) The purpose of coupling between primary and secondary is to adjust these two circuits to the condition of resonance desirable. When "loose" coupling is used the circuit is said to be sharply tuned and is therefore selective. When "tight" coupling is used the circuit is said to be broadly tuned and in this condition it is not selective to incoming signals.

(*b*) The coupling between the secondary and tickler directly controls the "feed-back" action of the detector tube, that is, it controls the regeneration of the circuit.

119. ***Question.*** **(a) What voltage is usually applied to the detector plate? (b) Why do amplifier tubes use different plate voltage than detector tubes?**

Answer. (a) A positive potential of 22.5 to 45 volts is usually applied to the detector plate.

(*b*) Amplifier tubes operate with higher plate e.m.f. than detector tubes in order to obtain a higher amplification factor. A "C" battery is practically always used in the grid circuit of amplifiers and, unless a relatively high potential is applied to the plate, the tube will "choke," that is, the electrons emitted by the filament will not be attracted in sufficient quantity to the plate.

120. ***Question.*** **Why is a "C" battery used in a receiver?**

Answer. The "C" battery is used in the grid circuit to maintain the grid sufficiently negative to cause a minimum of grid direct current flow and prevent the grid from actually becoming positive when signal voltages are applied to it. This is done to provide amplification without distortion. The "C" battery regulates the electronic emission from the filament to the plate, that is, the plate current.

121. ***Question.*** **(a) Draw a diagram of a wavemeter using a crystal detector. (b) Draw a diagram of a wavemeter using a thermo-coupled galvanometer. (c) Describe two ways of using a wavemeter.**

Answer. (*a*) A wavemeter employing a crystal detector is shown in Figure 64.

(*b*) A wavemeter employing a thermo-galvanometer is shown in Figure 65.

(*c*) A wavemeter may be used to calibrate a receiver by removing the crystal detector and phones and then connecting a buzzer and battery in series with the wavemeter circuit. With the wavemeter coil in inductive relation to the receiver, the buzzer is energized and the condenser is set for a certain frequency until maximum signal strength is heard in the headphones after which the emitted frequency (or wavelength) is marked on the receiving set dials. By repeating this process several times, using various frequencies produced by different wavemeter coils and by different adjustments of the condenser, the receiving set can be entirely calibrated.

A wavemeter may be used when tuning a transmitter to ascertain that the transmitter is properly tuned. The best and most accurate method of adjusting a spark transmitter to a given wavelength is by employing a wavemeter as follows:

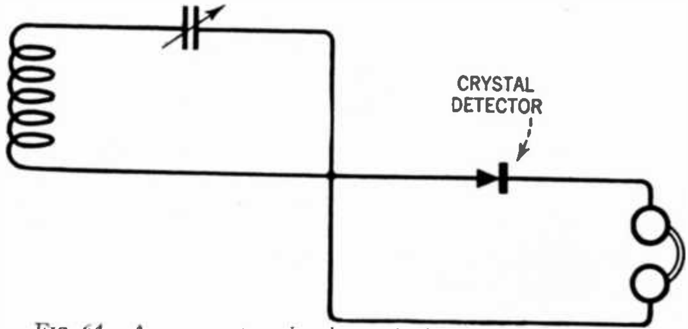


FIG. 64.—A wavemeter circuit employing a crystal detector.

To adjust the wavelength of the closed circuit disconnect the aerial from the aerial tuning inductance and place the primary (closed) circuit in inductive relation to the secondary (open) circuit. Energize the spark gap as usual but with the smallest amount of power available from the transformer. The wavemeter is now placed in inductive relation to the primary with the meter set at the desired wavelength. Do not place the wavemeter too close to the primary or the induced current may be great enough to burn it out. The transmitter is now operated by pressing the sending key, and the inductance in the closed circuit is varied until

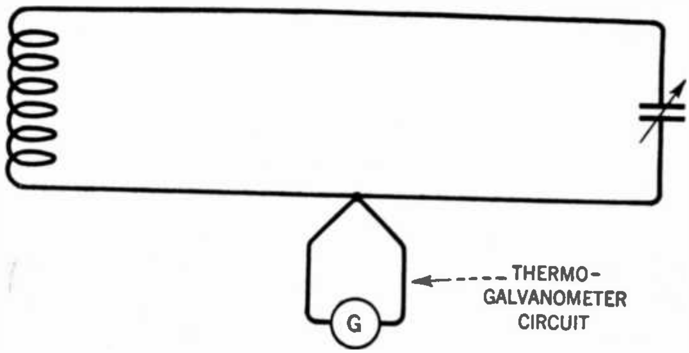


FIG. 65.—A wavemeter circuit using a thermo-galvanometer.

the meter in the wavemeter gives the greatest deflection. At this point the closed circuit is in resonance with the wavemeter circuit and is considered as being adjusted to the desired wavelength.

When tuning the secondary circuit the coupling should be separated as far as possible from the primary to minimize induction between these two circuits. The open circuit is now energized independently of the primary (with the antenna and ground connected) by placing a small fixed open gap in series with the ground lead. The gap is then connected to the secondary terminals of a small spark coil of sufficient potential to produce a spark across the gap.

The wavemeter is set to the same wavelength as used in testing the closed circuit and then placed in inductive relation to the ground wire. The inductance and capacity (if a series condenser is used) are now varied until the greatest deflection of the meter in the wavemeter circuit is obtained. At this point the open circuit is in resonance with the wavemeter and also in resonance with the closed circuit. The spark gap should now be removed from the secondary circuit and the two circuits, primary and secondary, coupled in the regular manner. The transmitter is now placed in operation and the wavemeter, set at the desired wavelength, is located in inductive relation to the ground lead. The coupling between the open and closed circuits should be sufficiently loose so that, principally, only one wave will be radiated. By slightly varying the inductance of both circuits while the transmitter is in operation, the transmitter may be adjusted to the correct wavelength, as indicated when the meter in the wavemeter circuit gives maximum deflection.

All wavelength bands in the immediate vicinity of the radiated wave should be searched with the wavemeter to determine if the transmitter is radiating two different wavelengths. If it is, measure the power in the two waves and continue to adjust the coupling between primary and secondary until the amplitude of one radiated wave does not exceed 10 per cent of that of the other radiated wave. At this proper adjustment a lawful wave will be radiated.

122. *Question.* Draw a diagram of a wavemeter using a crystal detector.

Answer. Refer to Figure 64.

123. *Question.* What are some of the values of condensers ordinarily used in receiving apparatus?

Answer. The values of fixed and variable condensers ordinarily used in receiving apparatus are .0005 mfd., .001 mfd., .002 mfd., .00025 mfd., 0.1 mfd., .00005 mfd., and 0.25 mfd. capacity.

124. *Question.* What measures would you take to protect head telephones?

Answer. Head telephones may be protected by employing loose coupling and by detuning the receiver. When not listening in, the lightning switch should be thrown to the ground position.

125. *Question.* Draw a diagram of a two-stage audio amplifier employing a push-pull circuit.

Answer. Refer to Figure 66.

126. *Question.* What causes a blue glow between the plate and filament of a vacuum tube?

Answer. A blue glow indicates a defective tube, perhaps one with an air leak; in the gas type tube it indicates excessive plate potential.

127. *Question.* Describe a method of controlling regeneration.

Answer. Regeneration in the r-f. stages is due to the grid-plate capacity within the r-f. tubes. A grid potentiometer may be effectively employed to reduce or control regeneration by connecting it to the grid return leads of the tubes used for r-f. amplification.

Regeneration may also be controlled by means of a variable plate coil (tickler) inductively related to a grid coil. Also a variable resistance in the plate circuit, as shown in Figure 54, may be employed.

Means for suppressing oscillations due to regeneration are: shunt resistances on transformers, reversed-capacity feed-back coupling method, high resistance transformer windings, and resistors inserted in series with the grid circuit.

128. *Question.* How would you place a vacuum tube receiver in operation?

Answer. Refer to the answer to Question 1 regarding the IP-501 receiver, beginning with the seventh paragraph on page 17.

129. *Question.* How is the radio compass installation on board a ship protected while the transmitter is in operation?

Answer. The radio compass installation is usually protected by an interlocking device which prevents it from being operated during the time when the ship's transmitter is in operation. A system of lights between the radio operating room and the location of the compass controls indicate when the ship's transmitter is in operation.

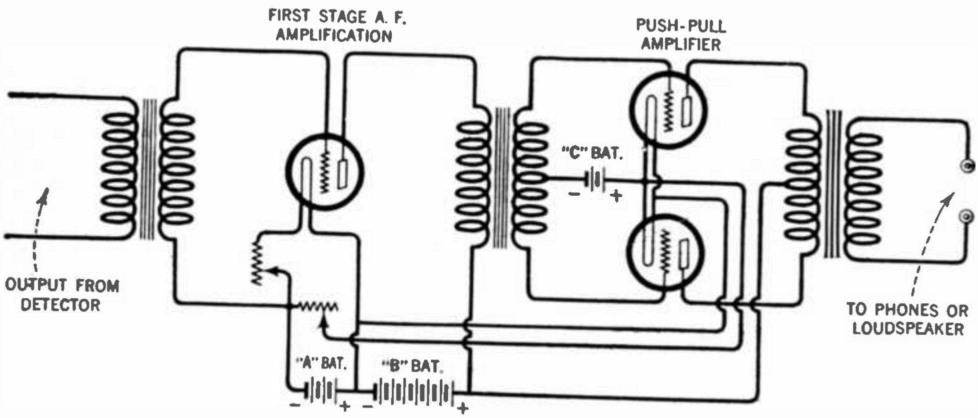


FIG. 66.—An audio-frequency amplifier circuit employing push-pull amplification.

130. *Question.* How would you obtain reception of wavelengths up to 30,000 meters if the range of the receiver is 8000 meters?

Answer. In order to receive wavelengths of 30,000 meters with a receiver having a range of 8000 meters it would be necessary to employ loading coils in the primary, secondary, and tickler circuits. Honeycomb or duolateral-wound coils would prove satisfactory for this purpose by using one of approximately 1000 turns in the primary circuit, one of approximately 1000 turns in the secondary circuit, and one of about 750 turns in the tickler circuit.

131. *Question.* How would you determine the causes of noise in a receiver?

Answer. Noise in a receiver may be caused by:

1. "Treeing"[1] effect in the "A" battery which results in momentary short-

[1] This "treeing" condition generally is present only in old storage batteries and is the result of a lead tree building up on the plates in such a way as to penetrate the separator. This lead tree builds up until it touches the opposite plate and causes a short-circuit of the plates involved. The short-circuit burns off the lead tree and immediately the building up process starts again. When the short-circuit occurs there is a slight decrease in the output voltage of the battery.

circuits within the battery. This, in turn, produces momentary increases and decreases in the potential applied across the filament and may cause a crackling noise to be heard.

2. Run down "B" and "C" batteries may cause sputtering and hissing noises. It is generally conceded that a "B" or "C" battery whose voltage has dropped 25 per cent from its normal rating should be discarded.

3. Poor connections in the antenna or ground systems will cause noise in the receiver. The antenna and ground connections should be gone over carefully and it should be ascertained that the antenna wires and lead-in are not making occasional or permanent contact with halyards, guys, or other obstructions. The noises may be assumed to originate within the receiver, or caused by inductive interference, if they persist after the antenna and ground have been disconnected from the receiver.

4. Defective condensers will produce noises, especially a variable condenser

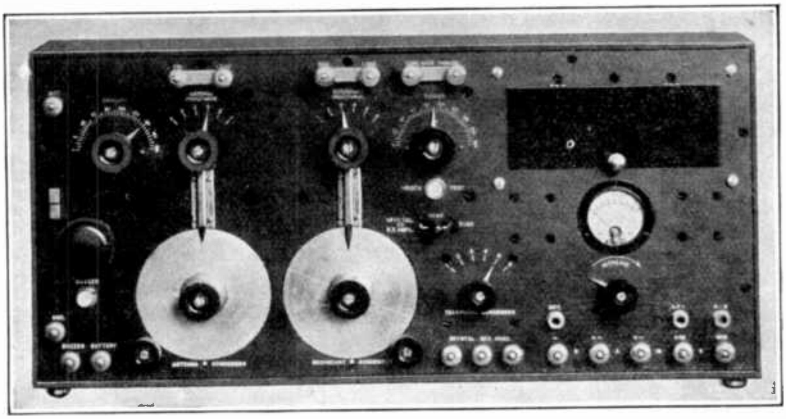


FIG. 67.—Commercial long-short wave receiver, type IP-501A, containing detector and audio-amplifier system.

whose plates touch. If this trouble is suspected the condenser should be tested in the manner as explained in the answer to Question 102.

5. Defective headphones will cause noises and if they are suspected they should be tested in the manner as explained in the answer to Question 102.

6. Too little or too much "A," "B" and "C" potential will often cause noises. The tubes should be supplied with the voltages specified by the manufacturer.

7. Defective tubes often create noises. The tubes may be replaced by known good ones to ascertain if they are causing the noise. Often it is advantageous to interchange tubes of the same type in the receiver; a tube may operate satisfactorily as a detector but not as an amplifier, and vice versa.

8. A defective transformer will produce a "frying" noise. If a transformer is suspected it may be tested in the manner as explained in the answer to Question 96.

9. A defective grid leak will result in noises and if it is suspected that the grid leak is at fault it should be tested as explained in answer to Question 102.

10. Loose or poor soldered connections anywhere in the receiver are likely to cause crackling and sputtering noises.

132. *Question.* (a) What is a pure wave? (b) What is a sharp wave?

Answer. (*a*) The radiated wave of a transmitter is considered pure when if the antenna system oscillates at two or more frequencies, the energy in the smaller wave is 10 per cent or less than that in the greatest wave. A pure wave is also a sharp wave, but a sharp wave is not always pure.

(*b*) A sharp wave is one in which the decrement of damping for a complete oscillation is 0.2 or less.

133. *Question.* What advantage has a 500-cycle note over a 60-cycle note?

Answer. Because a 500-cycle note is high pitched it is more easily copied through interference and static than is a 60-cycle note.

134. *Question.* Why is it necessary to employ a detector element in a receiver?

Answer. Because the incoming signal is an alternating current of very high frequency it would be impossible for the telephone diaphragms to follow its reversal of polarity until rectified by a detecting element.

135. *Question.* Why are permanent magnets used in headphones?

Answer. Permanent magnets are used in headphones because the incoming signals do not produce a current great enough in the phones to set up a magnetic flux of sufficient strength to move the diaphragms freely. Therefore the magnetic lines of force produced by the incoming signal current is used to add to, or subtract from, the flux of the permanent magnets.

136. *Question.* What usually constitutes the ground on shipboard?

Answer. If the ship has a steel hull the ground lead is connected to some part of the hull. On wooden vessels the ground lead is usually connected to steam or water pipes or to the propeller shaft, or a copper plate is attached to the hull to form the ground.

137. *Question.* Explain the theory and operation of two distinct types of direction finding systems (radio compass).

Answer. One type of direction finder developed by the U. S. Bureau of Standards is shown in Figure 68. The loop L_1 together with variable condenser C_1 form the main oscillatory circuit which is tuned to the wavelength of the transmitting (bearing) station. Connected across the condenser C_1, either directly or through a "potential" transformer P, is the vacuum tube amplifying and detecting apparatus. As developed by the Bureau of Standards this receiver consists of three stages of r-f. amplification, a detector, and two stages of a-f. amplification. It may, however, be of any standard design. In one type of direction finder (RCA) the receiver is an eight-tube super-heterodyne.

The telephone receivers, T, are located at a sufficient distance from the magnetic compass to avoid any effect upon the compass due to the magnets within the telephone receivers.

When the switch S is closed to the right the middle plates of the double condenser C_4 are directly grounded. The double condenser is utilized to bring about electrical symmetry of the loop system with respect to earth. In other words, by adjusting the middle plates of the condenser C_4 to the right or left, the earth connection is brought to the electrical mid-point of the loop system, and the signal received in the telephones, T, results only from the energy directly received in loop L_1.

With the switch, *S*, closed to the left, a small condenser C_3 is connected across half of the double condenser C_4 and inductance L_2 and tuning condenser C_2 are inserted in the ground lead. Under these conditions the loop system is no longer electrically symmetrical with respect to ground; received energy enters the loop circuit L_1 C_1 indirectly. The capacity of the complete loop system to earth forms a part of the tuned ground circuit.

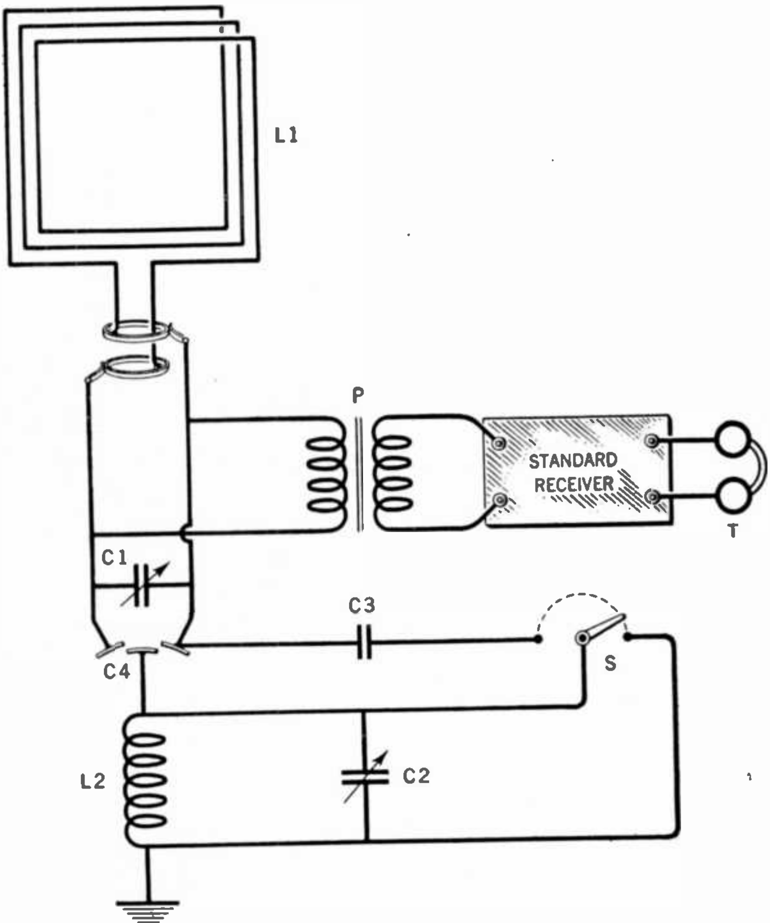


FIG. 68.—A type of radio direction finder developed by the U. S. Bureau of Standards.

By proper adjustments a complete uni-directional effect can be obtained.

In the practical operation of the direction finder, all tuning adjustments remain set for the wavelength of the transmitting (bearing) station. Switch *S* is closed to the right when observing the "line of direction" of a given signaling station and to the left when it is desired to determine the "sense of direction." In other words, to determine the line of direction of a station, the loop system which is directly grounded at its electrical mid-point by throwing switch *S* to the right is rotated to the position of critical silence, at which time the plane of the loop is normal to the direction of approach of the signaling wave. To determine the sense of direction of the station, switch S is closed to the left and the loop rotated to the position of maximum signal intensity, at which time the plane of the loop is in the direction of approach of the signaling (transmitted) wave and pointing toward the signaling station as indicated by an index pointer provided for that purpose.

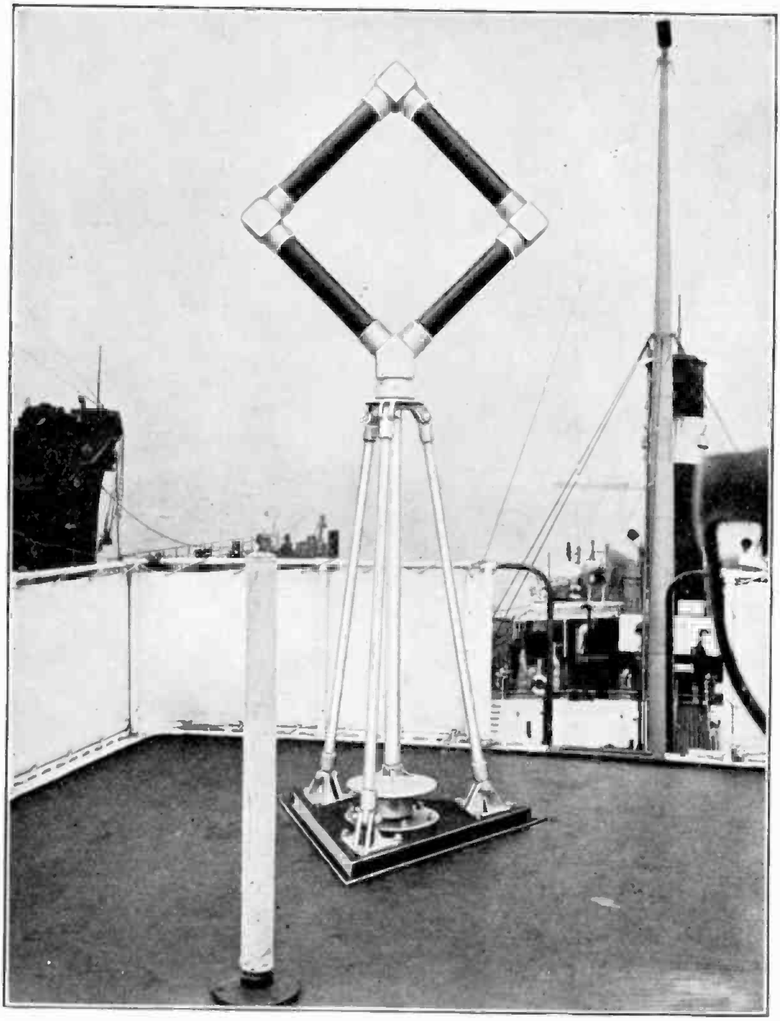


FIG. 69.—Coil antenna of the RCA direction finder mounted on upper deck.

The Bellini-Tosi goniometer is another type of direction finder, a fundamental circuit of which is shown in Figure 70. It consists chiefly of two fixed loops with their planes at right angles. One loop lies in a plane with the keel of the ship and the other perpendicular to it, or thwart-ship. The conducting wires leading from the terminals of the two loops, A_1 and A_2, are carried from the upper deck structure down to the radio room, or pilot house. The two loops are connected respectively in series with variable condensers C_1 and C_2 and also with field coils L_1 and L_2. The two field coils, L_1 and L_2, are in a fixed position with their planes at right angles and each comprises several turns of wire. A small exploring coil, L_3, is mounted within the field coils and may be rotated by a handle with its angular positions shown by an indicator attached to the compass card.

The action of each of the compass coils is the same as that of the single compass coil previously described. The function of the two field coils is to reproduce the energy in the loop coils, but to a lesser degree. It is essential that the two loops be mounted in a fixed position and at right angles. The condensers C_1, C_2 have identical capacity values and are tuned simultaneously by a handle to the wavelength of the signal to be received. If the waves advance in the direction of loop A_1, the oscillating current induced in this loop will be maximum, but

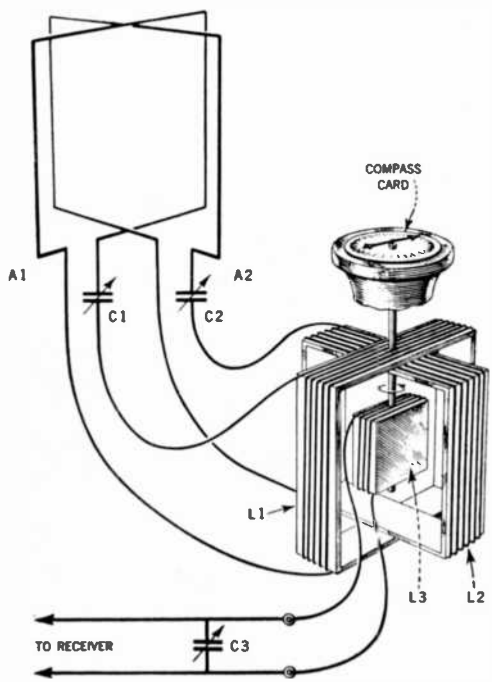


FIG. 70.—The Bellini-Tosi Goniometer. One type of radio direction finder.

at zero intensity in loop A_2. The current flowing in coils L_1 and L_2 produces about them magnetic fields which are proportional to the amount of energy received by the loops to which they are connected. The magnetic fields combine to produce a resultant field which is proportional in magnitude to the signal currents in the two loops. If the small exploring coil L_3 is rotated about its axis, the e.m.f. induced in this coil by the resultant field due to the flux set up by coils L_1 and L_2 will be maximum when the plane of coil L_3 lies parallel to the field coil producing the strongest magnetic field. In the case just cited, exploring coil L_3 would lie parallel to field coil L_1.

Again, if the waves advance in the general direction of loop A_2, the induction in A_2 will be maximum, and minimum or nil in A_1. Hence the exploring coil must now lie parallel to field coil L_2 to receive maximum induction. In order to supply maximum current to the detector circuit, the exploring coil L_3 must always be at right angles to the resultant magnetic field produced around the windings of L_1 and L_2, and the corresponding position of the exploring coil for

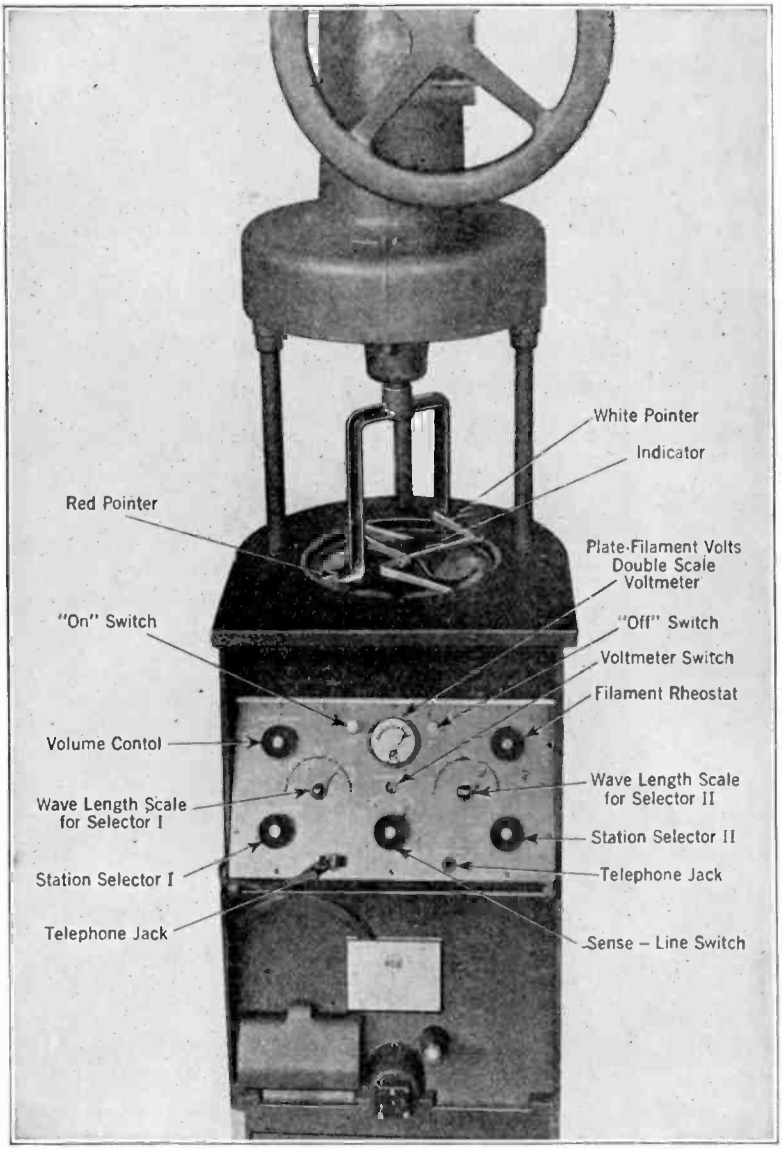


FIG. 71.—The RCA radio direction finder showing receiver controls and indicator. The rotating element with the red and white pointer is clearly shown mounted directly over the compass scale.

maximum induction of signal energy may be indicated by the pointer on the compass card. A minimum position may also be taken by turning L_3 until no signal is heard. By previous calibration of the compass the line of direction of the sending station may be determined.

The circuit is so arranged that the exploring coil is really acting as a miniature compass, depending for its operation upon the relative strength of the two magnetic fields surrounding L_1 and L_2, which in turn are dependent upon the induction of current from an advancing wave in the respective loops A_1 and A_2. The exploring coil, being inductively coupled to the field coils, is tuned by the variable condenser C_3 to obtain resonance with the incoming signal frequency. The radio-frequency current received in L_3 produces a potential difference across tuning condenser C_3, which, when applied as an e.m.f. to the grid of an electron tube detector, will be translated into modulated direct current suitable to actuate the telephone receivers.

Let us suppose that an advancing wave is in a direction which induces current of equal intensity in both coils at the same instant, when two such fixed loops are thus employed to obtain a bearing. Then the corresponding fluxes surrounding the field coils will be at right angles and of equal strength. It will be understood that current may or may not be induced in a conductor when current flows in another circuit. This action depends upon the inductive relationship, or the coupling between the two circuits. Since the coupling between the field coils and the exploring coil is purely electromagnetic and variable, a position may be found for L_3 for which no signal current is set up.

In the goniometer described, the coil L_3 will not point in a direction toward the transmitter station, but 90 degrees away from it at minimum signal. This system depends for its accuracy upon the perfect symmetry of the loops and coils, and several readings are taken, rotating the coil L_3 180 degrees each time.

CHAPTER IV

MOTORS AND GENERATORS

138. ***Question.*** **Draw a diagram and explain the action of a filter for generator commutator ripple.**

Answer. Commutator ripple is caused by slight voltage changes as the brush leaves one commutator segment and passes to the next one. The resultant fluctuating voltage is known as the "commutator ripple."

To eliminate or suppress this ripple, use is made of a filter unit consisting of one or two condensers, or a combination of condensers and choke coils suitably grounded. Figure 72 shows a condenser filter system, and a combination condenser and choke coil arrangement is shown in Figure 73.

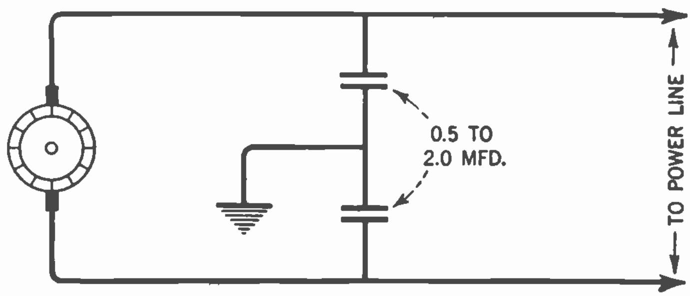


FIG. 72.—A simple filter system to eliminate commutator ripples.

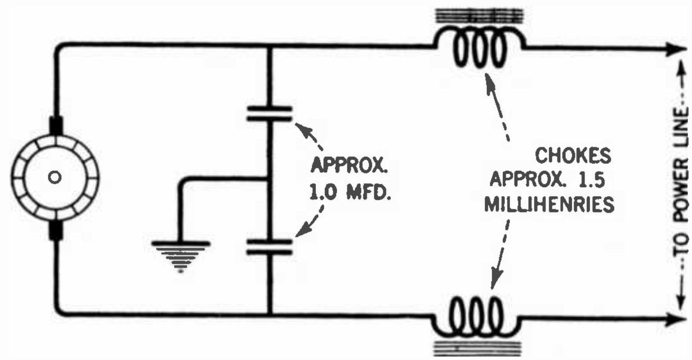


FIG. 73.—A filter system for the suppression of commutator ripples.

The condensers are usually of 1.0 to 2.0 capacity and should be capable of withstanding a test of 1000 volts direct current. The choke coil used in a filter system should have minimum resistance and sufficient inductance to oppose any variation in the direct flowing through it.

Refer to the answer to Question 6 for detailed instruction concerning the action of a filter system.

139. ***Question.*** **(a) What are the usual causes for a hot bearing in a motor? (b) In a generator? (c) What steps would you take to remedy such trouble?**

Answer. (*a* and *b*) A hot bearing is usually caused by improper lubrication, overload, or dust and other foreign substances entering the bearing housing. (c) A hot bearing is treated by supplying it with liberal quantities of oil and graphite. When cool enough to handle the bearing should be drained, flushed out with kerosene, and filled with a good grade of fresh machine oil.

140. ***Question.*** **What is the purpose of a commutator in a d-c. motor?**

Answer. The purpose of the commutator in a d-c. motor is to provide a reversal of the current flowing through the armature coils. This maintains the current flowing in the armature in the proper direction at all times so that the armature will rotate.

141. ***Question.*** **(a) Why are protective condensers necessary? (b) Where are they connected? (c) If a protective condenser was defective how could you detect it?**

Answer. (*a*) When a radio transmitter is in operation, a powerful electrostatic field is set up in the region about the aerial wires. If the power apparatus is installed in such a manner that the low voltage wires leading to the motor-generator or other apparatus lie parallel or in proximity to the antenna wires, currents of very high potential will be induced in the power wires which may puncture the insulation. A path is then afforded for the low voltage current which may cause an arc, completely short-circuiting the windings of a motor-generator. In other words, this induction sets up a difference of potential between the various windings or between the windings and frame of a motor-generator which may result in a disastrous burn-out. The low voltage wires may then be protected in iron conduit, the latter in turn being carefully connected to earth. The induced current will flow on the surface of the iron conduit and be neutralized by the earth connection, and thus do no harm to the power wiring. The power wires of commercial radio installations are either installed in iron conduit or in lead-covered cables, but, in addition to this protection, protective devices known as protective condensers are employed.

(*b*) Protective condensers are connected in series and in turn across the field or armature windings of a motor-generator or between these windings and the frame of the motor-generator.

(*c*) If the only ground on the d-c. supply is that which is made between the two protective condensers, then both condensers would have to become defective before the trouble would be made known. In this instance the fuses would blow causing the circuit breaker to trip.

When high potential condensers are tested they should be removed from the circuit. In testing use is made of a pair of headphones and a 90-volt "B" battery connected in series with the condenser. If a click is heard in the telephones when one terminal of the test lead is touched to a terminal of the condenser, the condenser may be assumed to be in good condition. If no click is heard the condenser is defective.

142. ***Question.*** **(a) State and compare the advantages and disadvantages of a series-wound motor, (b) a shunt-wound motor, (c) a compound-wound motor.**

Answer. (*a*) An elementary diagram of the series-wound motor is shown in

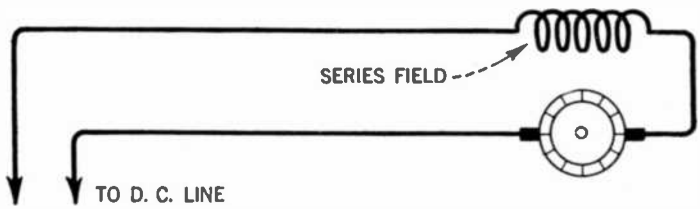


FIG. 74.—Elementary diagram of a series-wound motor.

Figure 74. The advantage of this type is its ability to pick up speed quickly; the disadvantage is its inability to maintain steady speed at variable loads.

(*b*) The advantage of the shunt-wound motor is its ability to maintain steady

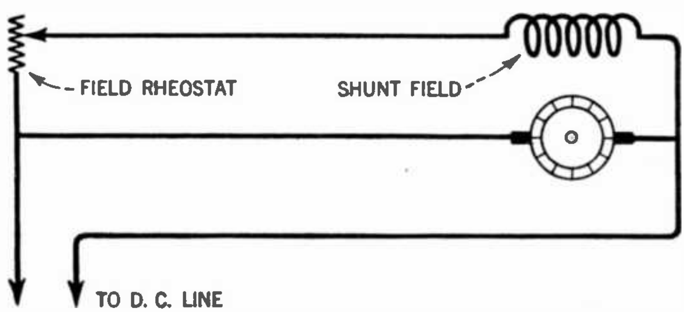


FIG. 75.—Schematic diagram of a shunt-wound motor.

speed at variable loads; the disadvantage is its slowness in picking up speed. A diagram of this type is shown in Figure 75.

(*c*) The compound-wound motor is shown in Figure 76. This type has the advantage of quick speed pick-up and it maintains a steady speed at variable loads. It has no disadvantages as compared to the other types.

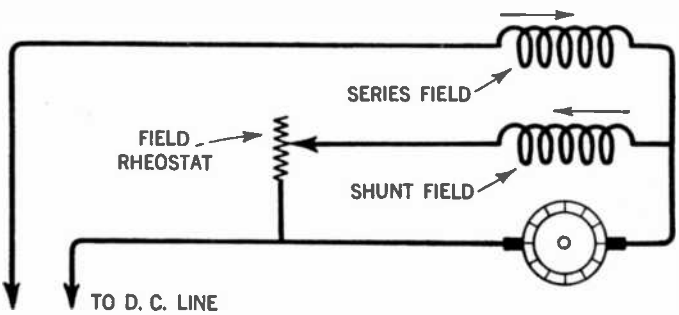


FIG. 76.—Motor with compound field windings.

143. ***Question.*** **What is the difference between alternating current and direct current?**

Answer. Alternating current rises to a maximum voltage in one direction and, after decreasing to zero, rises to maximum in the opposite direction and then back to zero again, thereby completing a cycle. The number of complete cycles occurring during one second is called the frequency of the e.m.f. or current. Direct current always flows in the same direction through conductors and therefore its polarity does not change. Direct current usually remains at a constant voltage, that is, the voltage does not rise and fall.

144. *Question.* How would a hot bearing of a motor be treated?

Answer. Refer to the answer to Question 139.

145. *Question.* How would you locate an "open" in a generator field rheostat? Give remedy.

Answer. An "open" in a generator field rheostat may be located by using a battery and headphone test set. By shunting the terminals of the test set across successive contacts on the rheostat the open will be made evident when no response is obtained in the headphones.

The "open" may be remedied by "jumping" it temporarily with a conductor.

146. *Question.* Why is a motor-generator necessary for a spark transmitter?

Answer. As practically all vessels are equipped with d-c. generators it is necessary to use a motor-generator to obtain an a-c. source of supply to furnish the high voltage alternating current required in spark transmission.

147. *Question.* (a) How is the voltage of a generator increased? (b) How is the voltage of a generator decreased? (c) What instrument is provided to effect these changes?

Answer. (*a*) The voltage of a generator is increased by decreasing the resistance of the field rheostat which permits more current to flow in the field windings.

(*b*) The voltage is decreased by increasing the resistance of the field rheostat thereby reducing the current flowing in the field windings.

(*c*) A variable resistance, called a rheostat, is provided to make these changes.

148. *Question.* (a) What is meant by "counter-electromotive force"? (b) What causes sparking at the commutator and how may it be remedied?

Answer. (*a*) When the armature of a motor rotates in the magnetic field set up by the field poles the armature coils cut these lines of force and induce an electromotive force in the armature. The induced electromotive force is opposite in direction to the applied e.m.f. and is called back or counter-e.m.f. because of its opposition to the applied e.m.f. Counter-electromotive force is very important in the operation of a motor because it acts as a resistance in limiting the amount of current flowing in the armature coils.

(*b*) Some of the causes and remedies for sparking at the commutator are:

1. Grooves worn in the commutator. In this case the commutator should be turned down so that its surface is level.

2. Dirty brushes which should be cleaned with fine sandpaper.

3. Dirty commutator which should be cleaned with fine sandpaper and gasoline.

4. A slightly raised segment. The raised segment should be ground down to the level of the other segments.

5. Brushes not bearing against the commutator with sufficient pressure to form a good contact. In this case the spring tension should be made greater so that the brushes will bear against the commutator with sufficient pressure.

6. An open circuit in one of the armature coils. It is quite impossible to repair an armature at sea and in this instance a new armature should be inserted.

7. Short-circuited field coil. This coil should be replaced with a perfect one.

149. *Question.* (a) How can the speed of a motor be increased? (b) How can the voltage of a generator be increased?

Answer. (*a*) The speed of a motor can be increased by increasing the resistance of the field rheostat.

(*b*) The voltage of a generator can be increased by decreasing the resistance in the generator field rheostat which allows more current to pass to the windings.

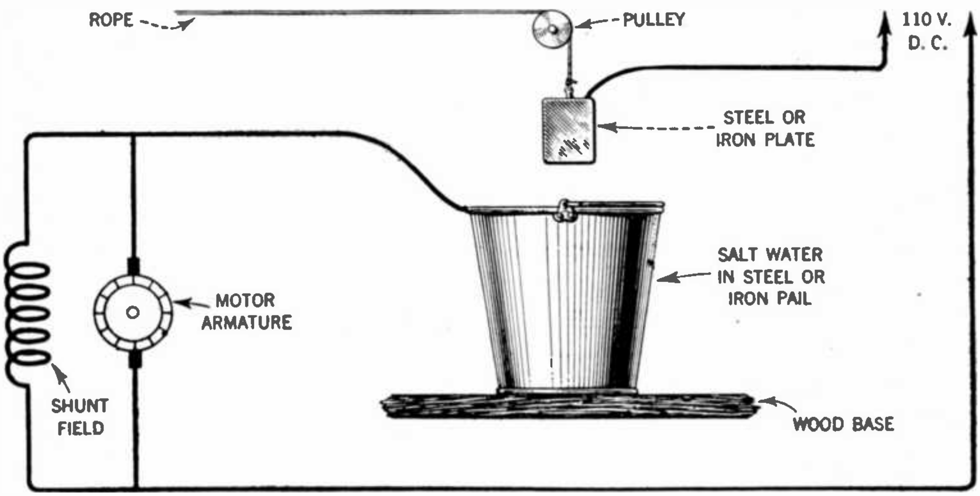


FIG. 77.—A water rheostat may be employed as an emergency starting resistance as shown in this illustration.

150. *Question.* What would you do to provide a means of supplying voltage to a motor in case the motor starting resistances were burned out or damaged beyond repair?

Answer. A water rheostat, as shown in Figure 77, could be employed. By means of a rope and pulley the iron or steel plate should be slowly lowered into the salt water, permitting it to get nearer to the bottom of the metal pail as the motor picks up speed. When the motor has gained full speed the iron or steel plate should rest on the bottom of the pail. The metal pail should rest on a dry wooden base to prevent possible short-circuit.

151. *Question.* Explain how you would care for the motor-generator on board a ship.

Answer. A motor-generator should be cared for by observing the following:

1. The brushes should be kept in good condition by occasionally cleaning them with a fine file or sandpaper.

2. The brushes should bear firmly against the commutator to avoid sparking.

3. The commutator should be cleaned occasionally with a fine grade of sand-paper or crocus cloth.

4. All petcock valves should be tight so that they will not loosen by vibration.

5. The bearings should be cleaned every few months by flushing them with kerosene and the oil wells should be filled frequently to insure sufficient lubrication.

6. The frame of the motor-generator should be kept clean; also the brush holders and rocker arm to prevent accumulation of carbon dust and grease.

7. The motor should not be operated above normal speed.

8. Protective condensers should be properly connected at all times. Punctured condensers should be removed or disconnected from the circuit.

152. *Question.* Why is a commutator not used on an alternator?

Answer. The purpose of an alternator is to supply alternating current. If a commutator were employed the output would be direct current instead of alternating current.

153. *Question.* Why are series motors not used in wireless telegraphy?

Answer. Series motors are not used in wireless telegraphy because of their inability to maintain a steady speed under heavy fluctuating loads. This would be detrimental to the quality of the note and the amplitude of the radiated wave.

154. *Question.* Are the resistances in a starter used temporarily or permanently in the circuit?

Answer. They are used temporarily—only long enough to bring the motor up to full speed.

155. *Question.* (a) What would be the result of starting a motor too quickly? (b) Too slowly?

Answer. (*a*) In starting a motor too quickly a heavy current would be drawn by the armature because the counter electromotive force could not build up to a value sufficient to limit the current taken by the armature to the normal starting value. This would cause the fuses to blow. If, however, the fuses are of excessive current-carrying capacity they will not blow and, therefore, severe sparking will be evidenced at the commutator, and in extreme cases injury might be done to the windings of the armature.

(*b*) If a motor is started too slowly the coils in the starter resistance will heat up and perhaps burn out as they are designed to withstand the starting current only for a short time.

156. *Question.* Why should emery paper not be used to clean the commutator of a motor?

Answer. Emery paper is an abrasive of a metallic nature and if used it may cause short-circuits between the segments of the commutator. If particles of emery come in contact with the bearings it will cut them. A fine grade of sand-paper or crocus cloth should be used to clean commutators.

157. *Question.* What causes a bearing to "freeze"?

Answer. A bearing will "freeze" if it is not kept supplied with oil or if the oil becomes excessively gummy because of any fibrous material. Also if an appreciable amount of foreign material enters the bearing it may "freeze."

158. *Question.* (a) What is a motor? (b) What is a generator?

Answer. (*a*) A motor is a device for converting electrical energy into mechanical energy.

(*b*) A generator converts mechanical energy into electrical energy.

159. *Question.* Where is the rheostat for speed control connected in a compound motor?

Answer. It is connected in series with the shunt field circuit.

160. *Question.* Draw a diagram of an automatic starter used with a compound-wound motor. Explain action.

Answer. The circuits of an automatic starter employed with a compound-wound motor are shown in Figure 78. When the main line d-c. switch and the starting switch (2) are closed, the solenoid (3) is connected in shunt to the d-c. line with contacts (14) open. The flux from this solenoid attracts the lever (4), making contact with point (5), thereby closing the circuit from the d-c. line

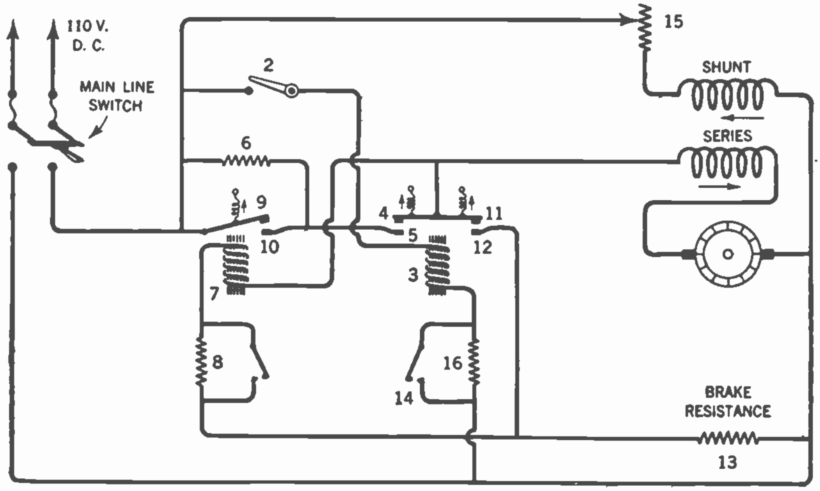


FIG. 78.—Automatic starter used with a compound-wound motor.

through the series field and to the motor armature through the resistance coil (6). Simultaneously the solenoid (7) is connected in shunt to the d-c. line (through the lever (4) which attracts the lever (9), making contact with point (10); this shorts resistance (6) out of the armature circuit, whereupon the motor is connected directly to the main d-c. line. It is apparent that the lever (4) of solenoid (3) opens and closes the main power circuit, while the lever (9) of solenoid (7) cuts out the resistance (6) in series with the motor armature. The solenoids (3) and (7) have the resistance coils (16) and (8) respectively, which are connected in series with them, being controlled automatically by the levers shown shunted around the resistances. These resistances prevent the solenoid windings from overheating.

The automatic starter also includes the elements of an electrodynamic brake. When the starting switch (2) is open, lever (4) drops back, also lever (9), followed by contact being made between points (11) and (12) connecting the resistance coil (13) in shunt to the motor armature and the series winding. The motor armature thus temporarily becomes a generator and, owing to the power expended in setting up a current through the resistance (13), a powerful braking action is set up against the armature, bringing it to a quick stop. The resistance coil (15) is the motor field rheostat, by which the speed of the motor can be regulated between certain limits.

The starting switch (2) is usually one of the snap type placed conveniently for the radio operator and near the aerial changeover switch. In some installations the starting circuit opens and closes through this switch, stopping the motor whenever the aerial switch is in the "Receiving" position. In case it becomes necessary to install the motor-generator in the operating room, it is essential that the motor be stopped immediately after the sending period, to permit the reply from a distant radio station to be deciphered without interference.

161. *Question.* Draw a diagram of a motor hand starter. Explain action.

Answer. A diagram of the Cutler-Hammer hand starter is shown in Figure 79 connected to a shunt-wound motor. The principal elements of the starter are the resistance coils R_1, the small holding magnet M and the handle H. The coils

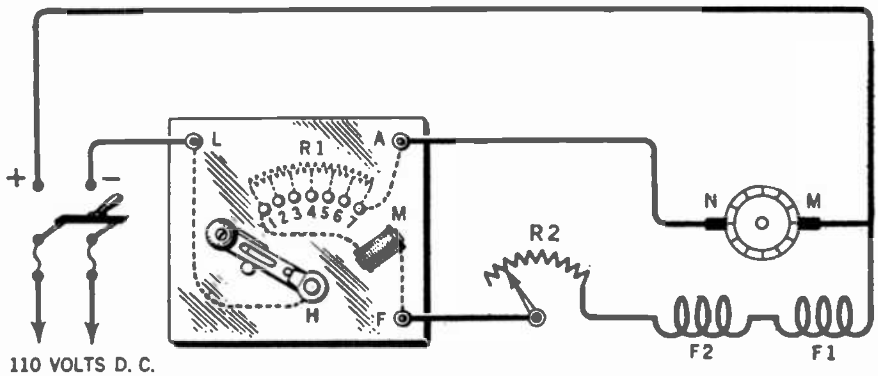


FIG. 79.—Cutter-hammer hand starter connected to a shunt-wound motor.

of R_1 are of German silver wire or composition wire, tapped at certain intervals and connected to the studs (1) to (7). The circuit from the negative side of the d-c. power line may be traced to the L post of starter through the handle H, which, when placed on the first point of contact, permits the current to flow through all coils of R_1, to the terminal A, thence to brush N on the commutator. The circuit continues through the armature coils to brush M and to the positive side of the line. One terminal of the field winding, F_1, receives current at the positive side of the line at brush M, but the other terminal, F_2, has the field rheostat R_2 connected in series, also the holding magnet M; moreover, this circuit continues to the first tap on the resistance coils R_1. Now, as the handle is moved slowly across the contact studs on the starter, current is admitted to the motor armature by small increments which set it into rotation, while the speed gradually increases as the handle moves toward the final or full running position. When this position is attained, the magnet M grips the handle and holds it in position until it is released by opening the main d-c. line switch.

It is important that a motor shall be started neither too rapidly nor too slowly. If the former condition obtains, the fuses in series with the line to the motor armature will melt; but if the starting handle is moved too slowly across the contact studs, the internal resistance coils will overheat and perhaps burn out. The speed of acceleration of the starting handle can usually be gaged by observing the speed of the motor armature. It should require no more than about 10 seconds to start the motors used in connection with radiotelegraph apparatus.

The release magnet *M*, serves to protect the motor in case the main line circuit is disconnected, or if the motor field windings of the circuit should be opened by accident. In either event the handle *H* flies back to the starting position by the tension of a spring attached to the bearing of the handle, and thus interrupts the circuit to the armature.

162. *Question.* Draw a diagram of a complete motor-generator installation and automatic starter of the type used on shipboard. Show protective condensers.

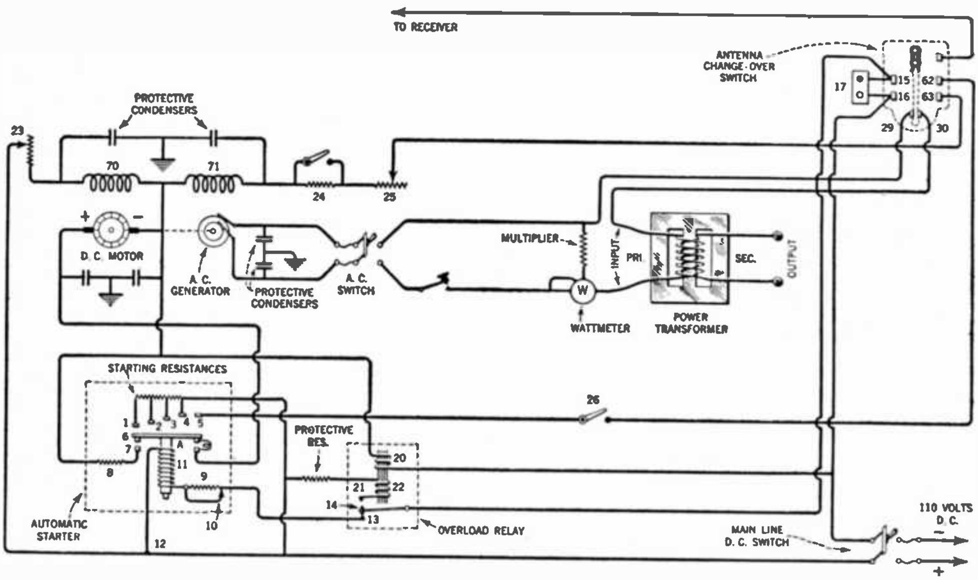


FIG. 80.—Diagram of a complete motor-generator installation and "finger" type automatic starter connected in the power circuit of a spark transmitter.

Answer. The diagram of an automatic starter supplied with 2-kw. 500-cycle transmitting sets is shown in Figure 80.

The action of this apparatus is as follows: In addition to acting as a motor starter, it performs the function of a main-line circuit-breaker through the medium of an overload relay switch. The starter has three resistance units connected in series with the motor armature.

It will be observed in the drawing that the field winding (70) of the motor is connected in shunt with the d-c. line through the regulating field rheostat (23). When resistance is increased at (23), the speed of the motor increases, and, consequently, the frequency of the generator also increases. The generator field winding (71) is connected in shunt to the d-c. line through the low-power resistance (24) and the voltage regulating rheostat (25). The field circuit continues to the contacts of the antenna switch (62) and (63) through single-pole switch (26) and finally to contact (5) of the automatic starter. By this connection the circuit to the generator field winding remains open until the bar (6) attached to the plunger *A* of the automatic starter has touched point (5). When the bar of the automatic starter makes contact with point (4), the d-c. armature is connected directly to the main d-c. line.

By increasing resistance at the rheostat (25), the voltage of the a-c. generator drops; conversely it increases by the reduction of resistance. Low values of voltage may be obtained at the terminals of the generator by an external fixed resistance (24) connected in series with the generator rheostat. This is shunted by the switch indicated in the drawing.

The overload relay employed in conjunction with the automatic starter has the magnet winding (20), which may be called the tripping magnet, and the second magnet winding (22), which may be called the holding magnet. Winding (20) is in series with the d-c. armature on the negative side of the line. If more than a predetermined number of amperes flow through this winding, the lever (14) is drawn up, breaking the circuit of the solenoid winding (11) through the contacts (13) and (14). Immediately afterward the circuit through winding (22) is closed through contacts (14) and (21). This causes the lever (14) to be held in the up position until either the main d-c. line switch or the starting switch (17) is opened.

One terminal of the solenoid winding (11) is connected to the positive pole of the d-c. line at point (12). The circuit continues through the fixed resistance (9), shunted by the switch (10), through the contacts (13) and (14) of the overload relay, and through contacts (15) and (16) of the antenna switch, to a terminal of the winding (20), which is of negative polarity. Hence it is readily observed that the solenoid winding is connected in shunt to the d-c. line when either contacts (15) and (16) or the starting switch (17) is closed. The switch (10) in shunt to the resistance (9) is automatically opened by the plunger *A* of the automatic starter when it is in the full vertical or running position.

The resistance coils of the motor starter, connected in series with the d-c. line to the armature, are progressively cut out of the circuit at contacts (1) to (4) by the bar (6). When the circuit to the solenoid (11) is closed, the plunger *A* with the bar (6) moves in a vertical position. The acceleration is regulated by a piston drawn through a vacuum chamber (dash pot). When connection is made between the bar (6) and contact (1), the circuit to the armature includes the entire set of resistance coils.

When the circuit to the winding (11) is interrupted, either at point (17) or at the aerial switch contacts (15) and (16), the plunger *A* drops downward, and through the medium of contacts (6) and (7) the dynamic brake resistance coil (8) is connected in shunt with the d-c. armature. At this stage of operation the momentum of the armature causes it to become temporarily a d-c. generator and current of large value flows for a few moments through the resistance (8). The magnetic field thus set up by the armature causes a powerful dragging action on the armature thus bringing it to a quick stop.

Reviewing the foregoing: When the handle of the aerial changeover switch is thrown to a transmitting position, the motor-generator is automatically started, provided the main d-c. line switch is closed. It will be brought to a quick stop when the antenna switch is placed in the receiving position, provided that switch (17) remains open. If switch (17) is closed, the motor-generator can be kept in a continuous state of operation during the receiving period.

The speed of acceleration of the starter arm *A* can be very closely regulated by an adjusting screw attached to the bottom of the vacuum chamber. It usually requires about 10 seconds to bring the starter up to the full running position.

163. *Question.* How are the fields of an alternator usually excited?

Answer. The fields of an alternator are usually excited by a direct current source, generally the source driving the motor.

164. *Question.* What is a no-voltage, no-field release coil?

Answer. This is the electromagnet, or holding magnet, which is a part of the Cutler-Hammer and General Electric starting boxes. When the starting arm of one type is in the "On" or full running position the holding magnet retains it in that position until the main line switch is opened, or until a break occurs in the motor field circuit. In either event the circuit to the no-voltage, no-field release coil is opened, thereby releasing the starting arm.

165. *Question.* Suppose, in starting a motor, the circuit-breaker tripped and the fuses blew, where would you look for the trouble and why?

Answer. The tripping of the circuit-breaker and the blowing of the fuses would probably be caused by too rapid rising of the automatic starter, an open circuit in one of the motor field coils, an open circuit in one of the motor armature coils, or, in case a hand starter is used, drawing it too rapidly over the contacts.

If, on starting the motor with either a hand or automatic starter, a hot flaming spark is obtained at the first contact, it indicates an open in the field circuit. If a snappy yellow spark is obtained it indicates an open in the armature circuit.

In case an automatic starter is used, and the foregoing difficulty arises, the valve at the bottom of the dash-pot should be adjusted until the plunger rises more slowly. In case the hand starter is employed the starting arm should be moved over the contacts slowly.

166. *Question.* Explain full-load and no-load voltage.

Answer. When a heavy load is placed on the generator, or considerable current is drawn from the armature, the voltage drops. The resulting voltage is known as the full-load voltage. When no load is placed on the generator the voltage measured across its terminals is called no-load voltage.

167. *Question.* Has the increase of voltage an effect on a-c. frequency?

Answer. No.

168. *Question.* If, after the motor has been brought to full speed, the starting lever flies back to off position when released, what would be the trouble?

Answer. This condition will be caused by a short-circuit in the release magnet of the starter, or by a sudden open in the field circuit to the motor in certain types. If a short-circuit has developed in the release magnet, the handle of the starter may be temporarily tied in place so as to remain in full running position, making certain that the field circuit is closed. If the field coil circuit is open at the field rheostat the burned out coil should be bridged by a jumper.

169. ***Question.*** **In case a field rheostat should burn out what temporary device could be used to replace it?**

Answer. Three or four 16-cp. (candle power) electric light lamps connected in parallel and then connected in series with the field in place of the burned-out rheostat. This improvisation would pass approximately 2 amperes.

170. ***Question.*** **Of what use are resistances in a motor starter? Do they function permanently or temporarily?**

Answer. The resistances in a starter take the place of the counter e.m.f. of the motor until the armature attains full speed. The resistances of a starter

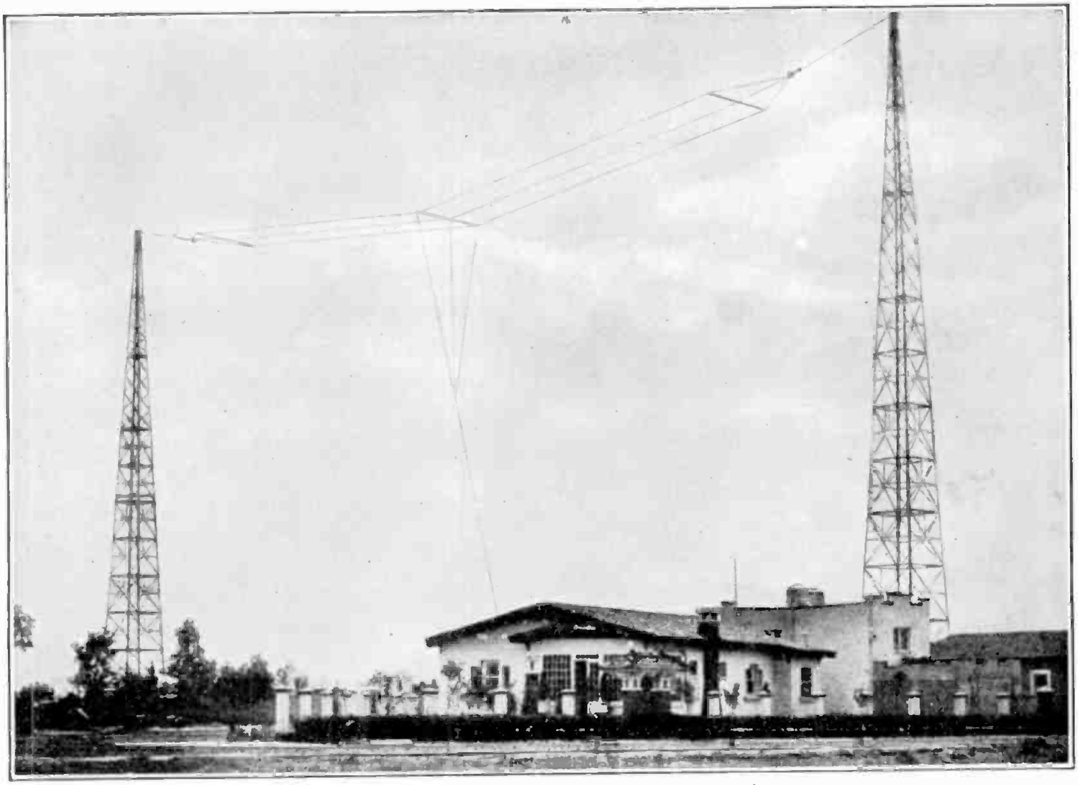


FIG. 81.—Illustrating "T" type antenna and supporting towers.

limit the amount of current which the armature draws, thus protecting the armature windings. They function only until the motor reaches its normal speed.

171. ***Question.*** **What is the frequency of an alternator with 24 field poles running 2400 revolutions per minute?**

Answer.

$$f = \frac{\text{r.p.m.} \times N}{60 \times 2}$$

$$f = \frac{2400 \times 24}{60 \times 2} = 480 \text{ cycles per second.}$$

where f = frequency
N = number of field poles
r.p.m. = revolutions per minute.

172. *Question.* What are some of the causes which make a generator overheat?

Answer. Improperly fitted brushes, too heavy a load, tight or dry bearings, excessive field current, or poor condition of the machine.

173. *Question.* Why are circuit-breakers and fuses used?

Answer. To protect electrical equipment from damage caused by possible short-circuits or the attempted passage of abnormally heavy current.

174. *Question.* What is the difference between alternating current and interrupted direct current?

Answer. Interrupted direct current periodically rises to maximum voltage and falls to zero in one direction only, whereas alternating current rises to maximum voltage in one direction, decreases to zero, then rises to maximum in the opposite direction and back to zero again, thereby completing a cycle.

175. *Question.* What happens when an open occurs in one of the armature coils?

Answer. Severe sparking will take place at the commutator thereby producing excessive heat; if allowed to continue the armature may be severely damaged, the circuit-breaker may trip, or the main fuses will blow.

176. *Question.* If the generator field burned out what would be the effect?

Answer. The output e.m.f. of the generator would fall to zero.

177. *Question.* What are some of the causes of an overheated motor?

Answer. A motor is usually overheated by placing too heavy a load on it. Improperly fitted bearings or bearings insufficiently oiled will also cause overheating.

CHAPTER V

STORAGE BATTERIES AND AUXILIARY APPARATUS

178. *Question.* Draw a diagram of an "A" battery charging unit for charging two batteries.

Answer. Figure 82 shows two batteries connected in series for charge through a variable rheostat. Figure 83 shows two batteries connected for charge through five 16-cp. lamps used as current-limiting devices (resistances). Conventional symbols for the storage battery cells may be used instead of a sketch of the batteries.

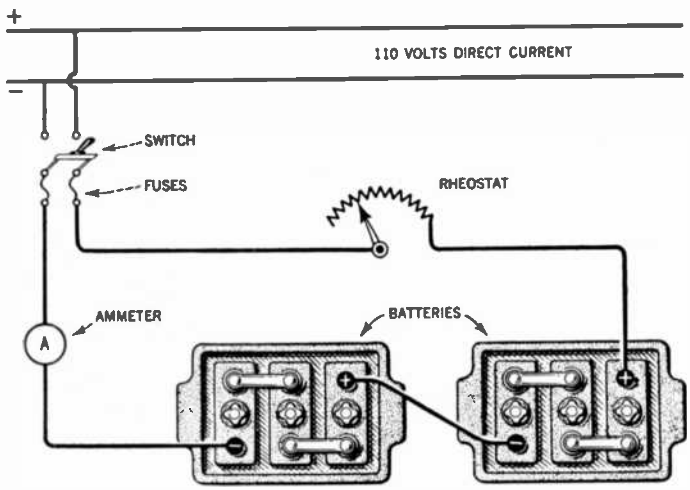


FIG. 82.—One method of charging "A" batteries. A variable rheostat is inserted in series in the 110-volt line to regulate the charging current.

179. *Question.* How would you determine the polarity of the ship's generator?

Answer. The polarity of the ship's generator may be determined by one or all of the following methods:

1. By the use of a direct current voltmeter of the movable coil type. The terminals of the voltmeter are usually marked with polarity signs, positive (+) and negative (—). If the meter is correctly connected across the line a deflection of the needle enables the operator to read the e.m.f. in volts.

2. By electrochemical means. Chemical polarity indicators are composed of a chemical composition within a glass tube provided with terminals. When connected to a source of direct current the positive terminal turns blue.

3. By immersing the terminals of the charging source in a solution of salt water. When the terminals are dipped in a glass of salt water (the terminals spaced about an inch and a half), bubbles will appear at the negative terminal.

180. *Question.* (a) What is meant by "normal discharge rate"? (b) Normal charging rate?

Answer. (*a*) The normal discharge rate is the amount of current which can be taken from a cell for a given length of time without damage to it.

(*b*) The normal charging rate is the amount of current which can be passed through a cell in charging without damage to it. The normal rate of charge and discharge of a cell is usually indicated by the manufacturer.

181. *Question.* What determines the capacity of a storage battery?

Answer. The capacity of a storage cell is determined by the quantity of current, in ampere-hours, which may be taken from it under normal conditions. An ampere-hour is the quantity of current passing through a circuit in one hour's time when the strength of the current is one ampere.

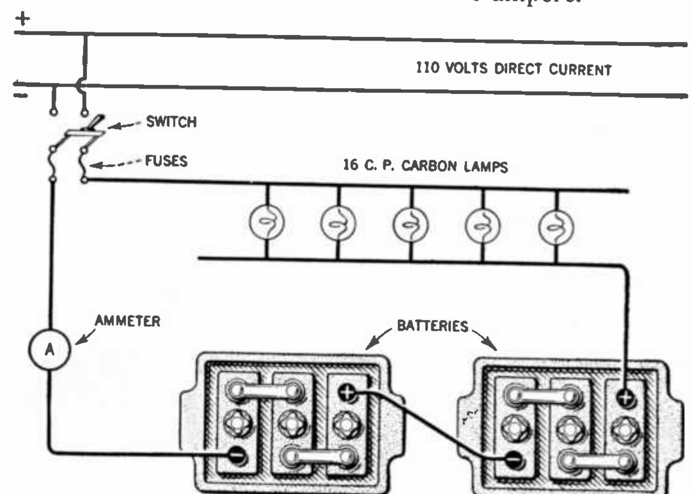


FIG. 83.—Another method of charging "A" batteries. Five 16-candle-power carbon lamps in parallel are connected in series with the 110-volt line to regulate the charging current.

182. *Question.* In case one of the storage batteries in a storage battery bank developed a leak what would you do in order to obtain service from the other batteries in the bank?

Answer. If one of the batteries developed a leak and no replacement was immediately available the leaky jar should be cut out of the circuit by opening its connector and "jumping" it to restore the circuit.

183. *Question.* How would electrolyte of the required density be obtained to fill a new lead-acid battery which was received dry?

Answer. By adding one part of concentrated sulphuric acid to four parts of water using a non-metallic receptacle to mix the solution. Always pour the acid slowly into the water—never the water into the acid because the chemical action of this combination is quite violent which might result in body burns due to the steam from the water throwing part of the acid out of the receptacle. Sulphuric acid is usually obtained in concentrated form and is much heavier than water.

Use is made of a hydrometer to measure the specific gravity of the electrolyte.

184. *Question.* What causes a lead-acid battery to sulphate?

Answer. When a lead cell is discharging, the positive plate absorbs a considerable portion of the acid from the electrolyte which, in combining with the lead in the active material, forms a coating of lead sulphate over the positive plate. As this coating builds up more and more on the positive plate it retards the circulation of the acid until finally the chemical action is so reduced that the voltage becomes negligible and the cell is said to be discharged. By passing a direct or rectified current through the battery, from the positive to the negative plate, the coating of sulphate which accumulated on the positive plate during charge is driven back into the solution. The acid is also forced back into the electrolyte. This process is known as charging.

185. *Question.* What kind of water would you put in a storage battery to make up for that lost through evaporation? Why?

Answer. Only distilled or chemically pure water (water kept in glass or wooden containers) should be used because it is free from injurious minerals and general impurities. Ordinary drawn water usually contains iron and other injurious minerals which, if used in storage cells, might collect and form between the plates, thereby shorting the cell; local action would also be promoted.

186. *Question.* What is the difference between a primary and a secondary cell?

Answer. A primary cell is one that, after discharge, cannot be re-charged. Dry cells are primary cells. They possess two dissimilar materials immersed in an electrolyte paste which acts more on one material than on the other.

A secondary cell is one that can be charged after being discharged. It will produce a potential after current has been passed through the electrolyte from the positive to the negative plate. The current in passing through the cell creates a chemical change causing a difference of potential between its plates. Storage batteries are secondary cells.

187. *Question.* How would you treat a battery so that it can be placed out of active service for an indefinite period?

Answer. The battery should be fully charged, the vent caps removed and the electrolyte poured out by turning the battery case upside down. The battery should then be filled with fresh pure water and allowed to stand 12 or 15 hours, after which the water is poured off, the case wiped dry and the terminals thoroughly greased with vaseline.

188. *Question.* (a) Describe a lead-acid cell. (b) Describe an Edison cell. (c) What are the advantages and disadvantages of each type?

Answer. (*a*) The lead cell comprises two sets of prepared lead plates, known as the "positive" and "negative" plates, immersed in a 20 percent solution of sulphuric acid. This dilute solution is known as the "electrolyte."

When a lead storage cell is put on discharge, the current is produced by the acid of the solution going into and combining with the porous part of the plate called the "active material." In the positive plate, the active material is lead peroxide and in the negative plate it is metallic lead in a spongy form.

When the sulphuric acid, H_2SO_4, in the electrolyte combines with the lead, Pb, in the active material of both plates, a compound known as lead sulphate, $PbSO_4$, is formed.

As the discharge progresses, the electrolyte becomes weaker by the amount of acid that is used in the plates and the formation of more water due to the chemical combination of the hydrogen, H, and oxygen, O. Consequently the voltage of the battery is lowered, because a compound of acid and lead, called lead sulphate, is produced on the plates. This sulphate continues to increase in quantity and bulk, thereby filling the pores of the plates. As the pores of the plates become thus filled with the sulphate, the free circulation of acid into the plates is retarded and, since the acid cannot then get into the plates fast enough to maintain the normal action, the battery becomes less active, as the rapid drop in voltage indicates.

During the charging period, direct current must pass through the cells in the direction opposite to that of discharge. This current will reverse the action which took place in the cells during discharge. As just mentioned, during discharge

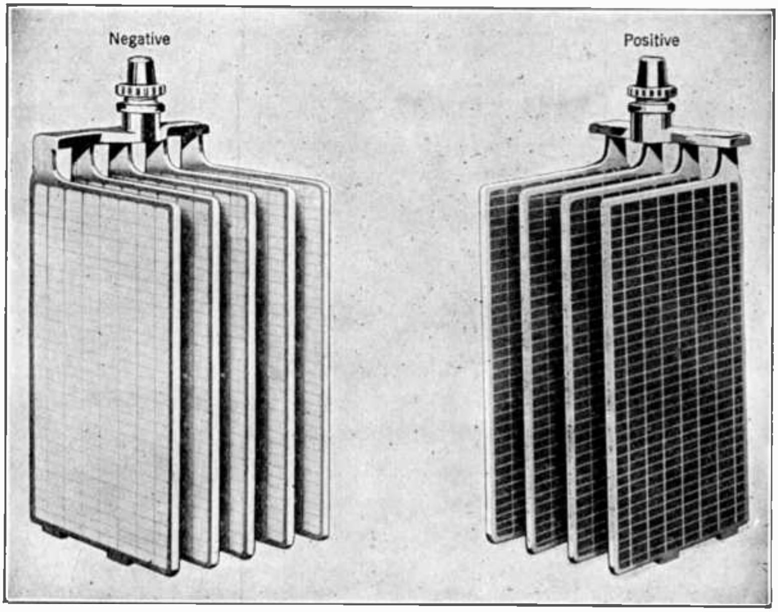


Fig. 84.—The negative and positive plates of the type MVA Exide cell.

the acid of the solution went in and combined with the active material, filling its pores with sulphate and causing the solution to become weaker; but reversing the current through the sulphate in the plate will restore the active material to its original condition and return the acid to the solution. Thus, during charge, the solution gradually becomes stronger as the sulphate in the plate decreases, until no more sulphate remains, and all of the acid has been returned to the solution, when it will be of the same strength as before the discharge. The same acid will be ready to be used over again during the next discharge. Since there is no loss of acid by this process, none should ever be added to the solution, except to replace any that is spilled out.

The whole object of charging, therefore, is to drive from the plates the acid which has been absorbed by them during discharge.

The chemical action which takes place in a lead cell during charge and discharge can be represented by the following equation:

$$PbO_2 + Pb + 2H_2SO_4 \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftarrows}} 2PbSO_4 + 2H_2O$$

From left to right, this equation represents discharge, and right to left represents charge.

(*b*) The Edison cell differs from the lead cell both in the construction of the plate and the electrolyte. The active materials of this cell are iron oxide and nickel hydrate. The alkaline electrolyte is a 21 per cent solution of potassium hydrate mixed with a small amount of lithium hydrate.

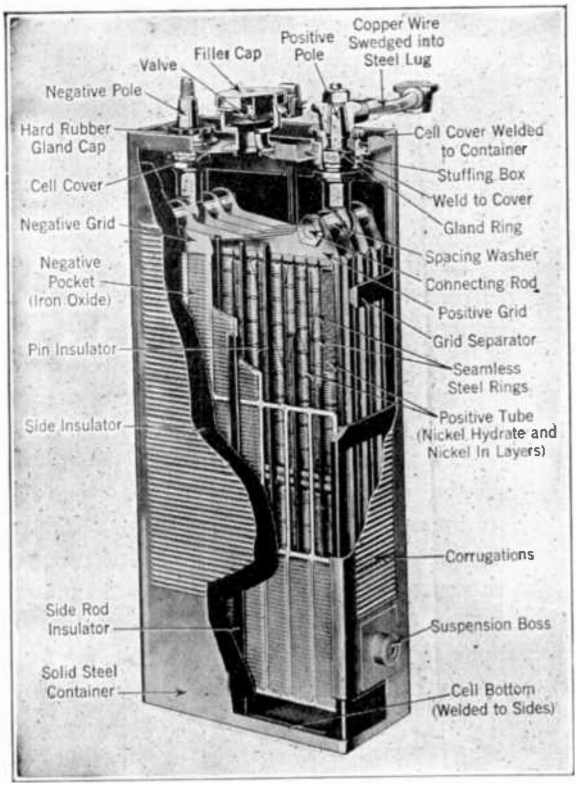


FIG. 85.—Cross-sectional view of the Edison storage cell.

The active material of the positive plate is nickel hydrate. It is loaded in layers, in ¼-in. perforated tubes formed of spirally wound steel ribbon. Alternating with the layers of nickel hydrate, layers of pure nickel flake are introduced to increase the electrical conductivity. When loaded, the tubes are reinforced by eight seamless steel rings equidistantly spaced. Thirty of these loaded perforated tubes are clamped on the steel supporting grid.

The active material of the negative plate is iron oxide and mixed with a small amount of oxide of mercury to increase the conductivity, it is loaded into perforated, rectangular, sheet-steel pockets, and solidly tamped down. When loaded, the pockets are placed in the interstices of the steel supporting grid and forced between corrugating dies into perfect electrical contact, under hydraulic pressure of 120 tons.

All the plates of like polarity in the cell are slipped over a steel connecting rod, through the hole provided for the purpose at the top of the grid; the cell poles are fastened at right angles to these connecting rods; proper spacing is provided by steel washers of correct thickness; and, finally, lock washers and nuts are fitted to the threaded end of the connecting rod, thus clamping all into a compact unit. The positive and negative plates are intermeshed, and small hard-rubber pins are so placed as to keep them apart. Grooved hard-rubber ladders are fitted over the side edges of the plates. These have shoulders at the bottom upon which the plates rest, and they perform the double function of keeping the proper distances between the plates and insulating them from the container.

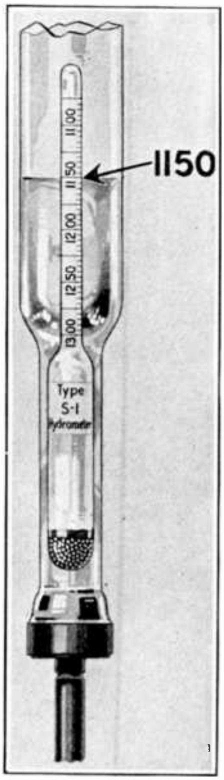


FIG. 86. — Showing how the specific gravity of a lead-acid cell is measured by a hydrometer.

(*c*) The disadvantages of the lead-acid battery are (1) injurious acid, (2) sulphation and buckling of plates when not properly cared for, and (3) it is likely to be damaged by a reversal of the charging current.

The advantages of the lead-acid battery are: (1) It delivers a steady flow of direct current until it is discharged, and (2) it operates satisfactorily in all climates.

The disadvantage of the Edison battery is that it is heavier than the lead-acid type and therefore not as easily handled.

The advantages of the Edison battery are: (1) It does not give off noxious fumes during charge, (2) the electrolyte is not injurious, (3) it is not liable to sulphation, and (4) it is not damaged by a reversal of polarity during the process of charging.

189. *Question.* What is meant by "ampere-hour capacity" of a battery?

Answer. Accurately stated the ampere-hour capacity of a storage battery is the ratio of the ampere-hours obtained from it to the ampere-hours required to charge it. For all practical purposes the term "ampere-hour capacity" is applied to the quantity of current (amperes) that may be drawn from a storage battery in a given length of time, dependent upon the ampere-hour rating of the battery.

190. *Question.* (a) Name two ways of ascertaining the state of charge of a lead-acid cell. (b) Name two ways of ascertaining the state of charge of an Edison cell.

Answer. (*a*) The charge of a lead-acid cell may be determined by the use of an ampere-hour meter or a hydrometer. (*b*) The charge of an Edison cell may be determined by the use of an ampere-hour meter or a low reading voltmeter.

191. *Question.* In general, how would you take care of a lead-acid battery?

Answer. 1. The battery should be kept fully charged at all times.

2. The electrolyte should be kept ½-inch above the plates.

3. The surface of the battery container should be kept clean and free from the bubbling gas which settles on it.

4. The battery should receive an overcharge of about 20 per cent once a month.

5. The voltage readings of each individual cell should be taken about twice each month.

6. The cells should be kept free of dirt and foreign substances.

7. The specific gravity of the electrolyte should be frequently tested.

8. The vent caps should be kept open when charging.

9. All flames should be kept away from the battery.

10. The temperature should not be permitted to get above 110 degrees Fahr. when charging.

11. When charging, the charging source should always be in excess of the voltage rating of the battery.

12. Correct charging polarity should be carefully watched, that is, the positive and negative sides of the charging line are connected to the positive and negative terminals of the battery, respectively.

13. The charging current (amperes) should never be permitted to exceed the amount specified for the particular battery.

192. *Question.* How would you treat a battery for sulphation?

Answer. By giving it long slow charges and long slow discharges until sulphation is driven off. Just as the human body is kept in good condition by exercise, so is a battery maintained in a state of efficiency by usage.

193. *Question.* How would you care for a 60-cell lead-acid storage battery installation?

Answer. Refer to the answer to Question 191.

194. *Question.* What are the active materials used for the plates of an Edison cell?

Answer. The active materials of the positive plate are nickel and nickel-hydrate; of the negative plate iron-oxide and a small quantity of oxide of mercury.

195. *Question.* How would you charge a 120-volt bank of storage batteries from a 110-volt generator?

Answer. On shipboard the 60-cell emergency radio battery has a combined voltage too high to be charged from the ship's 110-volt d-c. line and because of this the battery is divided into two equal banks of 30 cells (60-v) each for charging.

A switchboard panel especially designed and equipped with all the necessary apparatus for performing the various switching operations and for protecting the circuits is used on shipboard. Figure 87 is a diagram of the charging circuit connections and the meter circuit. Figure 88 shows the front panel view of the charging circuit in Figure 87.

Instructions concerning the operation of this panel are explained in the following:

The reversing switch is closed in the proper direction to give correct polarity. This will be indicated by the needle of the voltmeter which, if the polarity is correct, will give a reading. If the needle does not swing over the scale but tends to move to the left where no reading can be observed, it is an indication that the polarity is reversed, therefore the reversing switch must be thrown in the reverse position.

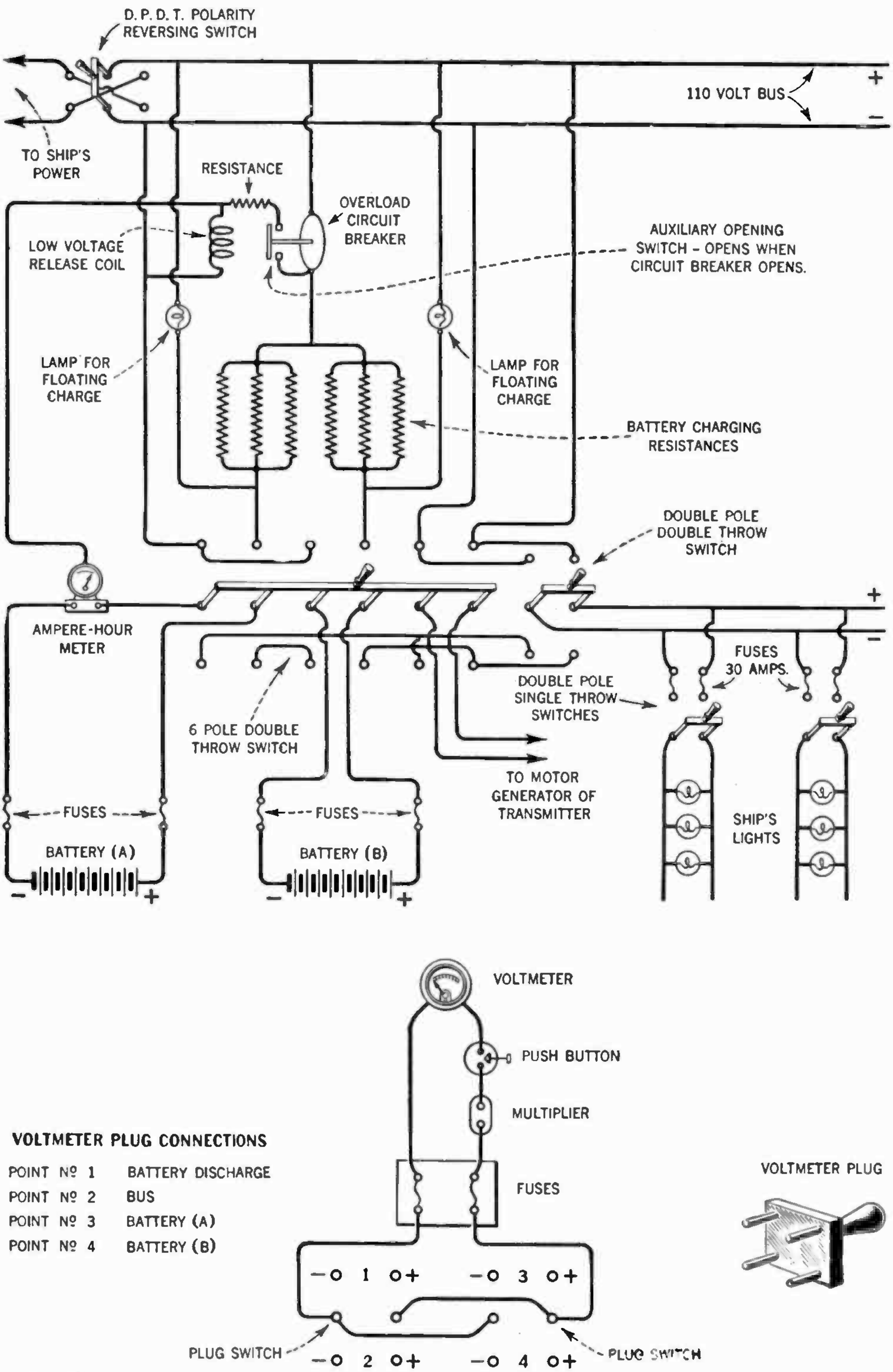


FIG. 87.—Diagram of a complete battery charging circuit of the type used on shipboard.

The voltage of the battery is obtained by inserting the plug switch in the upper and lower right hand receptacles connecting the voltmeter circuit. As the voltmeter circuit is normally open a push button switch is provided on the switchboard for closing the circuit when it is desired to take voltmeter readings. The reason for this circuit being open is to prevent stray high-frequency currents from flowing through the meter windings when the transmitter is in operation. The connections of this meter circuit are shown in Figure 87.

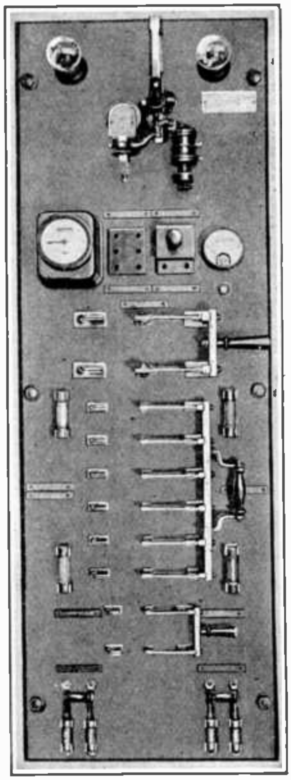


FIG. 88. — Marine storage battery charging panel.

The next step is to open the 6-pole double-throw switch and close the circuit-breaker, at the same time holding up the plunger of the low voltage release coil, now throw the 6-pole double-throw switch to the "Discharge" position. With the 6-pole double-throw switch in the "Charge" position the black hand will move toward zero and, when it reaches zero, the battery is charged. The black hand, on reaching the zero position, makes an electrical contact with a pin which short-circuits the holding-magnet windings of the circuit-breaker through a small resistance and the circuit-breaker trips, thus automatically opening the charging circuit.

At stated periods, generally about once each month, it is best to give the batteries an overcharge. To do this the cover of the ampere-hour meter is removed, the black hand set back half-way to the red hand and the cover then replaced, which puts the battery on charge.

At the completion of the overcharge the charging current is automatically cut off by the black hand making contact at the zero position and thereby opening the circuit-breaker. It is important that the ampere-hour meter be given the proper attention that will insure its being maintained in good operating condition.

196. ***Question.*** **Why is a no-load voltage test reading of a lead-acid cell inaccurate?**

Answer. Because if there were no load on the cell, that is, if it were not discharging, the voltage test may show "full charge" even though the cell might be somewhat discharged.

197. ***Question.*** **How should an Edison cell be cared for?**

Answer. 1. Charge soon after discharge.

2. Keep all flames away.

3. Keep terminals and top clean.

4. Keep charging polarity correct in respect to battery.

5. Add distilled or chemically pure water to replace evaporation to maintain the electrolyte ½-inch above the plates.

6. Give a four-hour overcharge twice each month.

7. After each overcharge the voltage of each cell should be tested. If any cells are below normal an immediate investigation should be made.

8. Do not allow the temperature of the cell to rise above 115 degrees Fahr.

198. *Question.* (a) What is the electrolyte of an Edison cell composed of? (b) The positive plate? (c) The negative plate?

Answer. Refer to the answer to Question 188.

199. *Question.* What chemical is used to neutralize the acid spray from a lead cell?

Answer. Ammonia liquid is preferable, or chloride of lime may be used.

200. *Question.* What is the unit of capacity of a storage cell?

Answer. The capacity of a storage cell is determined by the quantity of current, in ampere-hours, that may be taken from it under normal conditions. One ampere-hour is the quantity of current passing through a circuit in one hour's time when the strength of the current is one ampere.

201. *Question.* What is meant by local action? What causes it? How may it be prevented?

Answer. The impure and foreign metals which the plates of all storage batteries contain causes local action to set in. The contact of these impure and dissimilar metals with the plates causes a chemical action which produces a current that slowly eats away the plates and builds up sulphation. This is known as local action. In time this decreases the e.m.f. of the cell.

Local action may be almost entirely prevented by keeping the cell in good condition, by maintaining the correct charge and discharge rates and by keeping the battery on trickle charge when not in active use.

202. *Question.* What are the active materials in a lead cell?

Answer. The positive plates of a lead cell are composed of peroxide of lead (litharge) and the negative plates are composed of pure sponge lead.

203. *Question.* At what temperature does a cell work best?

Answer. A cell operates best at temperatures ranging from 70 to 90 degrees Fahr.

204. *Question.* What is the charged, discharged and charging voltage of an Edison cell?

Answer. The charged voltage is 1.2 volts, the discharged voltage 0.9 volt and the charging voltage 1.5 to 1.85 volts.

205. *Question.* What determines the voltage of a storage cell?

Answer. The voltage of a storage cell is determined by the degree at which the chemical discharging action takes place within the cell to restore the active material on the plates to their normal condition.

206. *Question.* (a) What is the effect of charging a lead cell in the wrong direction? (b) An Edison cell?

Answer. (*a*) If an attempt was made to charge a lead cell in the wrong direction it would totally discharge at a very rapid rate. the lead peroxide would decompose, the plates would buckle and the cell would be practically ruined.

(*b*) The Edison cell would be rapidly discharged but it could be recharged by charging in the right direction. No permanent damage would result from attempted reversed charging.

CHAPTER VI

RADIO LAWS AND REGULATIONS

207. ***Question.*** **What is the law in regard to the transmission of fraudulent signals?**

Answer. 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.

208. ***Question.*** **Compose an ordinary paid message and compute the charges when the ship tax is 8 cents per word, coast tax 10 cents per word, and land line charge 3 cents per word.**

Answer.

P 1 R 16 Radio S. S. Mallory 3:20 A. M.
To: James Brown,
28 Hunter St., Washington (D. C.)
Arriving Tuesday please meet me Hotel Astor NewYork love
Helen.

Total words	=	16	
Ship tax	=	.08 x 16 =	$1.28
Coast tax	=	.10 x 16 =	1.60
Land Line tax	=	.03 x 16 =	.48
			$3.36

209. ***Question.*** **Give 15 International abbreviations and their meanings.**

Answer. Refer to the list of abbreviations on page 165 and choose any fifteen of them for your answer to this question.

210. ***Question.*** **What determines whether or not an American vessel must carry radio apparatus?**

Answer. The number of persons aboard and the waters through which the vessel navigates.

211. ***Question.*** **(a) What are the International requirements relative to the exchange of unnecessary signals? (b) To conducting experiments? (c) To conducting tests?**

Answer. (*a*) The exchange of unnecessary signals is forbidden. (*b* and *c*) Experiments and tests may be made and must be conducted so as not to interfere or disturb the service of stations engaged in authorized radio correspondence. A station sending out experimental and test signals must transmit its call signal at frequent intervals. The test and adjustment signals must be chosen so that no confusion with signals of special meaning can be produced.

212. *Question.* What are the United States distance and time requirements for auxiliary apparatus?

Answer. Auxiliary (emergency) apparatus must be capable of transmitting and receiving messages over a distance of at least one hundred miles by day or night for a period of at least four hours.

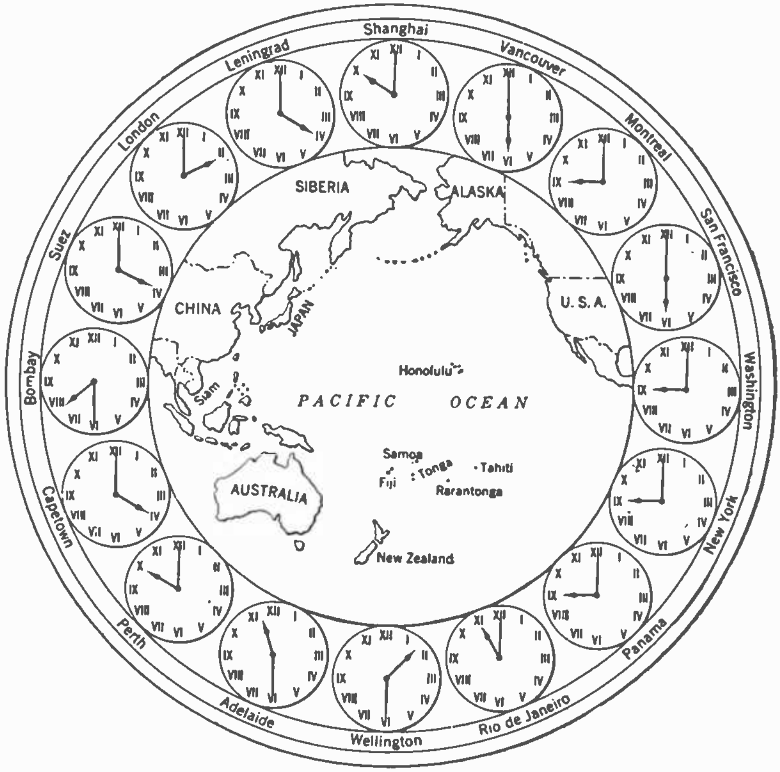


FIG. 89.—Standard Time Chart. Radiotelegrams are filed on the basis of 24-hour time. Time changes 1 hour with each 15 degrees difference in longitude. When it is 2 A.M. in London, G.M.T. (Greenwich mean time) it is 9 P.M. in New York, E.S.T. (Eastern standard time) and 6 P.M. in San Francisco, P.S.T. (Pacific standard time).

213. *Question.* What is the law in regard to willful (malicious) interference?

Answer. It is the duty of the Secretary of Commerce of the United States to suspend, for a period of not more than two years, the license of any radio operator who has willfully or maliciously interfered with any radio communications or signals.

214. *Question.* What is the difference between Greenwich Mean Time, and Eastern Standard Time? What is the difference between Greenwich Mean Time and Pacific Standard Time?

Answer. There is a difference of five hours between Greenwich Mean Time and Eastern Standard Time, and a difference of eight hours between Greenwich Mean Time and Pacific Standard Time. That is to say, when it is 2 A. M. Greenwich Mean Time it is 9 P. M. Eastern Standard Time and 6 P. M. Pacific Standard Time. Refer to Figure 89.

215. *Question.* What determines whether or not a ship must be provided with emergency apparatus?

Answer. The "Convention for the Safety of Life at Sea" determines which ships must be provided with emergency installations, and defines the conditions to be fulfilled by installations of this class. All ships required by law to carry radio apparatus must carry auxiliary apparatus.

216. *Question.* Write a code message giving cable count requirements for this type of message. Indicate the preamble, body and signature.

Answer. Code language messages may consist of words belonging to one or more of the following languages: English, French, German, Italian, Portuguese, Dutch, Spanish and Latin. The use of words of other languages is not allowed. Code language messages may also consist of artificial words; that is, groups of letters so combined as to be pronounceable in at least one of the eight admitted languages. In code language messages, each code word (whether genuine or artificial) of ten letters or less, is counted as a word, and no code word of more than ten letters can be accepted. If any words in plain language, of more than ten letters each, are used in code messages, they should be counted at the rate of ten letters or fraction of ten letters to a word. Immediately following is an example of a code message.

Preamble:——→ P 1 R 13 Radio S.S. America 4 P. M.

Address→ To: Henry King Co.
39 Market St., San Francisco (Cal.)

Body:——→ BELLAMELLE OMARMAXIME WAVECHIMES
DELLMITTEN LURANITSCH

Signature:——→ Dixon

217. *Question.* If you were on board ship and were asked to obtain a bearing, what steps would you take to do so?

Answer. After ascertaining the wavelength used by the compass station I would call the compass station or stations and follow with the signal QTE? which asks, "What is my true bearing?" (or) "What is my true bearing relative to ....?" When the compass station or stations respond I would reply by sending my call signal and the letters MO alternately for a period not longer than 50 seconds. After receiving the bearing I would repeat it back to the compass station for verification. The compass station or stations shall be called on their "watching" wave. (In the United States all compass communications are handled on a wavelength of 800 meters.) When the radio-direction-finding station is certain that the station requesting the bearing has correctly received it, it shall transmit the signal . . . — . — This signal is then repeated by the station which requested the bearing, as an indication that the operation is finished. Note: The ship which requested the bearing repeats the bearing back to the sending station for verification before signal . . . — . — is transmitted.

218. *Question.* What are the International requirements relative to emergency installations?

Answer. The "Convention for the Safety of Life at Sea" will determine which ships must be provided with emergency installations, and shall define the conditions to be fulfilled by installations of this class. The emergency apparatus shall be capable of functioning for six hours over a distance of 80 nautical miles day and night range in case of a ship having constant radio service, and 50 miles in case of a ship having a service of limited duration.

219. *Question.* What is the urgency signal for aircraft radio service?

Answer. The indication PAN shall be used as the urgency signal in aircraft radio service.

220. *Question.* How would you obtain a radio compass bearing?

Answer. Refer to the answer to Question 217.

221. *Question.* What are the penalties to which an operator is subject under the Radio Act of 1927?

Answer. An operator's license may be suspended for a period not exceeding two years for: (a) failure to carry out the lawful orders of the master of the vessel on which he is employed, (b) willfully damaging or permitting radio apparatus to be damaged, (c) transmitting superfluous radio communications or signals or radio communications containing profane or obscene words or language, (d) willfully or maliciously interfering with any radio communications or signals, (e) any improper alteration of the service record on the license, or the forgery of masters' or employers' signatures thereon or (f) violation of any provision of any act or treaty binding on the United States which the Secretary of Commerce or the commission is authorized by the act of 1927 to administer, or of any regulation made by the commission or the Secretary of Commerce under any such act or treaty.

Any operator failing or refusing to observe or violating any rule, regulation, restriction, or condition made or imposed by the licensing authority under the authority of 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 offense.

Any operator who shall violate any provision of the Radio Act of 1927, or shall knowingly make any false oath or affirmation in any affidavit required or authorized by the Radio Act of 1927, or shall knowingly swear falsely to a material matter in any hearing authorized by the Act, upon the conviction thereof in any court of competent jurisdiction shall be punished by a fine of not more than $5000 or by imprisonment for a term of not more than five years, or both, for each and every such offense.

222. *Question.* Has the ship's master the right to censor any messages received and transmitted by the radio station on shipboard?

Answer. Yes.

223. *Question.* What are the International requirements governing transmission to the nearest coast station?

Answer. In principle, ships using modulated continuous-wave transmitters or damped-wave transmitters, shall send their radiotelegrams to the nearest land station. However, when the ship has the choice between several land stations situated at approximately the same distance, it shall give preference to the one located on the territory of the country of destination or of the normal routing of the radiotelegrams to be sent.

Ships using continuous-wave transmitters may transmit their radiotelegrams to a land station which is not the nearest providing they do not interfere with nearer stations. It is recommended, however, in this case that preference be given to the land station established on the territory of the country of destination or to the country which it appears could in the most normal manner handle the transit of the radiotelegrams to be transmitted.

224. *Question.* What are the International requirements regarding the non-delivery of radiotelegrams?

Answer. When a radiotelegram coming from a ship station and destined to the mainland cannot be delivered to the addressee, a notice of non-delivery is issued and addressed to the land station which received the radiotelegram from the ship station. This land station, after verification of the address, shall resend the notice to the mobile station, if that is possible, and in case of need if the existing state of affairs or particular agreements permit, through the intermediary of a land station of the same country or of a neighboring country.

When a radiotelegram received at a ship station can not be delivered, this station will inform the office or ship station of origin by a service message. In the case of a radiotelegram emanating from the mainland, this service advice shall be sent, when possible, to the land station through which the radiotelegram was routed or, if necessary, to another land station of the same country or of a neighboring country.

225. *Question.* How would you take bearings with direction-finding apparatus on shipboard?

Answer. By reference to call books, Radio Aids to Navigation, or similar available data, the operator may ascertain the geographical location (longitude and latitude) of radio beacon stations in his vicinity, and the distinguishing test signals used by automatic stations, for purpose of identification. Radio beacon stations are authorized to operate on wavelengths ranging from 950 to 1050 meters (315 to 285 kc.). The United States wave used is 1000 meters (300 kc.).

In the case of automatic stations the operator tunes his direction-finder receiver to the wave of the station from which he desires a bearing and, in the manner prescribed for the particular type of direction-finding apparatus in use, obtains the bearing. With the exception of the automatic signal transmitted by beacon stations no transmitting is required.

Some radio beacon stations operate only upon request during certain periods (usually the first 15 minutes after each hour). These stations are assigned call letters and maintain a listening-in watch on 600 meters (500 kc.) during the periods mentioned. A station desiring a bearing calls the beacon station on 600 meters and transmits QTL? which means, "Send radio signals to enable me to determine my bearing with respect to the radio beacon." When the beacon station responds the receiving operator must listen in on his direction-finder receiver tuned to the working wave of the beacon station. When the bearing is obtained the receiving station notifies the beacon station.

Bearings may also be taken from other stations when the geographical location of the other stations is known.

226. ***Question.*** **Give a full explanation of the cable count.**

Answer. Cable count is the system employed by the cable and radio companies for counting the words in a radiogram or cablegram. The cable count system is drawn up by international agreement at the International Telegraph Conferences.

In the cable count system, all words in the address, text and signature of a message are counted and charged for. Any message, whether originating ashore or aboard ship, handled via radio or cable over any part of its route must be computed by this system.

The cable count system is divided into two classes, plain language and secret language, the latter being subdivided into two classes, code and cipher language.

PLAIN LANGUAGE is that which presents an intelligible meaning in one or more of the languages authorized for international telegraphic correspondence, each word and each expression having the meaning which is normally attributed to them in the language to which they belong. The misspelling or abbreviation of plain language words for the purpose of evasion, or the combination of two or more plain language words contrary to usage, or words concealed by reversing the order of the syllables or letters is prohibited.

The classification of the text of a message is determined independent of the address and signature. The use of Registered code addresses is permissible without changing the count, such code addresses, however, never exceeding ten letters and being pronounceable. The office of destination in the address of a message may be accepted as one word regardless of the number of letters or groups forming it. Example: CROTON ON THE HUDSON (NY) is counted as one word. CITY OF HONOLULU (Name of a ship) is counted as one word. The word "Steamship," or symbol "SS" preceding the name of the ship is counted separately. In messages written entirely in plain language, the maximum length of a chargeable word is fixed at 15 letters. Words of less than 15 letters may not be joined together to form one word. When a word regularly used exceeds fifteen letters and is less than thirty letters it will be charged for as two words. Subject to this limit authorized compound words, names of towns, countries, provinces, places, family names, and names of ships are counted as single words, provided they are written without a break or hyphen. If joined by a hyphen, or separated by an apostrophe, or spaced, they are counted as so many separate words, and the hyphen or apostrophe, if transmitted, will be chargeable as an additional word. The number of a street written, for example, as 146th street, is counted as one word providing the total number of characters, including figures and letters, does not exceed five. Telephone numbers in the address must always be followed by the name of the office of destination. Letters following telephone numbers are counted in the same group subject to the limit of five characters. Messages containing one or more code words in the text are code messages.

CODE LANGUAGE may consist of words not having the meaning normally attributed to them, belonging to one or more of the following languages: English, French, German, Italian, Dutch, Portuguese, Spanish, and Latin. The use of other words is not allowed. Code language may also consist of artificial words; that is, groups of letters so combined as to be pronounceable in at least one of the eight admitted languages. In code language messages, each code word (whether genuine or artificial) of ten letters or less, is counted as a word, and no code word of more than ten letters can be accepted. If any words in plain language, and of more than ten letters each, are used in code messages they should be counted at the rate of ten letters or fraction of ten letters to a word. The combination CH, which is counted as one letter in plain language, must always be counted as two letters when used in code.

CIPHER LANGUAGE is formed of groups of figures or groups of letters not complying with the conditions of plain or code language. The accented letters are not admitted. Each group of figures or letters is charged at the rate of five figures or five letters, or fraction of five to the word and at the same rate for any excess. The mixture in one group of figures and letters having a secret meaning is permitted, but each uninterrupted series of letters or figures subject to maximum of five must be counted separately. Example: AB 5 is counted as two words; A5B is counted as three words; ABCDE12345FGHIJ is also counted three words, and so on. This prohibition does not extend to registered commercial trade marks or trade terms such as "106D" and "501A" which are not considered as having a secret meaning.

In all radiograms every isolated letter or figure is charged for as one word. The cipher count is applicable to groups of letters forming a commercial expression, such as "COD," "FOB," or commercial marks. Letters added to figures to form a number of an address or a commercial mark are considered as figures and charged accordingly. Fraction bars, decimals and stops, used in the formation of numbers are counted as figures. Otherwise signs of punctuations are not transmitted, except at the special request of the sender, and they are then charged for as separate words.

When a message consists of a mixture of plain, code, and cipher languages, the passages in both plain and code language are charged as code language and the passages in cipher are charged as cipher.

In messages written in plain and cipher languages the plain is counted as plain and the cipher as cipher language.

227. *Question.* (a) What is meant by the zones of watch? (b) What is the approximate location of each zone and watch duration required?

Answer. (*a*) By zones of watch is meant those zones where a radio watch must be maintained regardless of the number of radio operators aboard the ship. (*b*) The approximate location of each zone and watch duration required is shown in the chart on the following page.

Zones	Duration of Hours of Service (Greenwich Mean Time)	
	On Ships Carrying One Operator	On Ships Carrying Two Operators
A Eastern Atlantic Ocean, Mediterranean, North Sea, Baltic	From 8h to 10h From 12h to 14h From 16h to 18h From 20h to 22h	From 0h to 6h From 8h to 14h From 16h to 18h From 20h to 22h
B Indian Ocean, Eastern Arctic Ocean	From 4h to 6h From 8h to 10h From 12h to 14h From 16h to 18h	From 0h to 2h From 4h to 10h From 12h to 14h From 16h to 18h From 20h to 24h
C China Sea, Western Pacific Ocean	From 0h to 2h From 4h to 6h From 8h to 10h From 12h to 14h	From 0h to 6h From 8h to 10h From 12h to 14h From 16h to 22h
D Central Pacific Ocean	From 0h to 2h From 4h to 6h From 8h to 10h From 20h to 22h	From 0h to 2h From 4h to 6h From 8h to 10h From 12h to 18h From 20h to 24h
E Eastern Pacific Ocean	From 0h to 2h From 4h to 6h From 16h to 18h From 20h to 22h	From 0h to 2h From 4h to 6h From 8h to 14h From 16h to 22h
F Western Atlantic Ocean and Gulf of Mexico	From 0h to 2h From 12h to 14h From 16h to 18h From 20h to 22h	From 0h to 2h From 4h to 10h From 12h to 18h From 20h to 22h

228. ***Question.*** **What is the law in regard to the secrecy of messages?**

Answer. No person receiving or assisting in receiving any radio communication shall divulge or publish its contents or any part of it to any person other than the addressee, his agent, or attorney, or master of the ship on which the message is sent or received, or in response to a subpoena issued by a court of competent jurisdiction, or on demand of other lawful authority. For violating this law the violator may be punished by a fine of not more than $500 for each and every offense.

229. ***Question.*** **(a) What is the procedure to be followed in calling a station? (b) What is the procedure to be followed in answering a call?**

Answer. (*a*) After ascertaining that no excessive interference will be caused with other stations the station is called by transmitting its call letters no more than three times, followed by the word DE and the call letters of the calling station transmitted no more than three times. If a station called does not answer a call sent three times at intervals of two minutes, the call must cease and it may be resumed only after an interval of fifteen minutes. The calling station, before resuming the call, must be assured that the station called is not at that time in communication with another station.

(*b*) A station called shall reply by transmitting the call letters of the calling station not more than three times, followed by the signal DE, its own call letters once and the letter K. (The letter K is the invitation to transmit.)

230. *Question.* What is the law in regard to inter-communication?

Answer. All stations are bound to exchange radio communications or signals with other stations regardless of the radio systems used.

231. *Question.* What is the meaning of the signal CQ?

Answer. The signal CQ is the signal of inquiry. Stations desiring to enter into communication with mobile stations (moving stations such as ships), without, however, knowing the names of the mobile stations which are within their range of action, may use the signal of the station called in the calling formula, this formula being followed by the letter K (general call for all mobile stations without request for reply).

In regions where traffic is heavy, the use of the call CQ, followed by the letter K, is 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.

232. *Question.* What are the calling frequencies and when are they used?

Answer. The calling frequencies are 500 kilocycles (600 meters) and 143 kilocycles (2100 meters) and are to be used for calling purposes only. As soon as communication has been established on either of these frequencies the frequency should be changed to one of other prescribed frequencies for the handling of communications. (This does not apply to the handling of distress messages.)

233. *Question.* What is the urgent signal? When is it used?

Answer. The urgent signal is XXX sent several times before the call letters. It shall be transmitted only with the authorization of the master or person responsible for the ship. It is used to indicate that the calling station has a very urgent message concerning the safety of the ship or another ship, or the safety of any person on board the ship or in sight of the ship.

234. *Question.* What signal denotes that a message has been received OK?

Answer. The letter R denotes that a message has been received OK.

235. *Question.* What signal is used as an invitation to go ahead with ·ansmission?

Answer. The letter K.

236. *Question.* (a) What is the end of message signal? (b) What is the ' of traffic signal?

Answer. (*a*) The transmission of a radiotelegram shall be terminated by the . — . — . followed by the call letters of the sending station and the letter

ıl

(*b*) The end of work between two stations shall be indicated by each of them, by means of the signal . . . — . — followed by their own call letters.

237. ***Question.*** **Who has the power to determine when the urgent signal shall be transmitted?**

Answer. The ship's master or person responsible for the ship.

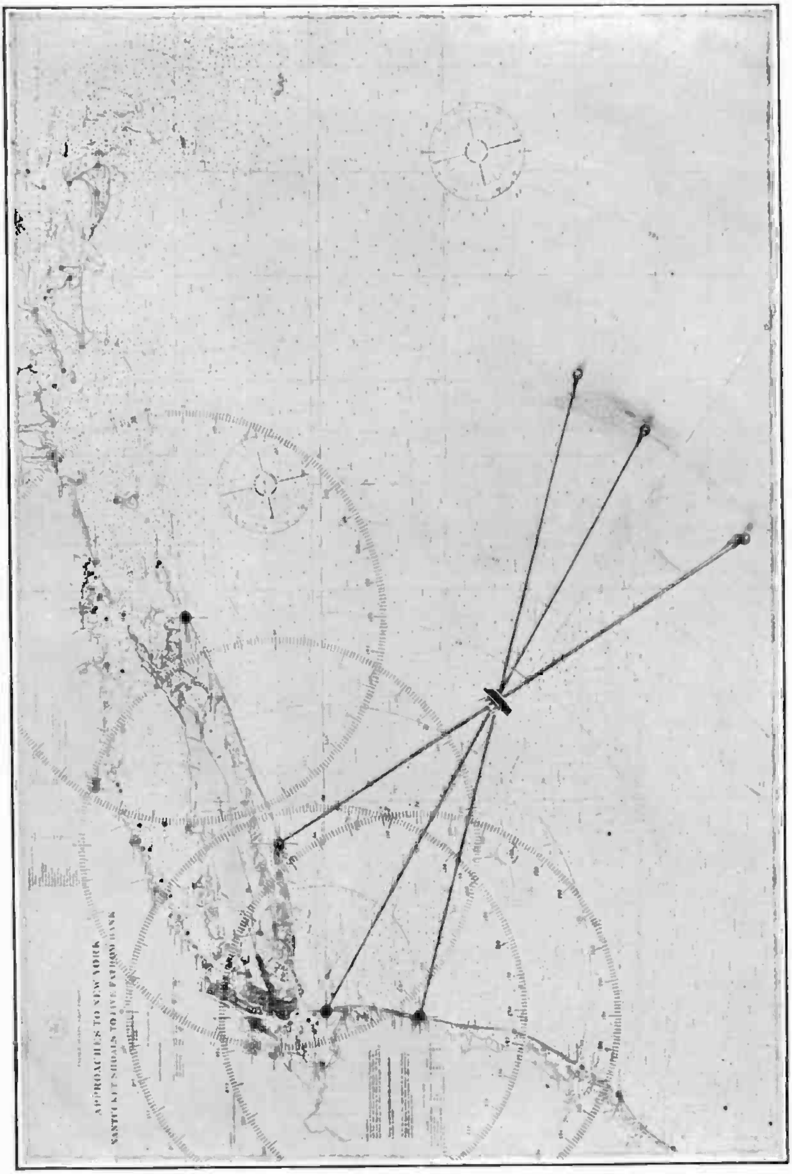


Fig. 90.—Illustrating intersection of three cross-bearings plotted against north and south line to determine position of vessels entering New York harbor.

238. ***Question.*** **How would you communicate with a foreign vessel whose crew can not understand English?**

Answer. By means of the International Signal Code and the International Radiotelegraphic Abbreviations.

239. *Question.* What would you do upon hearing an SOS? Explain fully.

Answer. All transmissions capable of interfering with the signal or message of distress must immediately cease. A ship which receives a distress message may transmit the distress message if the ship in distress is not itself in a position to transmit it, or if the master of the vessel judges that further help is necessary.

Stations which receive a distress message from a station which is evidently in the neighborhood must immediately acknowledge receipt thereof, taking care not to interfere with the transmission of the acknowledgment of receipt of the distress message sent by other stations.

Stations which receive a distress message from a station which is not evidently in their immediate vicinity must wait for a short period before acknowledging receipt thereof, for the purpose of permitting the station nearer to the station in distress to answer and acknowledge receipt, without interference.

The receipt of a distress message is acknowledged by transmitting the call letters of the station in distress three times, the word DE, the call letters of the station acknowledging receipt three times, the group RRR, and the distress signal.

Every station which acknowledges receipt of distress messages must make known as soon as possible its name and its position, taking care not to interfere with other stations which are in better position to carry immediate help to the station in distress.

All communications relating to distress messages must be delivered immediately to the master of the ship.

240. *Question.* What does the signal QSR mean?

Answer. The signal QSR, when followed by a question mark means, "Has the distress call received from .... been attended to?" When not followed by a question mark, the signal QSR means, "The distress call received from ....has been attended to by ...."

241. *Question.* What is the automatic alarm signal and how is it transmitted?

Answer. The automatic alarm signal is used to announce that a distress call will follow immediately. The alarm signal is composed of a series of 12 dashes sent in one minute, the duration of each dash being 4 seconds and the duration of the interval between 2 dashes, 1 second.

242. *Question.* What are the United States Regulations for auxiliary apparatus relative to distance and time?

Answer. An emergency power supply, independent of the ship's main power supply, must be provided which will enable radio messages to be sent for at least four hours over a distance of 100 miles day or night.

243. *Question.* What type of wave is used to transmit distress signals?

Answer. A modulated continuous wave (I.C.W. or A.C.C.W.) or a damped wave (spark) is used to transmit distress signals. Distress signals are transmitted on a wave of 500 kc. (600 meters) with maximum power.

244. *Question.* What is the priority of various classes of radio communications in their order?

Answer. 1. Distress calls and communications relating thereto.

2. Communications preceded by an urgent signal.

3. Communications preceded by the safety signal.

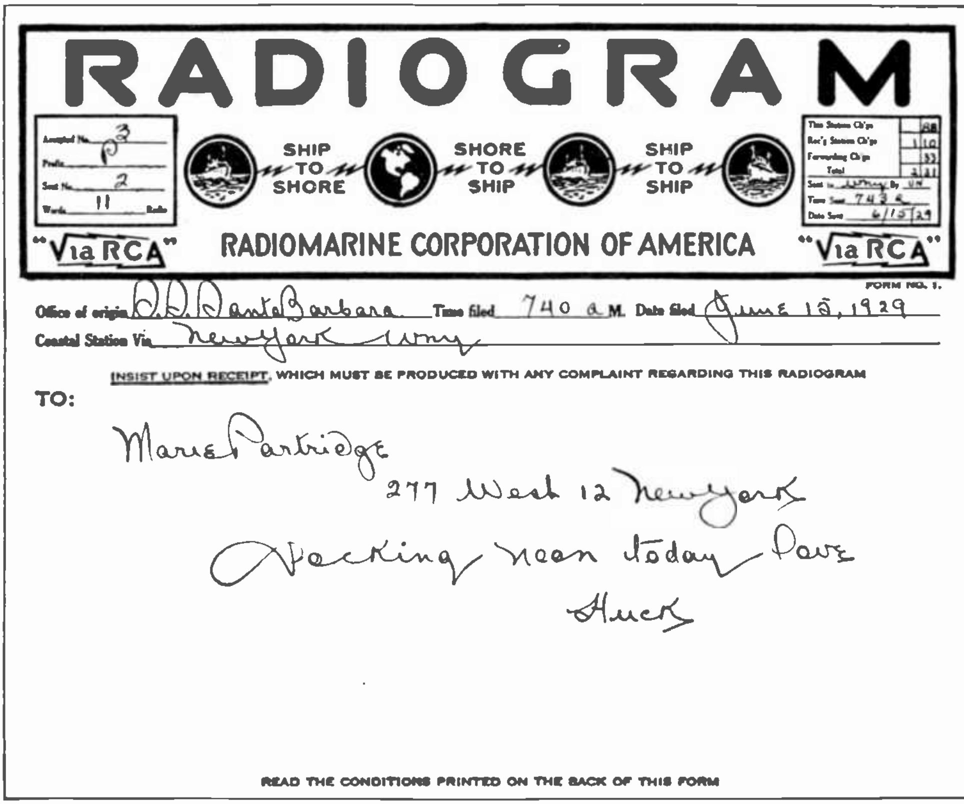
4. Communications relative to radio compass bearings.

5. Government radiotelegrams.

6. 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.

7. Service radiotelegrams relative to the operation of the radio service or to radiotelegrams previously exchanged.

8. Public correspondence radiotelegrams.


RADIOGRAM

SHIP TO SHORE — SHORE TO SHIP — SHIP TO SHIP

"Via RCA" RADIOMARINE CORPORATION OF AMERICA "Via RCA"

FORM NO. 1.

Office of origin ______ Time filed 740 A.M. Date filed June 15, 1929

Coastal Station Via New York

INSIST UPON RECEIPT, WHICH MUST BE PRODUCED WITH ANY COMPLAINT REGARDING THIS RADIOGRAM

TO:

Marie Partridge

277 West 12 New York

READ THE CONDITIONS PRINTED ON THE BACK OF THIS FORM

FIG. 91.—A radiogram originating on shipboard.

245. *Question.* What are the penalties which may be imposed for each violation of the United States Radio Act of 1927, and the regulations as they apply to operators?

Answer. Refer to the answer to Question 221.

246. *Question.* How is the filing time of a radiogram indicated?

Answer. The filing time of a radiogram is the time it was presented for transmission and, in transmission, immediately follows the office of origin. Greenwich Mean Time (0000 to 2359 hours) is used exclusively in Zone A. In other zones local ship (zone) time may be used (24 hour system followed by the letter F).

247. *Question.* Explain the system of checking the words in a radiogram.

Answer. All words in the address, text and signature are counted and charged for in accordance with the cable count system. (See the answer to Question 226.)

248. *Question.* What are the International requirements relative to a ship's arrival in port?

Answer. Every ship station whose radio service is on the verge of being closed by reason of its arrival in port must notify the nearest land station. A constant radio watch shall be maintained when entering any port of call, beginning eight hours before arrival.

249. *Question.* How should an SOS be sent?

Answer. The distress signal is transmitted three times, followed by the word DE and the call letters of the ship in distress transmitted three times. A wave of 500 kc. (600 meters) is used and the character of the emitted wave should be, preferably, modulated c.w. (I.C.W. or A.C.C.W.), or damped, with maximum output power.

The position of the ship should be expressed in latitude and longitude by the use of figures for degrees and minutes, accompanied by one of the words NORTH or SOUTH, and by one of the words EAST or WEST.

A dot separates the degrees from the minutes. Where necessary, the true bearing and the distance in nautical miles by relation to a known geographic point may be given.

The call and message of distress shall be sent out only with the authorization of the master or the person responsible for the ship. The distress call and the distress message must be repeated at frequent intervals until an answer has been received.

250. *Question.* What is meant by "superfluous signals"?

Answer. Superfluous signals are those which are unnecessary in carrying out efficient radio correspondence. They are forbidden.

251. *Question.* How would you find the nearest coast station when at sea?

Answer. (a) By sending the signal CQ three times followed by my call letters three times and inquiring of the station answering my CQ the call letters of the nearest shore station.

(b) By obtaining the ship's latitude and longitude from the master together with reference to the navigation chart whereon the location of land stations may be noted.

(c) By referring to charts furnished by radio operating companies and the Hydrographic Department which show the location of land stations.

252. *Question.* What is the law regarding the amount of power to be used in transmitting radio communications?

Answer. (a) Maximum power shall be used in transmitting distress messages or messages relating thereto.

(b) In all other classes of radio correspondence only that amount of power necessary to insure reliable communication shall be used.

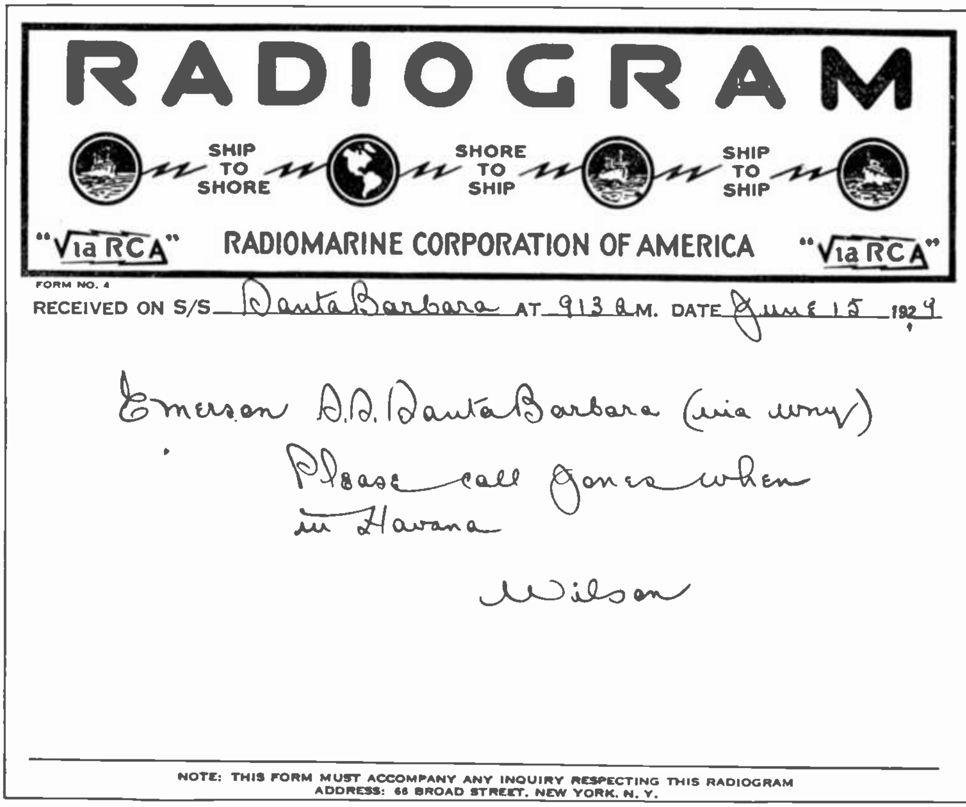
(c) When within 5 nautical miles of Naval or Military stations the transformer input shall not exceed ½ kw. and when within 15 miles of such stations the transformer input shall not exceed 1 kw.

253. *Question.* What is the penalty for disobeying the orders of the captain?

Answer. The operator's license will be suspended for a period not exceeding two years for failure to carry out the lawful orders of the master of the vessel on which the operator is employed.

254. *Question.* What station has control of distress traffic?

Answer. The station in distress has control of distress traffic. However, if another ship handles the distress traffic due to the inability of the ship in distress to communicate, then the other ship has control of the traffic.


RADIOGRAM
SHIP TO SHORE — SHORE TO SHIP — SHIP TO SHIP
"Via RCA" RADIOMARINE CORPORATION OF AMERICA "Via RCA"
FORM NO. 4
RECEIVED ON S/S Santa Barbara AT 913 A.M. DATE June 15 1924

Emerson S.S. Santa Barbara (via wny)
Please call Jones when in Havana
Wilson

NOTE: THIS FORM MUST ACCOMPANY ANY INQUIRY RESPECTING THIS RADIOGRAM
ADDRESS: 66 BROAD STREET, NEW YORK, N. Y.

FIG. 92.—A radiogram received on shipboard.

255. *Question.* What is the International law regarding the 600-meter watch?

Answer. All ships must listen in on the wave of 600 meters for three minutes twice each hour, beginning at the 15th minute and at the 45th minute after each hour, and also during the time of distress communications.

256. *Question.* Does the responsibility of communication rest with the ship or the coast station?

Answer. As a general rule, responsibility for establishing communication with the land station rests with the ship station.

257. *Question.* (a) What is the purpose of the Ship Act? (b) What is the main purpose of the International Radiotelegraphic Convention?

Answer. (*a*) The purpose of the Ship Act is to make it unlawful for any ship carrying fifty or more persons to leave or attempt to leave any port of the United States, navigating the ocean or the Great Lakes, unless such ship is equipped with radio apparatus capable of receiving and transmitting messages over a distance of at least 100 miles, day or night.

(*b*) To draft international radio regulations.

258. *Question.* In the case of a series of radiograms what signal is used to terminate the series?

Answer. In the case of a series of radiograms the call letters of the sending station followed by the signal — . — only shall terminate the series.

259. *Question.* How many times may a radiotelegram be repeated?

Answer. Three times.

CHAPTER VII

APPENDIX

Electrical Prefixes:

Kilo — Denotes a quantity one thousand times as great as a unit.
Milli — Denotes a quantity equal to one-thousandth part of a unit.
Micro — Denotes a quantity equal to one-millionth part of a unit.
Meg — Denotes a quantity one million times as great; for example, 1,000,000 cycles = 1 megacycle, and 1,000,000 ohms = 1 megohm.
Pica — Denotes a quantity one-millionth of one-millionth part of a unit (some authorities use picafarad to express the quantity micro-microfarad).

Ohm's Law for direct current

$$I = \frac{E}{R} \qquad R = \frac{E}{I} \qquad E = I \times R$$

where I = amperes;
E = volts;
R = resistance.

Formula for resistances in series

$$R_{(\text{Total})} = R_1 + R_2 + R_3 \quad \text{etc.}$$

Formula for resistances in parallel

$$R_{(\text{Total})} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \text{ etc.}}$$

Determination of frequency of an alternator

$$\text{Frequency} = \frac{N \times S}{2}$$

where N = the number of field poles;
S = the speed of the armature in revolutions per second.

Chemical action in a lead cell during charge and discharge

$$PbO_2 + Pb + 2H_2SO_4 \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftarrows}} 2PbSO_4 + 2H_2O$$

Fundamental frequency formula

$$f = \frac{1}{2\pi\sqrt{LC}}$$

where f = frequency in cycles per second;
L = inductance of the circuit in henries;
C = capacitance of the circuit in farads.

Inductive reactance formula

$$X_L = 2\pi f L$$

where X_L = inductive reactance;
L = inductance in henries.

Capacitive reactance formula

$$X_c = \frac{1}{2\pi f C}$$

where X_c = capacitive reactance;
C = capacity in farads.

Ohm's Law for alternating current

$$I = \frac{E}{Z} \quad \text{or} \quad I = \frac{E}{\sqrt{R^2 + \left[\left(2\pi f L\right) - \left(\frac{1}{2\pi f C}\right)\right]^2}}$$

where I = current;
E = voltage;
Z = impedance (total of all oppositions).

Condensers connected in parallel

$$C_{(\text{Total})} = C_1 + C_2 + C_3 \quad \text{etc.}$$

Condensers connected in series

$$C_{(\text{Total})} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \text{ etc.}}$$

Resonance formula

$$2\pi f L = \frac{1}{2\pi f C}$$

where $2\pi f L$ = inductive reactance;
and $\frac{1}{2\pi f C}$ = capacitive reactance.

Wavelength formula

$$(\lambda) \text{ wavelength} = 1884\sqrt{LC}$$

where L = inductance in microhenries;
and C = capacity in microfarads.

Antenna radiation formula

$$W = 1578 \times \frac{h^2}{\lambda^2} \times I^2$$

in which W = the energy radiated in watts effective;
h = the effective heighth of the antenna in meters;
λ = the wavelength of the antenna in meters;
I = the current in amperes at the base of the antenna or point of maximum current.

FREQUENCY VERSUS WAVELENGTH

$$f = \frac{V}{\lambda}$$

where f = frequency in cycles
λ = wavelength in meters
V = the velocity of propagation of electromagnetic waves, or 299,820,000 meters per second.

KILOCYCLES TO METERS, OR

Meters	Kilo-cycles	Meters	Kilo-cycles	Meters	Kilo-cycles	Meters	Kilo-cycles	Meters	Kilo-cycles
5	59960	500	599.6	1000	299.8	1500	199.9	2000	149.9
10	29980	510	587.9	1010	296.9	1510	198.6	2010	149.2
20	14990	520	576.6	1020	293.9	1520	197.2	2020	148.4
30	9994	530	565.7	1030	291.1	1530	196.0	2030	147.7
40	7496	540	555.2	1040	288.3	1540	194.7	2040	147.0
50	5996	550	545.1	1050	285.5	1550	193.4	2050	146.3
60	4997	560	535.4	1060	282.8	1560	192.2	2060	145.5
70	4283	570	526.0	1070	280.2	1570	191.0	2070	144.8
80	3748	580	516.9	1080	277.6	1580	189.0	2080	144.1
90	3331	590	508.2	1090	275.1	1590	188.6	2090	143.5
100	2998	600	499.7	1100	272.6	1600	187.4	2100	142.3
110	2726	610	491.5	1110	270.1	1610	186.2	2110	142.1
120	2499	620	483.6	1120	267.7	1620	185.1	2120	141.4
130	2306	630	475.9	1130	265.3	1630	183.9	2130	140.8
140	2142	640	468.5	1140	263.0	1640	182.8	2140	140.1
150	1999	650	461.3	1150	260.7	1650	181.7	2150	139.5
160	1874	660	454.3	1160	258.5	1660	180.6	2160	138.8
170	1764	670	447.5	1170	256.3	1670	179.5	2170	138.1
180	1666	680	440.9	1180	254.1	1680	178.5	2180	137.5
190	1578	690	434.5	1190	252.0	1690	177.4	2190	136.9
200	1499	700	428.3	1200	249.9	1700	176.4	2200	136.3
210	1428	710	422.3	1210	247.8	1710	175.3	2210	135.7
220	1363	720	416.4	1220	245.8	1720	174.3	2220	135.1
230	1304	730	410.7	1230	243.8	1730	173.3	2230	134.4
240	1249	740	405.2	1240	241.8	1740	172.3	2240	133.8
250	1199	750	399.8	1250	239.9	1750	171.3	2250	133.3
260	1153	760	394.5	1260	238.0	1760	170.4	2260	132.7
270	1110	770	389.4	1270	236.1	1770	169.4	2270	132.1
280	1071	780	384.4	1280	234.2	1780	168.4	2280	131.5
290	1034	790	379.5	1290	232.4	1790	167.5	2290	130.9
300	999.4	800	374.8	1300	230.6	1800	166.6	2300	130.4
310	967.2	810	370.2	1310	228.9	1810	165.6	2310	129.8
320	936.9	820	365.6	1320	227.1	1820	164.7	2320	129.2
330	908.6	830	361.2	1330	225.4	1830	163.8	2330	128.7
340	881.8	840	356.9	1340	223.7	1840	162.9	2340	128.1
350	856.6	850	352.7	1350	222.1	1850	162.1	2350	127.6
360	832.8	860	348.6	1360	220.4	1860	161.2	2360	127.0
370	810.3	870	344.6	1370	218.8	1870	160.3	2370	126.5
380	789.0	880	340.7	1380	217.3	1880	159.5	2380	126.0
390	768.8	890	336.9	1390	215.7	1890	158.6	2390	125.4
400	749.6	900	333.1	1400	214.2	1900	157.8	2400	124.9
410	731.3	910	329.5	1410	212.6	1910	157.0	2410	124.4
420	713.9	920	325.9	1420	211.1	1920	156.2	2420	123.9
430	697.3	930	322.4	1430	209.7	1930	155.3	2430	123.4
440	681.4	940	319.0	1440	208.2	1940	154.5	2440	122.9
450	666.3	950	315.6	1450	206.8	1950	153.8	2450	122.4
460	651.8	960	312.3	1460	205.4	1960	153.0	2460	121.9
470	637.9	970	309.1	1470	204.0	1970	152.2	2470	121.4
480	624.6	980	305.9	1480	202.6	1980	151.4	2480	120.9
490	611.9	990	302.8	1490	201.2	1990	150.7	2490	120.4

This table is used to convert wavelength in meters to kilocycles or kilocycles to meters. It should be remembered that the values are interchangeable, for example:

If the wavelength in meters is required for 1300 kilocycles, it can be found by referring to the figure 1300 in the "Meters" column. Here it is seen that the corresponding figure is 230.6 in the "Kilocycles" column.

Therefore,

1300 kc. = 230.6 meters.

Example: To find the frequency in cycles of a wavelength of 200 meters:

$$f = \frac{V}{\lambda} = \frac{299{,}820{,}000}{200} = 1{,}499{,}100 \text{ cycles,}$$

or 1499 kilocycles.

The wavelength may be obtained by transposing the above formula:

$$\lambda = \frac{V}{f} = \frac{299{,}820{,}000}{1{,}499{,}100} = 200 \text{ meters.}$$

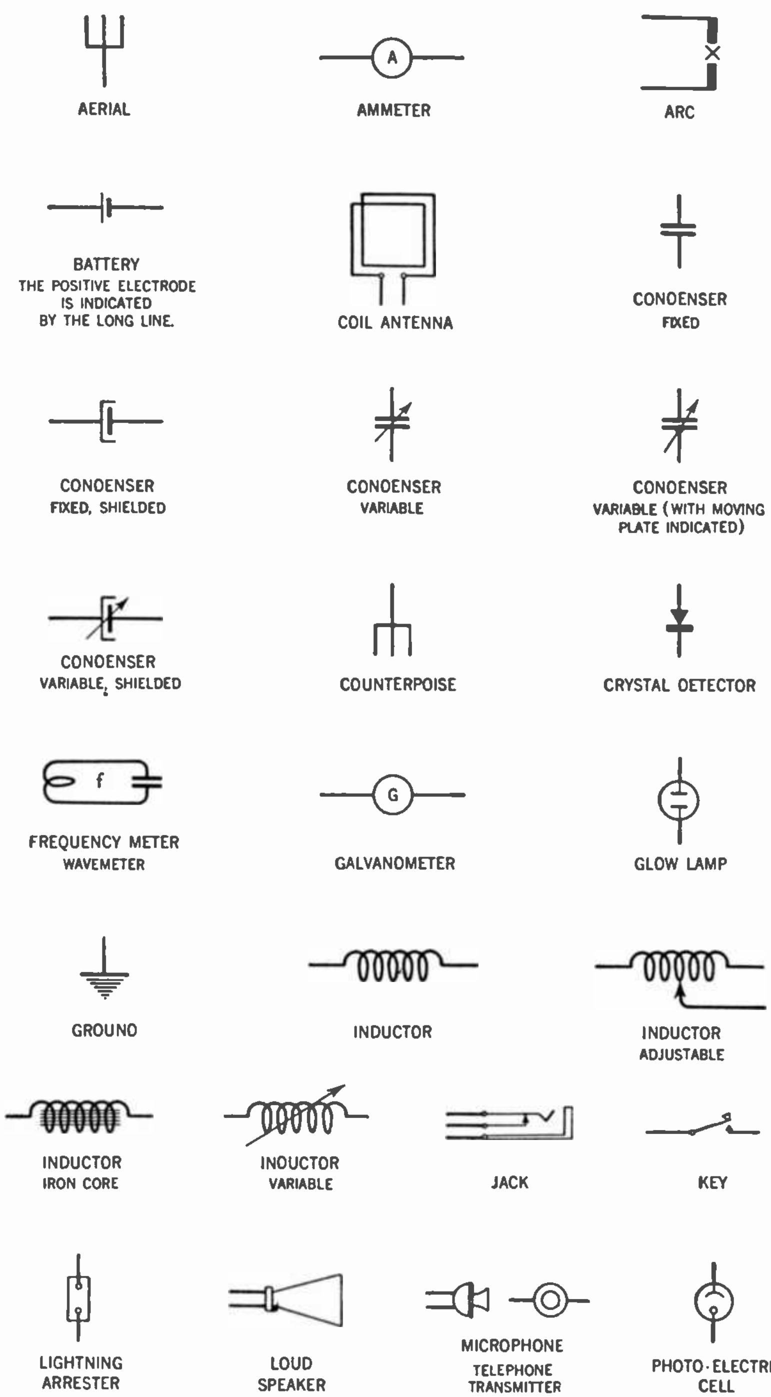
METERS TO KILOCYCLES

Meters	Kilo-cycles	Meters	Kilo-cycles	Meters	Kilo-cycles	Meters	Kilo-cycles	Meters	Kilo-cycles
2500	119.9	3000	99.94	4000	74.96	5000	59.96	7500	39.98
2510	119.5	3020	99.28	4020	74.58	5050	59.37	7550	39.71
2520	119.0	3040	98.62	4040	74.21	5100	58.79	7600	39.45
2530	118.5	3060	97.98	4060	73.85	5150	59.22	7650	39.19
2540	118.0	3080	97.34	4080	73.49	5200	57.66	7700	38.94
2550	117.6	3100	96.72	4100	73.13	5250	57.11	7750	38.69
2560	117.1	3120	96.10	4120	72.77	5300	56.75	7800	38.44
2570	116.7	3140	95.48	4140	72.42	5350	57.11	7850	38.19
2580	116.2	3160	94.88	4160	72.07	5400	55.52	7900	37.95
2590	115.8	3180	94.28	4180	71.73	5450	55.01	7950	37.71
2600	115.3	3200	93.69	4200	71.39	5500	54.51	8000	37.48
2610	114.9	3220	93.11	4220	71.05	5550	54.02	8050	37.25
2620	114.4	3240	92.54	4240	70.71	5600	53.54	8100	37.02
2630	114.0	3260	91.97	4260	70.38	5650	53.07	8150	36.79
2640	113.6	3280	91.41	4280	70.05	5700	52.60	8200	36.56
2650	113.1	3300	90.86	4300	69.73	5750	52.14	8250	36.34
2660	112.7	3320	90.31	4320	69.40	5800	51.69	8300	36.12
2670	112.3	3340	89.77	4340	69.08	5850	51.25	8350	35.91
2680	111.9	3360	89.23	4360	68.77	5900	50.82	8400	35.69
2690	111.5	3380	88.70	4380	68.45	5950	50.39	8450	35.48
2700	111.0	3400	88.18	4400	68.14	6000	49.97	8500	35.27
2710	110.6	3420	87.67	4420	67.83	6050	49.56	8550	35.07
2720	110.2	3440	87.16	4440	67.53	6100	49.15	8600	34.86
2730	109.8	3460	86.65	4460	67.22	6150	48.75	8650	34.66
2740	109.4	3480	86.16	4480	66.91	6200	48.36	8700	34.46
2750	109.0	3500	85.66	4500	66.63	6250	47.97	8750	34.27
2760	108.6	3520	85.18	4520	66.33	6300	47.59	8800	34.07
2770	108.2	3540	84.70	4540	66.04	6350	47.22	8850	33.88
2780	107.8	3560	84.22	4560	65.75	6400	46.85	8900	33.69
2790	107.5	3580	83.75	4580	65.46	6450	46.48	8950	33.50
2800	107.1	3600	83.28	4600	65.18	6500	46.13	9000	33.31
2810	106.7	3620	82.82	4620	64.90	6550	45.77	9050	33.13
2820	106.3	3640	82.37	4640	64.62	6600	45.43	9100	32.95
2830	105.9	3660	81.92	4660	64.34	6650	45.09	9150	32.77
2840	105.6	3680	81.47	4680	64.06	6700	44.75	9200	32.59
2850	105.2	3700	81.03	4700	63.79	6750	44.42	9250	32.41
2860	104.8	3720	80.60	4720	63.52	6800	44.09	9300	32.24
2870	104.5	3740	80.17	4740	63.25	6850	43.77	9350	32.07
2880	104.1	3760	79.74	4760	62.90	6900	43.45	9400	31.90
2890	103.7	3780	79.32	4780	62.72	6950	43.14	9450	31.73
2900	103.4	3800	78.90	4800	62.46	7000	42.83	9500	31.56
2910	103.0	3820	78.49	4820	62.20	7050	42.53	9550	31.39
2920	102.7	3840	78.08	4840	61.95	7100	42.23	9600	31.23
2930	102.3	3860	77.67	4860	61.69	7150	41.93	9650	31.07
2940	102.0	3880	77.27	4880	61.44	7200	41.64	9700	30.91
2950	101.6	3900	76.88	4900	61.19	7250	41.35	9750	30.75
2960	101.3	3920	76.49	4920	60.94	7300	41.07	9800	30.59
2970	100.9	3940	76.10	4940	60.69	7350	40.79	9850	30.44
2980	100.6	3960	75.71	4960	60.45	7400	40.52	9900	30.28
2990	100.3	3980	75.33	4980	60.20	7450	40.24	9950	30.13

Values of wavelengths not listed in the columns may be found by applying the decimal system. For example it may be desired to find the frequency corresponding to 372 meters. There is no wavelength value given to correspond to this number. Therefore, by multiplying 372 by 10, we obtain the figure 3720, which is found listed in the "Meters" column and corresponding to a frequency of 80.60. Since the first value is multiplied by 10, we can move the decimal point one place to the right, giving us a value of 806.0 kc. Therefore, a wavelength of 372 meters corresponds to a frequency of 806 kc.

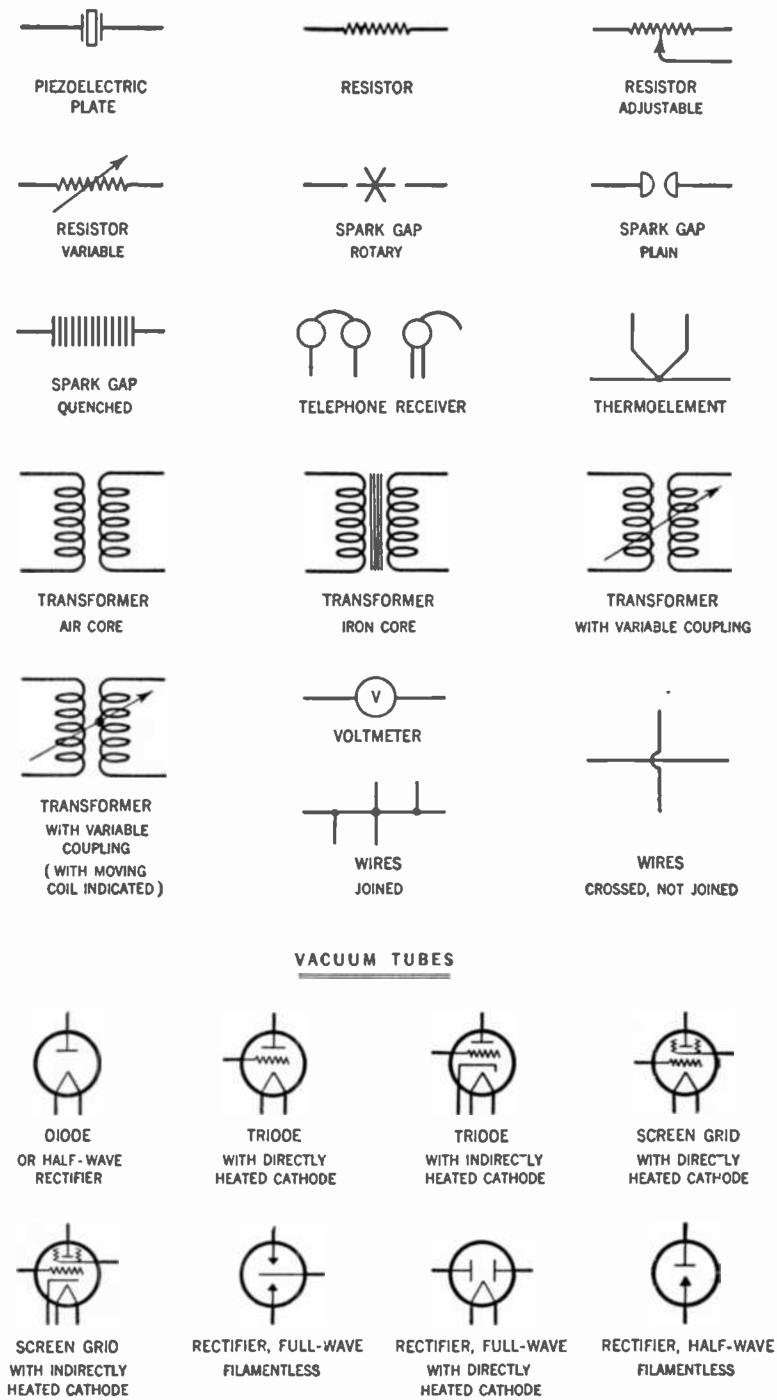
STANDARD RADIO SYMBOLS

COURTESY, INSTITUTE OF RADIO ENGINEERS



STANDARD RADIO SYMBOLS

COURTESY, INSTITUTE OF RADIO ENGINEERS



LOGARITHMIC DECREMENT

Logarithmic decrement (δ) of wave train and the approximate number of waves N in the wave train before the amplitude falls to 0.1 of the maximum amplitude.

δ	N	δ	N
0.20	12.5	0.03	78.0
0.15	16.0	0.02	116.0
0.10	24.0	0.01	231.0
0.05	47.0	0.005	462.0

If each wave train emitted by a spark transmitter possesses 15 or more oscillations good tuning is possible.

The formula for the number of waves in a wave train is:

$$N = \frac{2.3026 + \delta}{\delta}$$

where 2.3026 = Napierian logarithm of 10

δ = decrement of transmitter (antenna circuit).

Example: The number of waves in each wave train transmitted with a decrement of 0.02 is found in the following substitution:

$$N = \frac{2.3026 + 0.02}{0.02} = 116.$$

whence N = 116.

Greek alphabet

Letters	Names	Letters	Names	Letters	Names
Α α	Alpha	Ι ι	Iota	Ρ ρ	Rho
Β β	Beta	Κ κ	Kappa	Σ σ ς	Sigma
Γ γ	Gamma	Λ λ	Lambda	Τ τ	Tau
Δ δ	Delta	Μ μ	Mu	Υ υ	Upsilon
Ε ε	Epsilon	Ν ν	Nu	Φ φ	Phi
Ζ ζ	Zeta	Ξ ξ	Xi	Χ χ	Chi
Η η	Eta	Ο ο	Omicron	Ψ ψ	Psi
Θ θ	Theta	Π π	Pi	Ω ω	Omega

Signs

$\propto$	proportional to; varies as	$\angle$	angle
=	equal to	<	is less than
×	multiplied by	$\ll$	much less than
+	plus; addition	>	is greater than
−	minus; subtraction	$\gg$	much greater than
÷	divided by	∞	cycle
⊙	circle		

Symbols

μ = permeability (B/H)
π = 3.1416
ρ = volume resistivity
τ = thickness
κ = susceptibility
λ = wavelength in meters
δ = logarithmic decrement
ϵ = 2.7183 (base of Napierian logarithms)
η = efficiency (per cent)
θ = phase angle (degree or radian)
ϕ = angle
ψ = difference in phase
ω = $2\pi f$ (angular velocity in radians per second);
Φ = magnetic flux
Ψ = electrostatic flux
Ω = ohm
Υ = electric conductivity
$\mathcal{E}$ = electric field intensity
$\mathcal{F}$ = magnetomotive force
$\mathcal{R}$ = reluctance

a-f = audio-frequency
r-f = radio-frequency
e.m.f. = electromotive force
m.m.f. = magnetomotive force
a-c = alternating current
d-c = direct current
μf = microfarad
$\mu\mu$f = micro-microfarad
h = henry
mh = millihenry
μh = microhenry
f = frequency
MΩ = megohm
rms = root-mean-square
rpm = revolutions per minute
rps = revolutions per second

Abbreviations

C capacity (electrostatic capacity)
E effective electromotive force
I effective current
K dieletric constant
L inductance
M mutual inductance
N number of conductors or turns
Q quantity of electricity
R resistance
T period, or one complete cycle
W watts
X reactance
Z impedance

d diameter; distance
f frequency; cycles per second
g conductance
h height
i instantaneous current
k coefficient of coupling
l length
r distance from a point (radius)
t time
v velocity

THE TRANSMISSION UNIT *

A transmission unit is a unit for the logarithmic expression of ratios of power, voltages, or currents, in a transmission system.

There are now in rather widespread use, internationally, two transmission units, a Napierian unit called the "Neper," and a decimal unit called the "Bel." Decimal multiples or sub-multiples of either of these units may be used, such as "decineper" and "decibel."

The number of units of transmission in the case of a ratio of two powers, P_1 and P_2 is:

$$\text{in the napierian system: } 1/2 \log_e \frac{P_1}{P_2}$$

$$\text{in the decimal system: } \log_{10} \frac{P_1}{P_2}.$$

The number of units of transmission in the case of a ratio of two voltages, E_1 and E_2, of two currents I_1 and I_2, if the squares of these ratios are equal to the power ratio is:

$$\text{in the napierian system: } \log_e \frac{E_1}{E_2} \text{ or } \log \frac{I_1}{I_2}$$

$$\text{in the decimal system: } 2 \log_{10} \frac{E_1}{E_2} \text{ or } 2 \log_{10} \frac{I_1}{I_2}.$$

The unit based on the decimal system and having a size one-tenth of that here defined is widely used in the United States. This unit is, therefore, the "decibel" (abbreviated "db") and has been generally referred to merely as "the transmission unit" or "TU."

The following table gives the numerical values of power, voltage, and current ratios corresponding to particular numbers in decibels:

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

* Courtesy, Institute of Radio Engineers.

LIST OF ABBREVIATIONS TO BE USED IN RADIO TRANSMISSIONS

Q CODE [1]

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 station is ...... nautical miles (or ...... kilometers).
QRC	By what private company (or goverment 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 you receiving me badly? Are my signals weak?	I can not receive you. Your signals are too weak.
QRK	Are you 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 V's?	Send a series of V's.
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 signals is ...... (1 to 5).
QSB	Does the strength of my signals vary?	The strength of your signals 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.
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 .....

[1] The abbreviations take the form of questions when they are followed by question marks.

List of abbreviations to be used in radio transmissions—Continued

Abbreviation	Question	Answer
QSU (See page 168)	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 V's?	Shift to wave of ... meters (or of ...... kilocycles) for the balance of our communications and continue after having sent several V's.
QSW (See page 168)	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 one minute on a wave length of .... meters (or .... kilocycles) in order that I may take your bearing by radio compass?	I am sending my call signal for one minute on the wave length of .... meters (or .... kilocycles) in order that you may take my bearing by radio compass.
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 radio beacon.
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 ......

II. *Abbreviations more especially used in the aircraft radio service*

QAA..............	At what time do you expect to arrive at ......?	I expect to arrive at ...... at ...... (o'clock).
QAB..............	Are you en route to ......?..............	I am en route to ...... or Go to ......
QAC..............	Are you returning to ......?.............	I am returning to ...... or Return to....
QAD..............	At what time did you leave ...... ? (place of departure).	I left ...... (place of departure) at ...... (o'clock).
QAE..............	Have you news of ...... (call signal of the aircraft station)?	I have no news of ...... (call signal of the aircraft station).
QAF..............	At what time did you pass ......?.........	I passed ...... at ...... (o'clock).
QAH..............	What is your height?....................	My height is ...... meters (or according to any other indication).
QAI..............	Has any aircraft signaled in my neighborhood?	No aircraft has signaled in your neighborhood.
QAJ..............	Must I look for another aircraft in my neighborhood?	Look for another aircraft in your neighborhood (or) Look for ...... (call signal of the aircraft station) which was flying near ...... (or in the direction of ......) at ...... (o'clock).

List of abbreviations to be used in radio transmissions—Continued

Abbreviation	Question	Answer
QAK	On what wave are you going to send the meteorological warning messages?	I am going to send the meteorological warning messages on wave length of ...... meters (or ...... kilocycles).
QAL	Are you going to land at ......?	I am going to land at ...... or Land ......
QAM	Can you give me the latest meteorological message concerning weather for ...... (place of observation)?	Here is the latest meteorological message concerning weather for ...... (place of observation).
QAN	Can you give me the latest meterological message concerning surface wind for ...... (place of observation)?	Here is the latest meteorological message concerning surface wind for ...... (place of observation).
QAO	Can you give me the latest meteorological message concerning upper wind for ...... (place of observation)?	Here is the latest meteorological message concerning upper wind for ...... (place of observation).
QAP	Must I continue to listen for you (or for ......) on ...... meters (or ...... kilocycles?	Continue to listen for me (or for ......) on ...... meters (or ...... kilocycles).
QAQ	Will you hasten the reply to message No. ...... (or in accordance with any other indication)?	I hasten the reply to message No. ...... (or in accordance with any other indication).
QAR	Must I reply to ...... for you?	Reply to ...... for me.
QAS	Must I send message No. ...... (or in accordance with any other indication) to ......?	Send message No. ...... (or in accordance with any other indication) to ......
QAT	Must I continue to send	Listen before sending; you are interfering; or Listen before sending; you are sending at the same time as ......
QAU	What is the last message received by you from ......?	The last message received by me from ...... is ......
QAV	Are you calling me? or Are you calling ...... (call signal of the aircraft station?	I am calling you or I am calling ...... (call signal of the aircraft station).
QAW	Must I cease listening until ...... (o'clock)?	Cease listening until ...... (o'clock).
QAX	Have you received the urgent signal sent by ...... (call signal of the aircraft station)?	I received the urgent signal sent by ...... call signal of the aircraft station) at ...... (o'clock).
QAY	Have you received the distress signal sent by ...... (call signal of the aircraft station)?	I received the distress signal sent by ...... (call signal of the aircraft station) at ...... (o'clock).
QAZ	Can you receive in spite of the storm?	I can no longer receive. I am going off watch because of the storm.

III. *Miscellaneous Abbreviations*

Abbreviation	Meaning
C	Yes.
N	No.
P	Announcement of private telegram in the mobile service (to be used as a prefix).
W	Word or words.
AA	" All after ......" (to be used after a question mark to request a repetition).
AB	" All before ......" (to be used after a question mark to request a repetition).
AL	"All that has just been sent " (to be used after a question mark to request a repetition).
BN	" All between ......" (to be used after a question mark to request a repetition).
BQ	Announcement of reply to a request for rectification.
CL	" I am closing my station."
CS	Call signal (to be used to ask repetition of a call signal).
DB	" I cannot give you a bearing, you are not in the calibrated sector of this station."
DC	" The minimum of your signal is suitable for the bearing."
DF	Your bearing at ...... (o'clock) was ...... degrees, in the doubtful sector of this station with a possible error of two 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 two 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 radio-compass 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).

III. *Miscellaneous Abbreviations*—Continued

Abbreviation	Meaning
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 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 " only (to be used 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).

Scale used to express strength of signals:

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.

Types of Radio Waves

Refer to abbreviations QSU and QSW

A1 = continuous waves, unmodulated (CW)
A2 = continuous waves, modulated (ICW or ACCW)
A3 = continuous waves, modulated by speech or music (phone)
A4 = damped waves (spark).

INTERNATIONAL MORSE CODE AND CONVENTIONAL SIGNALS

To be used for all general public service radio communication

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

A • —
B — • • •
C — • — •
D — • •
E •
F • • — •
G — — •
H • • • •
I • •
J • — — —
K — • —
L • — • •
M — —
N — •
O — — —
P • — — •
Q — — • —
R • — •
S • • •
T —
U • • —
V • • • —
W • — —
X — • • —
Y — • — —
Z — — • •

Ä (German) • — • —
Á or Å (Spanish-Scandinavian) • — — • —
CH (German-Spanish) — — — —
É (French) • • — • •
Ñ (Spanish) — — • — —
Ö (German) — — — •
Ü (German) • • — —

1 • — — — —
2 • • — — —
3 • • • — —
4 • • • • —
5 • • • • •
6 — • • • •
7 — — • • •
8 — — — • •
9 — — — — •
0 — — — — —

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