RESTRICTED

INSTRUCTIONS

COMBINED HETERODYNE FREQ. METER AND CRYSTAL CONTROLLED CALIBRATOR EQUIPMENT

MODEL LR-1 SERIAL

FREQUENCY RANGE: 160-30,000 KCS.

SUPPLY: 110-115-120 VOLTS—60 CYCLES

SEE LICENSE NOTICE INSIDE

NAVY DEPARTMENT
BUREAU OF ENGINEERING

CONTRACTOR

GENERAL RADIO CO.
CAMBRIDGE, MASS.

CONTRACT NOs-83891 CONTRACT DATE: 7 APRIL 1941

GENERAL RADIO COMPANY

CAMBRIDGE, MASS.

Personnel engaged in the installation, operation and maintenance of this equipment or similar equipments are urged to become familiar with the following rules both *in theory and the practical application thereof.* It is the duty of every radio man to be prepared to give adequate first aid and thereby prevent avoidable loss of life. Your own life may depend on this.

ARTIFICIAL RESPIRATION

Prone-Pressure Method

When a person is shocked by electric current, first shut off the current if it can be done quickly. Otherwise set about removing subject from contact with wire or rail. During the process of removal, the rescuer must not come in contact with the body of the person shocked. Use rubber gloves, rubber coat, silk, dry board, dry cloth.

In gas poisoning from automobile exhaust gas, illuminating gases, and gas from burning charcoal, the carbon monoxide combines with the blood, actually diminishing the amount of oxygen the blood can absorb.

The prone-pressure method of artificial respiration described in these rules should be used in cases of suspended respiration from all causes — drowning, electric shock, carbon monoxide poisoning, injuries, etc. Follow the instructions even if the patient appears dead. Continue artificial respiration until natural breathing is restored or until a physician advises you to discontinue your efforts.

(1) Lay the patient on his stomach, one arm fully extended overhead, the other arm bent at elbow and with the face turned outward and resting on hand or forearm. (This protects the mouth and nose from dirt, provides a slant to head for drainage, and allows tongue to drop forward.)

(2) Kneel straddling the patient's thigh or thighs, with your knees placed at such distance from the hip bones as will allow you to lean forward with your hands on the patient's lower ribs.

Place palms of the hands over lower ribs, one on each side of the spine, about four inches apart, at right angles to spine, with the thumb and fingers in a natural position. The hands are in correct position when the little finger of each hand is over and following the line of the lowest rib. See Figure 1.

(3) Move weight of body slowly downward and forward for three seconds (count 1-2-3 slowly); do not let hands slip. Keep arms straight. The shoulder should be behind the hands, so that the pressure exerted is forward as well as downward, and by the "heels" of the hands, and not the fingers. See Figure 2.

(4) Release pressure suddenly, removing hands from the patient, allowing patient's chest to expand and fill with air. After two seconds interval (count 1-2 slowly) repeat pressure. This makes one respiration every five seconds, twelve per minute. *Do not work faster than this.* After rhythm is obtained actual counting can be stopped. See Figure 3.

During the interval operator can swing back and sit on his heels, thus relaxing muscles of his back. This will enable him to work for a much longer period.

(5) Do not give up! There are cases on record of resuscitation after thirty minutes' submersion. There is no certain sign by which you can determine that it is too late for artificial respiration. If no results are seen the patient should not be abandoned until at least three and one-half hours of effort have been made to revive him.

SUPPLEMENTAL TREATMENT

While carrying on artificial respiration organize helpers, *but do not stop artificial respiration for anything.* Send for a physician, blankets, hot-water bottles or heated bricks, hot water or tea or coffee for stimulants (no alcoholics). Have patient's clothing loosened around neck and chest, mouth and nose cleared of any mucus or mud, and tongue moved back and forth occasionally to stim-

FIG. 1

FIG. 2

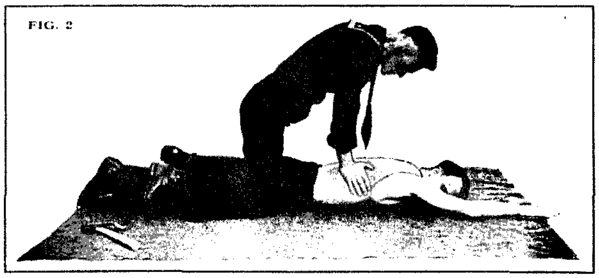


FIG. 3

ulate reflexes; body and limbs rubbed toward the heart. Have blankets and hot-water bottles applied but not any hot articles next to the patient's skin. If there is aromatic spirits of ammonia at hand have some poured on handkerchief and placed near patient's nose. Have the crowd that may have collected kept well back so as to give the patient plenty of air. Select an intelligent helper to watch you and so instruct him that he may be able to take your place when you need a relief.

When the patient begins to breathe and can swallow, give him sips of aromatic spirits of ammonia (teaspoonful to one-fourth glass of water), or hot water, coffee, or tea. Do not allow patient to walk or otherwise exert himself; he should be carried to some place where he can be put in bed and receive medical attention.

CAUTION

Often inexperienced or excited persons attempt to administer artificial respiration when there is no need for such treatment. It is not required when the patient, on removal from the water, is able to breathe. Such cases are in need of treatment for exposure and shock. They should be placed on a slanting surface, head down; covered by blankets and hot-water bottles; stimulated by hot drinks or aromatic spirits of ammonia (teaspoonful to one-fourth glass water); massage of limbs; carried to a bed for further medical attention.

Save the seconds and you have a better chance of saving the life. Do not waste time carrying patient to a quiet spot. Work where he is taken from the water. Do not waste time trying to get water out of the stomach. Turn patient's face down and *go to work immediately*.

RESTRICTED

INSTRUCTIONS

FOR

ASSEMBLY AND OPERATION

OF

COMBINED HETERODYNE FREQ. METER AND CRYSTAL CONTROLLED CALIBRATOR EQUIPMENT

MODEL LR-1 SERIAL

FREQUENCY RANGE: 160-30,000 KCS.

SUPPLY: 110-115-120 VOLTS — 60 CYCLES

SEE LICENSE NOTICE INSIDE

NAVY DEPARTMENT

BUREAU OF ENGINEERING

CONTRACTOR

GENERAL RADIO CO.

CAMBRIDGE, MASS.

CONTRACT NOs-83891 CONTRACT DATE: 7 APRIL 1941

DESIGNED AND MANUFACTURED BY

GENERAL RADIO COMPANY

CAMBRIDGE, MASS.

This instruction book is furnished for the information of commissioned, warrant, enlisted and civilian personnel of the Navy whose duties involve design, instruction, operation and installation of radio and sound equipment. The word "restricted" as applied to this instruction book signifies that the instruction book is to be read only by the above personnel, and that the contents of it should not be made known to persons not connected with the Navy.

FORM NO. 542-C

WARNING

Operation of this equipment involves the use of high voltages which are dangerous to life. Operating personnel must at all times observe all safety regulations. Do not change tubes or make adjustments inside equipment with high voltage supply on. Do not depend upon automatic connector for protection but always open main switch in power supply circuit particularly when using servicing cable for service tests. Under certain conditions dangerous potentials may exist in circuits with power control in the off position, due to charges retained by capacitors. To avoid casualties always discharge and ground circuits prior to touching them.

CAUTION: When the equipment is drawn forward on the slides, the power circuits to the supply (110–115–120 volt, 60-cycle) line are automatically broken on both sides.

CAUTION: When the automatic connector is bridged by the servicing cable, with the equipment drawn forward on the slides, for service tests or adjustments under operating conditions, great care must be taken not to touch the circuits until the power switch is thrown to the off position.

The attention of engineer officers, radio officers and operating personnel is directed to Bureau of Engineering Circular Letter No. 5a of October 3, 1934, or subsequent revisions thereof on the subject of "Radio-Safety Precautions to be Observed."

TABLE OF CONTENTS

SECTION	SUBJECT	PAGE
1	General Description	1
2	Installation	1
2.1	Drilling for Mounting	1
2.2	Release of Instrument from Slide Carriage	1
2.3	Bolting Down Shock Mountings	1
2.4	Grounding of Case	1
2.5	Connecting Power and Remote Telephone Leads	3
2.6	Replacing Instrument in Case	3
3	Principles of Operation; Engineering Discussion	3
3.1	General Statement	3
3.2	Component Elements	4
4	Operating Instructions	17
4.1	General	17
4.2	To Place Equipment in Operating Condition	17
4.3	Test of INTERPOLATOR Scale Alignment; Check of Heterodyne Frequency Meter (H.F.M.) Against Calibrator	18
4.4	To Set Up or Measure a Frequency — QUICK METHOD	19
4.5	To Set Up or Measure a Frequency — ACCURATE METHOD	20
4.6	Checking and Adjusting Calibrator Against Standard Frequency Transmissions; Using Calibrator Output in External Circuits	22
4.7	Use of Interpolator on Audio Frequencies from an External Source	23
4.8	Use of Equipment as a Source of Known Audio Frequencies	24
4.9	Operation if Part of Equipment is Faulty	24
5	Probable Troubles: Locating, Overcoming	26
5.1	General Statement	26
5.2	Calibrator	26
5.3	Heterodyne Frequency Meter	28
5.4	Detector and A. F. Amplifier	28
5.5	Interpolator	29
5.6	Power Supply	30
5.7	Locating Trouble	31
6	Access	33
6.1	General Statement	33
6.2	Access to Power Supply and By-Pass Capacitors of Audio-Frequency Amplifier	33
6.3	Access to Crystal Mounting; Heaters of Temperature Control. Removal of Crystal Mounting or Thermostat	33
6.4	Access to Connections of Main Tuning Capacitor, C-135; Heterodyne Frequency Meter Oscillator Circuits	33
6.5	To Remove Main Tuning Capacitor, C-135	33
6.6	To Remove the Main Direct-Reading Dial, N-103	34
6.7	To Remove RANGE SELECTOR Switch, S-102, and Coil Assembly	34
6.8	Access to Power Switch, S-106	34
6.9	Access to Sub-Assembly Under Tube Shelf Mounted on Main Top Shelf	34

(Continued on next page)

TABLE OF CONTENTS — *Continued*

SECTION	SUBJECT	PAGE
PARTS LISTS		35
Table I.	List of Major Units	35
Table II.	Parts List by Symbol Designation	35
Table III.	Parts List by Navy Type Numbers	50
Table IV.	Spare Parts List by Navy Type Numbers	53
Table V.	Applicable Color Codes — RMA Resistor	59
Table VI.	List of Manufacturers	60
PHOTOGRAPHS		61
VACUUM-TUBE DATA		69
	Socket Voltages and Currents	70
COMPLETE WIRING DIAGRAMS		72
WIRE COLOR CODE LIST		77

LIST OF ILLUSTRATIONS

Artificial Respiration		i
Frontispiece: Complete Model LR-1 Equipment		viii
DRAWINGS		
Figure 2.1	Mounting Dimensions	2
Figure 3.12	Functional Block Diagram of Model LR-1 Equipment	4
Figure 3.22	Schematic Circuit Diagram of Crystal-Controlled Calibrator	5
Figure 3.23	Schematic Circuit Diagram of Heterodyne-Frequency Meter	6
Figure 3.237	Harmonic Range and Multiplier Chart	9
Figure 3.24	Schematic Circuit Diagram of Detector and Audio Amplifier	10
Figure 3.245	Formation of Beat Frequencies	11
Figure 3.246	Formation of Extraneous Beat Frequencies	12
Figure 3.25	Schematic Circuit Diagram of Interpolator	13
Figure 3.252	Relation Between Beat Frequencies and Interpolator Scale	14
Figure 3.26	Schematic Circuit Diagram of Power Supply	16
Figure 4.632	Frequency Change vs. Dial Setting for Crystal Oscillator	23
Figure 4.962	Interpolation by Scale of Equal Parts	26
PHOTOGRAPHS		
	Complete Model LR-1 Equipment	viii
	Panel View	62
	Oblique View Showing Unit Drawn Forward on Slides	63
	Rear View with Cabinet Removed	64
	Front Oblique View of Left Side with Cabinet Removed	65
	Rear Oblique View of Left Side with Cabinet Removed	66
	Front Oblique View of Right Side with Cabinet Removed	67
	Rear Oblique View of Right Side with Cabinet Removed	68
COMPLETE WIRING DIAGRAMS		
Figure 1.	Calibrator	72
Figure 2.	Heterodyne Frequency Meter	73
Figure 3.	Detector and A-F Amplifier	74
Figure 4.	Interpolator	75
Figure 5.	Power Supply	76

CONTRACTUAL GUARANTEE

This equipment, including all parts and spare parts, except vacuum tubes, is guaranteed for a service period of ONE YEAR with the understanding that, as a condition of this contract, all items found to be defective as to design, material, workmanship or manufacture will be replaced without delay and at no expense to the Government; provided that such guarantee and agreement will not obligate the contractor to make replacement of defective material unless the failure, exclusive of normal expected shelf life deterioration, occurs within a period of TWO YEARS from the date of delivery of the equipment to and acceptance by the Government, and provided further, that if any part or parts (except vacuum tubes) fail or are found defective to the extent of ten per cent (10%) or more of the total number of similar units furnished under the contract (exclusive of spares), such part or parts, whether supplied in the equipment or as spares, will be conclusively presumed to be of defective design, and as a condition of contract subject to one hundred per cent (100%) replacement by suitable redesigned units.

Failure due to poor workmanship while not necessarily indicating poor design, will be considered in the same category as failure due to poor design. Redesigned replacements which will assure proper operation of the equipment will be supplied promptly, transportation paid, to the Naval activity using such equipment, upon receipt of proper notice and without cost to the Government.

All such defective parts will be subject to ultimate return to the contractor. In view of the fact that normal activities of the Naval Service may result in the use of equipment in such remote portions of the world under such conditions as to preclude the return of the defective item or unit prior to replacement without jeopardizing the integrity of Naval communications, the exigencies of the Service therefore may necessitate expeditious repair of such item or unit in order to prevent extended interruption of communications. In such cases the return of a defective item or unit, for examination by the contractor, prior to replacement will not be required. The report of a responsible authority, including details of the conditions surrounding the failure will be acceptable for effective adjustment under the provisions of this contractual guarantee.

The above period of TWO YEARS and the service period of ONE YEAR will not include any portion of the time that the equipment fails to give satisfactory performance due to defective items and the necessity for replacement thereof. All replacement parts will be guaranteed to give ONE YEAR of satisfactory service.

Report of failure of any part of this equipment, during its service life, shall be made to the Bureau of Engineering in accordance with current instructions. The report shall cover all details of the failure and give the date of installation of the equipment. Refer to latest revision of Bureau of Engineering Circular Letter 40 for instructions concerning Reports of Failures, etc.

Contract No.: NOs. 83891 Date of Contract: 7 April, 1941

Serial Number of Equipment..

Date of acceptance by the Navy..

Date of delivery to contract destination..

Date of completion of installation...

Date placed in service..

FRONTISPIECE. MODEL LR-1 EQUIPMENT

INSTRUCTIONS
FOR
COMBINED HETERODYNE FREQUENCY METER
AND
CRYSTAL CONTROLLED CALIBRATOR EQUIPMENT
MODEL LR-1

SECTION 1. GENERAL DESCRIPTION

1.1 The overall dimensions of this equipment are:
Width: 18 inches
Height: 23 inches
Depth: 17½ inches

1.2 The total weight of the equipment, uncrated and ready for operation, is 155 pounds. The total weight of spare parts is 59 pounds.

1.3 The equipment is used on 110–115–120 volt, 60-cycle, power supply. The power demand on STAND BY is 43 watts and for full operation is 160 watts.

1.4 The equipment is intended for measuring the frequency of radio transmitters, or for setting radio receivers to desired frequencies, in the range 160 kc to 30 Mc. By harmonic extension, frequencies above 30 Mc may be measured.

1.5 The equipment consists of a single unit which includes all power supply equipment, heterodyne frequency meter, crystal calibrator, detector-audio amplifier and interpolator (electronic frequency meter).

SECTION 2. INSTALLATION

2.1 DRILLING FOR MOUNTING

2.11 Drill four holes in bench or desk for the four bolts for holding the shock mountings, as shown in Figure 2.1. Drill also a large hole, as shown, for power leads.

2.2 RELEASE OF INSTRUMENT FROM SLIDE CARRIAGE

2.21 Place the instrument *on deck or on a large desk*, so that when the slide carriage is drawn forward, the instrument will not tip forward and be damaged.

2.22 Unlock the four fasteners, H-102, H-103, near each corner of the main panel, by turning one-quarter turn to the left. Slide instrument forward in its carriage to the full extent of the slide, then move it back about one-half inch. Release the two stop latches, H-104, on each of the side frames of the instrument at lower rear, by raising the latches, H-104, with the fingers. Holding these latches up, draw the instrument forward far enough for the latch bars to clear the stops. The equipment may be held by two persons; the one on the left grasping the left panel handle, H-101, with his right hand, and the handle H-105 (left side, rear) with his left hand (remove V-117, with shield, and V-116 for easier access to handle, H-105, if desired), the one on the right grasping the right panel handle, H-101, with his left hand and the opening on top shelf rear with his right hand. Then withdraw the instrument completely from the case. Place it on a desk or on the deck, where it has a good support, and there is no danger of damaging it.

2.3 BOLTING DOWN SHOCK MOUNTINGS

2.31 Place the housing in position over the holes drilled for mounting. Place a check washer on a mounting bolt, and drop the bolt down through the right rear shock mounting. Run on a washer and nut from below the desk, tightening up from below. If necessary, the bolt head may be held with an open-end wrench while the nut is being tightened. Repeat for the left rear shock mounting but *note grounding connection, Section 2.4, following*. Repeat for the front mountings.

2.4 GROUNDING OF CASE

2.41 The case of the instrument *must be grounded* on installation. Provision for this is made within the case as follows. A flexible braid connection is supplied *connected to the base casting* at one of the mounting screws of the left rear shock mounting. One of the check washers is supplied with a screw and nut for bolting on the terminal of this braid connection. Take this washer, take off the outer nut, place the terminal of the braid connection on the screw, and lock tight with the nut. Place the washer over the shock mounting with the terminal on the *upper*

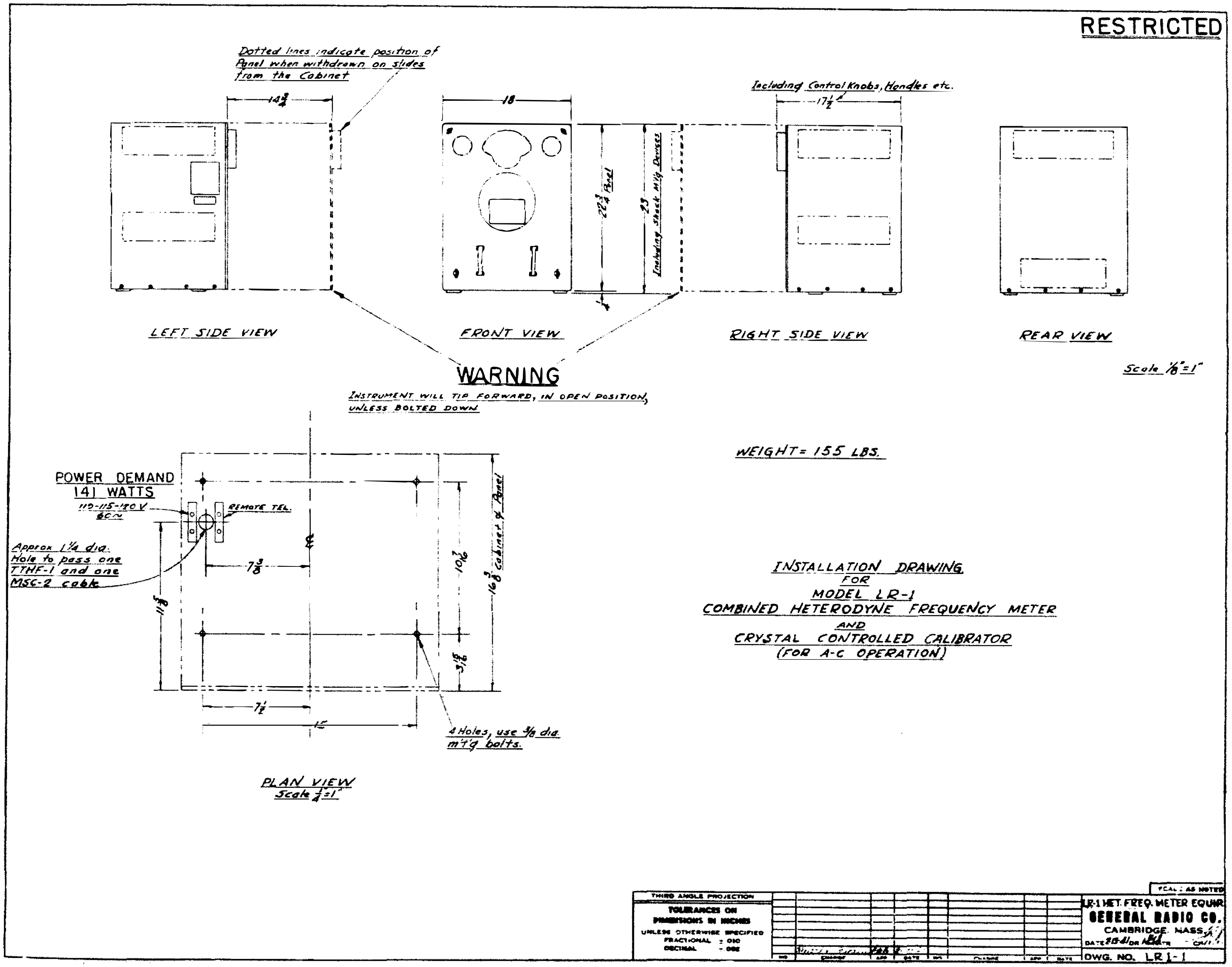


FIGURE 2.1. Mounting Dimensions

side and run the mounting bolt down through the washer, shock mounting and desk. Run washer and nut onto bolt from below. *Provide a ground connection from this left rear mounting bolt to ground.* This conductor need not be large, as it carries no appreciable current.

2.5 CONNECTING POWER AND REMOTE TELEPHONE LEADS

2.51 Remove the cover of the terminal and filter assembly, which is located on the left-hand side of the main base casting. Loosen both clamps located on middle web of the terminal and filter assembly.

2.52 Run the remote telephone cable up through the hole provided in the desk or bench, through the right-hand hole in the base casting, then up through the clamp to the terminal block marked TEL. Solder or screw the wires to the terminals. Tighten clamp on cable so that no strain will come at the terminal connections.

2.53 The cable clamps mentioned in Paragraphs 2.51 and 2.52 are suitable for clamping the ends of Type TTHF-1 and MSC-2 cables. The bodies of the cables can be firmly clamped so that no strain will be taken by the conductors exposed for making connections to the terminals.

2.54 Replace the cover of the terminal and filter assembly.

2.6 REPLACING INSTRUMENT IN CASE

2.61 First push the "half-speed" carriage back into the cabinet. Pick up instrument as described in Paragraph 2.22 and set the roller rails on the front rollers of the half-speed carriage. Still holding the weight of the instrument and guiding it approximately level into the slides, move the instrument back into the case. When the roller rails strike the half-speed rollers, ease the rails past the rollers by raising the front of the instrument a little, taking the weight off the front rollers. When the roller rails go by the half-speed rollers, ease the instrument down so the weight is taken by the roller rails. Then roll the instrument slowly full into the case. The stop latches, H-104, should lift over the stops automatically, and, when the instrument is nearly all the way into place, should fall into the lock position. *Before locking the instrument into place, slowly withdraw it on the slide carriage,* until the stop latches, H-104, are visible. Inspect them to make certain they are in the *lock position*, that is, with the ends of the latch bars resting on the top of the carriage frames. Replace V-117 and shield and V-116 if removed for access to left side frame handle, H-105. Slide instrument into the cabinet and lock the four fasteners, H-102, H-103, near each corner of the main panel, by turning one-quarter turn to right.

SECTION 3

PRINCIPLES OF OPERATION; ENGINEERING DISCUSSION

3.1 GENERAL STATEMENT

3.11 This section gives an engineering discussion covering the component circuits and the principles of operation. This section does NOT cover operating instructions. FOR OPERATING INSTRUCTIONS, SEE SECTION 4.

3.12 Without details as to the individual components, the principles of operation of the equipment may be understood with reference to Figure 3.12. The principal controls associated with each portion of the equipment are indicated by symbol designation and may be identified on the photograph of the panel, page 62.

3.13 The general principles of operation may be outlined as follows:

3.131 *In measuring a frequency f_x,* introduced at the R. F. INPUT terminal, the DETECTOR INPUT switch S-103 is thrown to the MATCH position. Beats between the fundamental, or a harmonic, frequency of the heterodyne frequency meter, HFM, and the frequency, f_x, under measurement, are then produced in the detector, amplified in the audio frequency amplifier and may be heard in the telephone receivers. The heterodyne frequency meter is then adjusted carefully by C-135-A, -B, to obtain zero beat, matching the used output frequency to the frequency being measured. This process is advantageous, particularly if the frequency, f_x, being measured is intermittently applied, as by keying of the transmitter.

3.132 Having matched the heterodyne frequency meter to the frequency, f_x, to be measured, *the controls of the frequency meter are left strictly alone.* The DETECTOR INPUT switch, S-103, is then thrown to the MEASURE position, and the CALIBRATOR is turned on at S-101, operating at 10 kc. A beat is then obtained in the detector between the *fundamental* frequency of the heterodyne frequency meter, HFM, and a harmonic of the CALIBRATOR. This beat frequency is amplified in the audio-frequency amplifier and may be heard in the telephones. This beat frequency is always less than about 5 kc. (See paragraph 3.245 following for discussion of the formation and frequency ranges of these beat frequencies.) While an output voltage is applied to the telephones, so that the beat

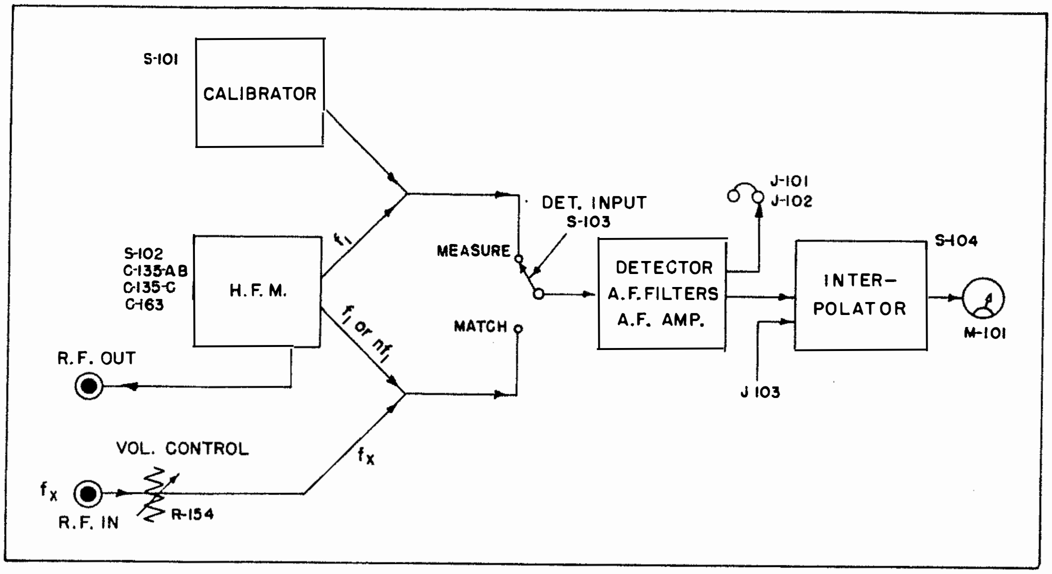


FIGURE 3.12. Block Diagram Illustrating General Principle of Operation

frequency may be *heard*, a voltage is also applied to the Interpolator, which automatically indicates on the meter, M-101, the value of this beat frequency. *The value of the frequency being measured is then given by the sum of the calibrator harmonic frequency and the beat frequency indicated by the interpolator.* The calibrator harmonic frequency is given by the HFM FREQUENCY dial, and the beat frequency is given by the reading of the INTERPOLATOR meter M-101 on the proper scale.

3.133 *In setting up a desired frequency,* the DETECTOR INPUT switch, S-103, is thrown to the MEASURE position. With the calibrator running at 10 kc, as selected at S-101, set the Heterodyne Frequency Meter to a selected calibrator harmonic (identified on the HFM FREQUENCY dial) and then adjust (by C-135-A, -B) until the beat frequency, indicated on the proper scale of the INTERPOLATOR meter, M-101, is of the proper value. The frequency thus set up is available at the R. F. OUTPUT terminal for use in external receivers. This frequency may be compared with an incoming signal applied at the the R. F. INPUT terminal by throwing DETECTOR INPUT switch, S-103, to the MATCH position. The beat frequency difference between the frequency set up on the heterodyne frequency meter and the incoming frequency may then be heard in the telephones.

3.2 COMPONENT ELEMENTS

3.21 The circuits of the Model LR Combined Heterodyne Frequency Meter and Crystal Controlled Calibrator may be broken down into the following component elements:

3.22 Crystal Controlled Calibrator
- 3.221 Crystal Oscillator
- 3.222 Temperature-Control System
- 3.223 Multivibrator
- 3.224 Output Amplifier

3.23 Heterodyne Frequency Meter
- 3.231 Oscillator
- 3.232 Ranges of Frequency Meter
- 3.233 Scales of Frequency Meter
- 3.234 Compensator Capacitor
- 3.235 Interpolator Scale-Test Capacitor
- 3.236 Output Circuits
- 3.237 Harmonic Range and Multiplier Chart

3.24 Detector and Audio-Frequency Amplifier
- 3.241 Detector and R-F Input Circuits
- 3.242 Impedance Transforming Tube and First Filter
- 3.243 Audio-Frequency Amplifier
- 3.244 Second Filter and Output Circuit
- 3.245 Formation of Beat Frequencies
- 3.246 Formation of Extraneous Beat Frequencies

3.25 Interpolator
- 3.251 Input Amplifier
- 3.252 Electronic Frequency Meter
- 3.253 Scales, Scale Test and Selector

3.26 Power Supply
- 3.261 110-115-120 volt, 60-cycle supply
- 3.262 Power Switch
- 3.263 Voltage Regulator

3.22 Crystal Controlled Calibrator

3.221 *Crystal Oscillator*

3.2211 The crystal oscillator circuit fundamentally consists of a Colpitts Oscillator, using a screen-grid tube, V-101, in which the 100-kc quartz bar, Y-101, replaces the oscillator circuit inductance. A portion of one of the oscillator circuit capacities is made variable, C-102, for the purpose of permitting small changes in frequency to be made. This adjustment is made at the factory and locked. In service, when a series of careful measurements demonstrates that the necessity exists, the frequency of the crystal oscillator may be brought into agreement with standard frequency transmissions by unlocking this control, adjusting for zero beat, and then locking the control again. See Section 4.6.

3.2212 The crystal, Y-101, is of the bar type, vibrating, in the direction of its length, at a frequency of 100 kc$\pm$1 cycle at 50° C. The electrodes are formed directly on the surface of the quartz, eliminating air-gaps and any variations in frequency resulting from changes in air-gaps with time, temperature or vibration. Adjustable baffles, set and locked at the factory, greatly reduce the supersonic damping of the bar and variations in frequency due to variable air columns. The proportions of the bar are carefully chosen to provide adequate excitation and low temperature coefficient of frequency. The bar is mounted by clamping at the mid-point, which is a node of mechanical vibration.

3.2213 By taking the output voltage of the crystal oscillator by electron coupling in the tube, V-101, the output is practically constant for any setting of the frequency adjusting capacitor, C-102. This voltage is impressed on the grid of a degenerative triode amplifier, V-102, which provides for isolating the multivibrator from the crystal oscillator, for introducing the control voltage into the multivibrator circuit, and for adjusting the magnitude of this voltage by adjustment of the cathode resistor, R-109. Through the use of degeneration, the gain of this amplifier, V-102, is made nearly independent of tubes or supply voltages.

3.222 *Temperature-Control System*

3.2221 Since the temperature coefficient of frequency of the crystal oscillator is low, about one part per million per degree Centigrade, accurate temperature control is unnecessary. Consequently, the temperature-control system has been designed for simplicity, compactness, low power consumption and quick warm-up. The control system consists of an aluminum plate, on which are mounted the heaters, R-101, and crystal, Y-101. A thin aluminum box attaches to the base and carries the thermostat,

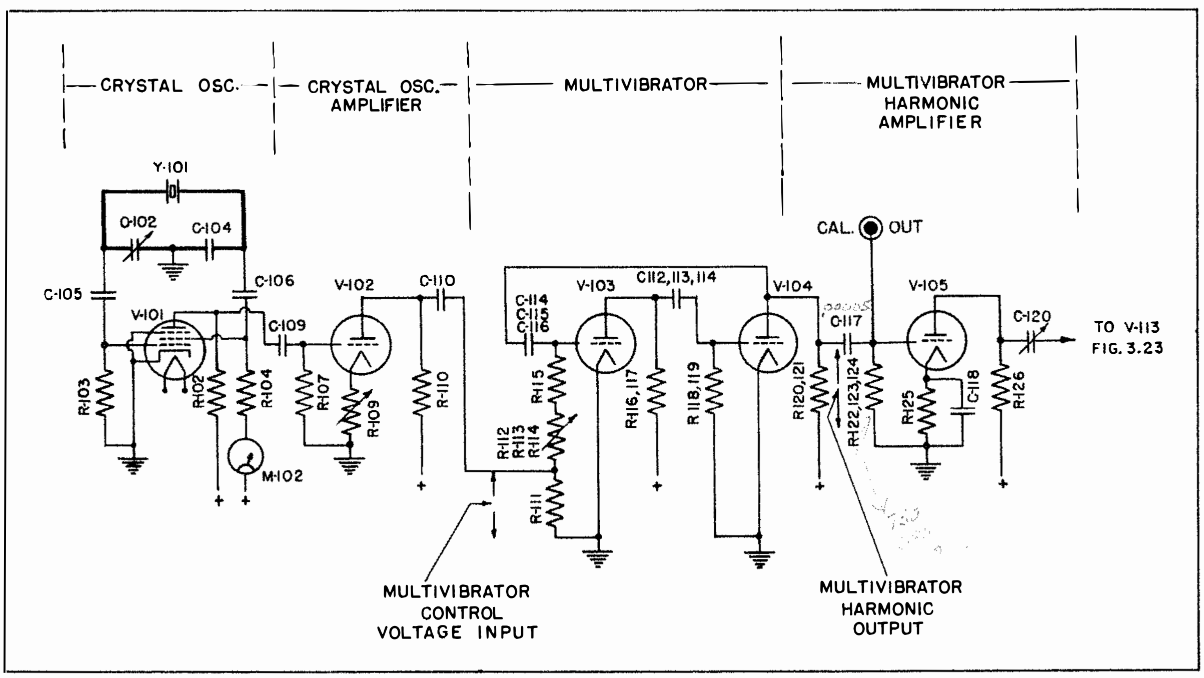


FIGURE 3.22. Schematic Circuit Diagram of Crystal-Controlled Calibrator. For Complete Wiring Diagram, See Page 72

S-107. Within the aluminum box is placed the crystal holder, which consists of a heavy isolantite plate on which the crystal is mounted and to which a heavy metal cover, for mechanical and thermal protection of the crystal, is attached. The power demand is approximately ten watts. This power is handled directly by the contacts of the bimetallic vacuum-mounted thermostat, S-107. The normal working temperature is 50°C ± 2.5°C. Variations in temperature from the normal do not usually exceed 0.5°C. Operation of the temperature control system is indicated by the signal lamp marked CRYS. HEAT, I-101.

3.223 *Multivibrator*

3.2231 The multivibrator is a relaxation oscillator having two special properties which are utilized in this equipment. First, the harmonic content is high, providing usable harmonics throughout the fundamental range of the heterodyne frequency meter (160–7500 kc); second, the multivibrator frequency is readily controlled, or locked, by injection of a small voltage from the crystal oscillator. In effect, this results in a large number of harmonic frequencies, each as accurate as the crystal oscillator frequency.

3.2232 If the fundamental frequency of the multivibrator is 100 kc, that is, equal to the frequency of the crystal oscillator, the harmonics will, of course, be the same as those which might be obtained directly from the crystal oscillator, but generally will be very much stronger. This is particularly true of the higher harmonics, which would normally be very weak in a crystal oscillator. An important feature of the multivibrator is that the fundamental frequency may be any integral sub-multiple of the crystal oscillator, or control, frequency. That is, if the multivibrator fundamental frequency is set to $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, . . . of the crystal oscillator frequency (100 kc), it can be controlled by the crystal oscillator at 50, 33.3, 25, 20 . . . kc. In this equipment the multivibrator may be operated at any one of three fundamental frequencies, 100, 20 and 10 kc, selected by the switch, S-101.

3.224 *Output Amplifier*

3.2241 For any fundamental frequency of the multivibrator, the amplitude of the successive harmonics tends to fall off, roughly in proportion to the number of the harmonic. That is, if the fundamental amplitude is 1.0, the amplitude of the 10th harmonic is roughly 0.1; that of the 100th harmonic is roughly 0.01, and so on. In covering the range of the heterodyne frequency meter of 160–7500 kc, harmonics of 100 kc up to the 75th are used; of 20 kc up to the 375th, and of 10 kc up to the 750th. If the output

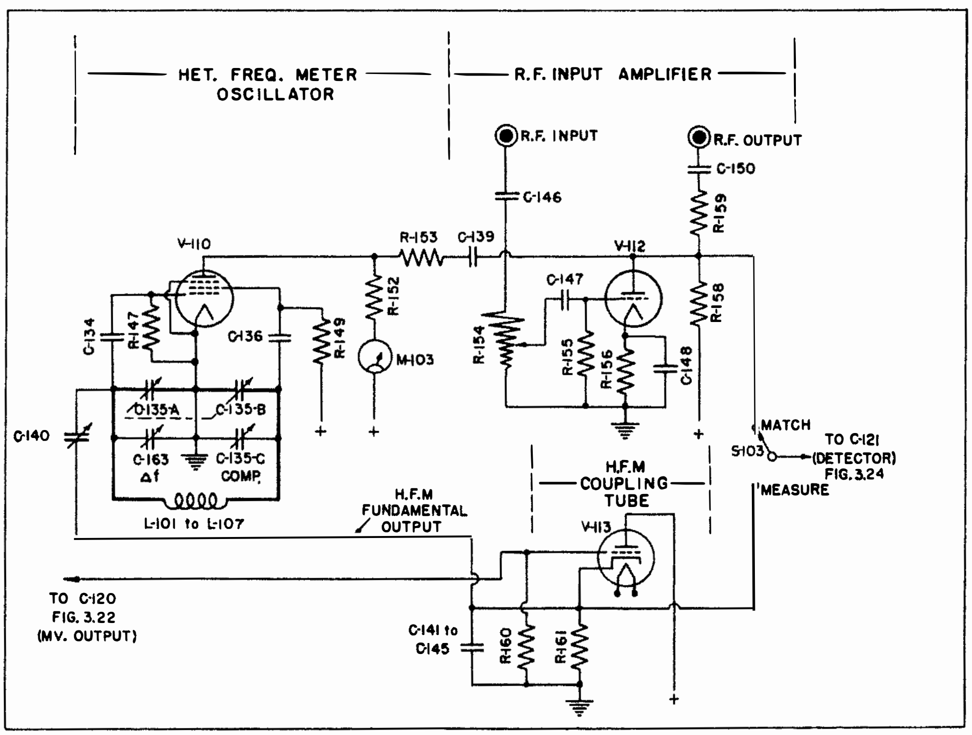


FIGURE 3.23. Schematic Wiring Diagram of Heterodyne Frequency Meter. For Complete Wiring Diagram, See Page 73

of the multivibrator were used directly, in obtaining beats against the heterodyne frequency meter, the amplitudes of the beats would vary tremendously (roughly 1000:1) over the range of the frequency meter. This discrepancy is greatly reduced by the coupling system connecting the multivibrator to the output amplifier. A very small capacitance, C-117, and low resistance, R-122, 123 or 124, are connected in series across the multivibrator output, with the amplifier input connected across the resistance. This arrangement greatly reduces the amplitude of the lower harmonics at the amplifier grid, without materially affecting the higher harmonics. A further equalization is obtained in the coupling system to the detector, detailed in Section 3.24.

3.23 Heterodyne Frequency Meter

3.231 *Heterodyne Frequency Meter Oscillator*

3.2311 The heterodyne frequency meter oscillator is of the Colpitts electron-coupled (Dow) type, V-110, with plate voltage regulator, V-111. Seven fundamental frequency ranges are provided, each having its own inductor, L-101 to L-107; the inductor in circuit is selected by the RANGE SELECTOR switch, S-102. For each range a variation of frequency of 1.414:1 is obtained by means of the precision worm-drive variable capacitor. The range switch automatically changes the coupling between the heterodyne frequency meter, the calibrator and the detector by capacitors C-141 to C-145, so as to maintain suitable amplitudes of beat notes for beats between the frequency meter and calibrator.

3.232 *Ranges of Frequency Meter*

3.2321 While there are but seven fundamental frequency ranges, there are 13 effective ranges, each having a scale on the direct-reading frequency dial, N-103. The appropriate scale is exposed by a mask automatically operated from the range switch, S-102. In addition, a fourteenth scale, of equal parts, used with the vernier scale, N-104, on the precision capacitor shaft, is exposed at all times. Below are the design limits of the 13 effective ranges.

3.2322 In connection with the use of a single inductance for two ranges, it may be demonstrated that the performance on the second harmonic is identical with that which would be obtained with a second coil designed to cover the same frequency range as the second harmonic of the first coil. For example, the "kilocycles per division" on the HFM frequency dial, N-103, is the same in the second harmonic ranges of the coils used as the "kilocycles per division" which would be obtained on other coils covering the same ranges by means of the fundamental.

3.233 *Scales of Frequency Meter*

3.2331 The direct-reading frequency scales are calibrated so that every used harmonic of the crystal calibrator is directly identified, on both fundamental and second harmonic ranges of the heterodyne frequency meter covering a total range from 160 kc to 15 Mc. With the direct-reading frequency scales, the frequency meter may be set to a desired frequency, or a frequency may be read from the scales, just as readily and simply on the second harmonic ranges as on the fundamental ranges.

3.234 *Compensator Capacitor*

3.2341 One of two auxiliary controls of frequency provided on the frequency meter, is called the COMPENSATOR, C-135-C. The compensator is provided for bringing the direct-reading dial into agreement with the calibrator, if the calibration should not agree because of long time drift. If any question arises as to whether the alignment adjustment is through

Range (on S-102)	*Frequency Min.*	*Frequency Max.*	*Notes*	*Scale on Dial N-103*
1	160 kc	232 kc	Fundamental	BLACK
2	232	330	Fundamental	BLACK
3	330	470	Fundamental	BLACK
4	470	660	Second Harmonic of 2	RED
5	660	940	Second Harmonic of 3	RED
6	940	1330	Fundamental	BLACK
7	1.33 Mc	1.87 Mc	Fundamental	BLACK
8	1.87	2.65	Second Harmonic of 6	RED
9	2.65	3.75	Second Harmonic of 7	RED
10	3.75	5.3	Fundamental	BLACK
11	5.3	7.5	Fundamental	BLACK
12	7.5	10.6	Second Harmonic of 10	RED
13	10.6	15.0	Second Harmonic of 11	RED

error being made against a 10-kc harmonic above or below the correct one, it can be answered by use of either the 20-kc or 100-kc harmonics of the calibrator. In general, the calibration will not be in error by an amount which would lead to such ambiguity.

3.235 *Interpolator Scale-Test Capacitor*

3.2351 The second auxiliary control is called the INTERPOLATOR SCALE-TEST control, C-163, and is provided for producing a smoothly controllable change in frequency of the heterodyne frequency meter, *without the need of changing the setting of the main frequency control.* This control is used in determining the sense, or sign, of the beat frequency indication given by the interpolator. The capacitor, C-163, is held in the minimum position by a spring return, so that it is effective in the circuit only while the control is being used. On advancing the control from the position of rest, the frequency of the heterodyne frequency meter is *reduced*, very gradually at first and then more and more rapidly. Consequently, for any frequency in the range of the frequency meter and for any beat frequency, it is possible to reduce the frequency gradually enough to make a small change in a low beat frequency obtained at high radio frequencies, or rapidly enough to make a noticeable change in a high beat frequency obtained at low radio frequencies. See also paragraph 3.253, particularly 3.2536 and following paragraphs.

3.236 *Output Circuits*

3.2361 Two output circuits are provided for the heterodyne frequency meter, one for the purpose of obtaining an output voltage of fundamental or harmonic frequency, and used to produce beats against the frequency being measured, and the other for obtaining beats at *fundamental frequency only* with harmonics of the calibrator. The first output circuit is utilized when the detector input is switched to the MATCH position, S-103. When so connected, and with a frequency to be measured applied at the RF INPUT terminal, the beat between the heterodyne frequency meter and the unknown frequency is heard in the telephones. The frequency meter is then adjusted so as to obtain zero beat. When the detector input is switched to the MEASURE position, at S-103, *without changing the setting of the heterodyne frequency meter*, the beat between the heterodyne frequency meter fundamental and the calibrator is heard. Since the calibrator harmonic is identified immediately from the direct-reading dial, the beat frequency is the amount that the unknown frequency is above or below the known standard frequency. The beat frequency *value* is indicated automatically by the interpolator meter, M-101. The *sign* is determined by use of the INTERPOLATOR SCALE-TEST capacitor, C-163. See paragraphs 3.235 and 3.253.

3.237 *Harmonic Range and Multiplier Chart*

3.2371 The harmonic range and multiplier chart, N-106, secured to the housing of the HFM FREQUENCY dial, N-103, is for aid in quickly determining which range of the heterodyne frequency meter and what multiplier should be used when frequencies above the direct-reading range of 160 kc to 15 Mc are to be set up or measured.

3.2372 From the range table, paragraph 3.232, it is evident that ranges 10 and 11, covering 3.75–5.3 and 5.3–7.5 Mc by the fundamental frequency, carry *fundamental* frequency calibrations on the HFM dial. Similarly, ranges 12 and 13, covering 7.5–10.6 and 10.6–15.0 Mc on the second harmonic, are really direct-reading *second harmonic* ranges of ranges 10 and 11. Another way of stating it is that the first two harmonics of ranges 10 and 11 carry direct-reading calibrations.

3.2373 If use is made of ranges 10 and 11 at harmonics higher than the second, the frequency read from the dial and interpolator must be multiplied by factors corresponding to the number of the harmonic used. For example, the *fundamental* range would be multiplied by 3 if the third harmonic were used; by 4 for the fourth harmonic and so on. Having a direct-reading second harmonic scale, however, permits the use of smaller multipliers. For example, for the fourth harmonic, the fundamental scale must be multiplied by 4, but the second harmonic scale needs only to be multiplied by 2.

3.2374 It will be seen from the above that if an *odd* numbered harmonic is used, the *fundamental* scale must be multiplied by this *odd* harmonic number. If an *even* numbered harmonic is used, the *fundamental* scale must be multiplied by this *even* harmonic number, or the *second harmonic* scale must be multiplied by one-half of this *even* harmonic number.

3.2375 All of these factors are taken into account in the harmonic range and multiplier chart, and the correct interpretation of any harmonic range and its corresponding multiplier is given for all harmonics up to the eighth.

3.2376 The use of the chart is illustrated as follows:

EXAMPLE A

(*1*) *To find the proper range and multiplier for setting up a desired frequency.*

(*a*) Enter chart with desired frequency, on frequency scale at top. (Example: 24.0 Mc.)

(*b*) Note where desired frequency crosses a *heavy solid range line.* (Example: 24.0 Mc crosses the 13×2 range line roughly 1/3 from the left end).

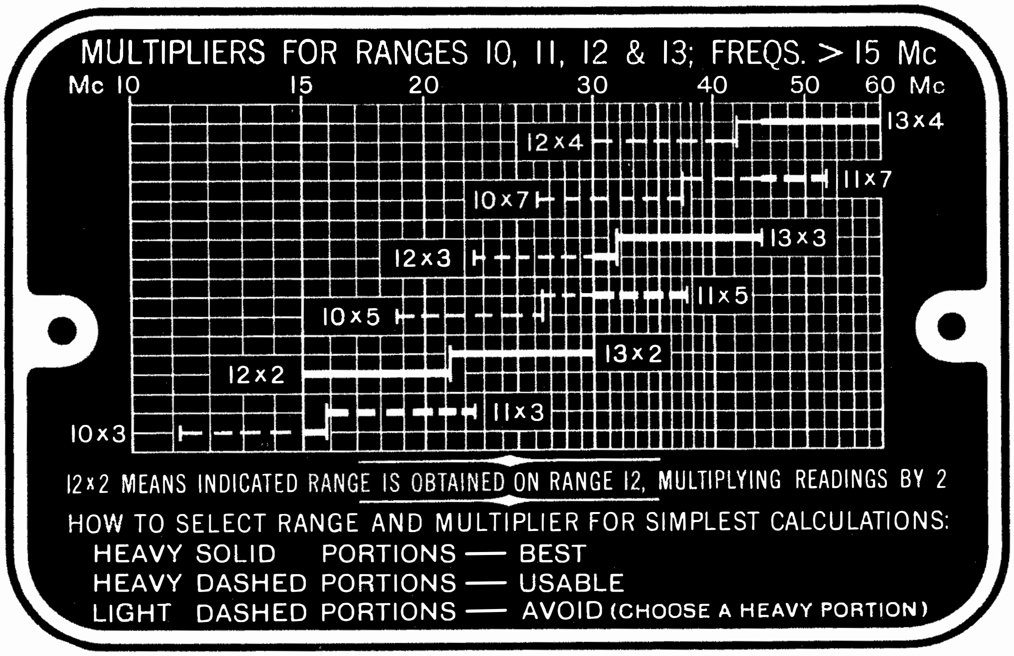


FIGURE 3.237. HARMONIC RANGE AND MULTIPLIER CHART

(*c*) The range to be used is 13.

(*d*) The multiplier to be used is 2.

(*e*) Take ½ of the desired frequency. (Example: 24.0/2=12.0 Mc.)

(*f*) Set heterodyne frequency meter to 12.0 Mc on range 13 (which will lie at roughly ⅓ scale from low-frequency end, see (*b*) above).

(*g*) The harmonic used then falls at 12.0×2 =24.0 Mc, the desired frequency.

(*2*) *To measure a frequency in the harmonic range.*

(*a*) Enter chart with approximate value of frequency. (Example: 24.1 Mc.)

(*b*) Note where the approximate frequency crosses a *heavy solid range line.* (Example: 24.1 Mc crosses the 13×2 range line roughly ⅓ from the left end.)

(*c*) The range to be used is 13.

(*d*) The multiplier to be used is 2.

(*e*) Take ½ of approximate frequency. (Example: 24.1/2=12.05 Mc.)

(*f*) Set heterodyne frequency meter to 12.05 Mc on range 13 (which will lie at roughly ⅓ scale from the low-frequency end, see (*b*) above).

(*g*) Vary heterodyne frequency meter setting slightly either way until a beat against the frequency being measured is heard. Set for zero beat.

(*h*) Measure HFM frequency in regular way. (Example: 12.063 Mc.)

(*i*) Multiply result obtained by 2 to get final result. (Example: 12.063×2=24.126 Mc.)

EXAMPLE B

(*1*) *To find the proper range and multiplier for setting up a desired frequency.*

(*a*) Enter chart with desired frequency, on frequency scale at top. (Example: 19.4 Mc.)

(*b*) Note where desired frequency crosses a *heavy solid range line.* (Example: 19.4 Mc crosses the 12×2 range line roughly ¾ from the left end.)

(*c*) The range to be used is 12.

(*d*) The multiplier to be used is 2.

(*e*) Take ½ of the desired frequency. (Example: 19.4/2=9.7 Mc.)

(*f*) Set heterodyne frequency meter to 9.7 Mc on range 12 (which will lie at roughly ¾ scale from low-frequency end, see (*b*) above).

(*g*) The harmonic used then falls at 9.7×2 =19.4 Mc, the desired frequency.

(*2*) *To measure a frequency in the harmonic range.*

(*a*) Enter chart with approximate value of frequency. (Example: 19.5 Mc.)

(*b*) Note where the approximate frequency crosses a *heavy solid range line.* (Example: 19.5 Mc crosses the 12×2 range line roughly ¾ from the left end.)

(*c*) The range to be used is 12.

(*d*) The multiplier to be used is 2.

(*e*) Take ½ of approximate frequency. (Example: 19.5/2=9.75 Mc.)

(*f*) Set heterodyne frequency meter to 9.75 Mc on range 12 (which will lie at roughly ¾ scale from the low frequency end, see (*b*) above).

(*g*) Vary heterodyne frequency meter setting slightly either way until a beat against the frequency being measured is heard. Set for zero beat.

(*h*) Measure HFM frequency in regular way. (Example: 9.752 Mc.)

(*i*) Multiply result obtained by 2 to get final result. (Example: 9.752×2=19.504 Mc.)

3.2377 *The chart shows, by the heavy solid range lines, the* simplest *choice of of ranges and multipliers.* These ranges are preferred for *simplest* calculations using multipliers and would therefore normally be used. Those ranges leading to more complicated calculations would therefore normally be *avoided.* These heavy lines show that using ranges 12 and 13 with a multiplier of 2, a frequency range from 15 to 30 Mc is obtained (lines 12×2 and 13×2). Using a part of range 12 and all of range 13, with a multiplier of 3, a frequency range of 30 to 45 Mc is obtained (lines 12×3 and 13×3). Using a part of range 13 and a multiplier of 4, a frequency range of 45 to 60 Mc is obtained (line 13×4).

3.2378 Since there are harmonics present in the HFM output other than the used harmonic, the ranges and multipliers for each are indicated on the chart so that all possible zero beat settings are accounted for, in the event that one of these other harmonics is used.

3.2379 For example, 24.0 Mc could be set up or measured using range 10 and multiplier of 5 (line 10×5) or range 12 and multiplier of 3 (line 12×3), but neither of these is as convenient as the use of range 13 and multiplier of 2 (line 13×2) previously designated in the example, and shown on the chart as the preferred choice, *by heavy solid line.*

3.24 Detector and Audio Amplifier

3.241 *Detector and R-F Input Circuits*

3.2411 A diode detector (diode section of V-106) is employed principally because of its freedom from serious distortion and from overloading limitations. Separate circuits are provided for the audio-frequency *a-c* and the *d-c* components of the detector current so that the detector may be biased independently of the bias of the triode amplifier section of the detector tube. The radio-frequency inputs to the detector are as follows, for the two positions of the detector input switch, S-103:

Switch Position, S-103

MATCH

Detector Inputs

1. External source, the frequency of which is to be measured, introduced at coupling post "R-F Input"; level controlled at R-F Input Control, R-154, via R-F Input Amplifier, V-112.
2. Harmonic output of HFM oscillator, obtained from plate of V-110.

MEASURE

1. Calibrator output from V-105, as selected by calibrator switch, S-101.
2. Fundamental frequency of HFM from tuned circuit, via C-140 and automatic coupling system, C-141 to C-145, and HFM coupling tube, V-113.

3.2412 With the switch S-103 in the MATCH position, beats may be obtained between the frequency of the external source and the fundamental or harmonics of the HFM. Within the direct-reading range, 160 kc to 15 Mc, the fundamental or second harmonic only would be used. In going to higher frequencies, using the multiplier chart, harmonics of the HFM higher than the second are used.

3.242 *Impedance Transforming Tube and First Filter*

3.2421 Since the output impedance of the first stage amplifier, V-106, is high, for audio and low radio frequencies, it would be difficult to build a filter to operate at this impedance. Consequently, a completely degenerated amplifier stage, V-107, is used to transform from the high first-stage amplifier impedance to about 600 ohms. The filter, LC-101, is designed for this impedance level.

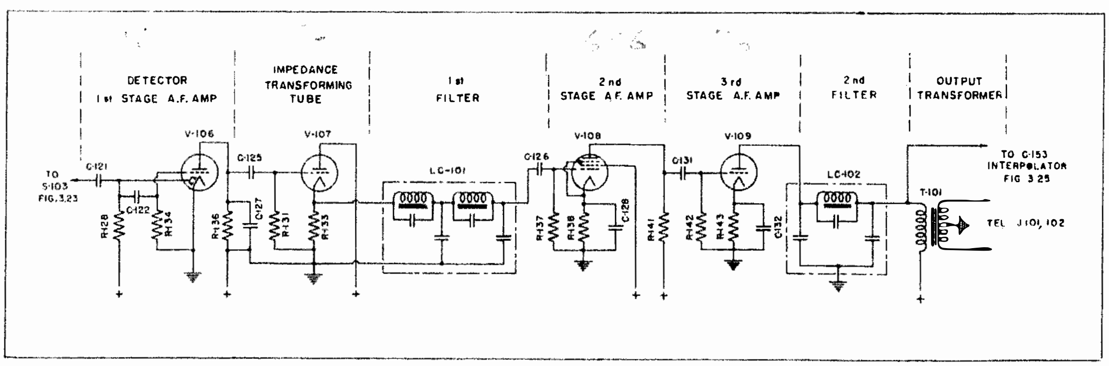


FIGURE 3.24. Schematic Circuit Diagram of Detector and Audio Amplifier. For Complete Wiring Diagram, See Page 74

3.2422 The first filter, LC-101, is for the purpose of suppressing beat frequencies higher than, roughly, 5 kc, and for preventing the 10 kc and 20-kc calibrator frequencies from passing directly through the amplifier. Both of these conditions must be guarded against if spurious or "extra" beat notes are to be eliminated or reduced, and if the beat frequency waveform is to be good over the desired working range from 0 to 5 kc.

3.243 *Audio-Frequency Amplifier*

3.2431 The audio-frequency output of the first filter, LC-101, is passed through a two-stage resistance-capacitance-coupled amplifier, V-108, -109, to obtain the required audio-frequency output power delivered to the telephones. The first stage consists of the screen-grid tube V-108 and the second of the triode V-109. The amplifier proper has an essentially flat frequency-gain characteristic from a few cycles to well above the working limit of 5 kc. No appreciable overloading occurs until the output level is many times the required 6 milliwatts into the telephones.

3.244 *Second Filter and Output Circuit*

3.2441 Because of the wide range of input voltages applied to the amplifier, some distortion might occur within the amplifier itself. To avoid the possible resulting change in output waveform, which might affect the performance of the interpolator, and to sharpen still further the cut-off of the overall frequency-gain characteristic, a second filter, LC-102, is employed, preceding the output transformer, T-101.

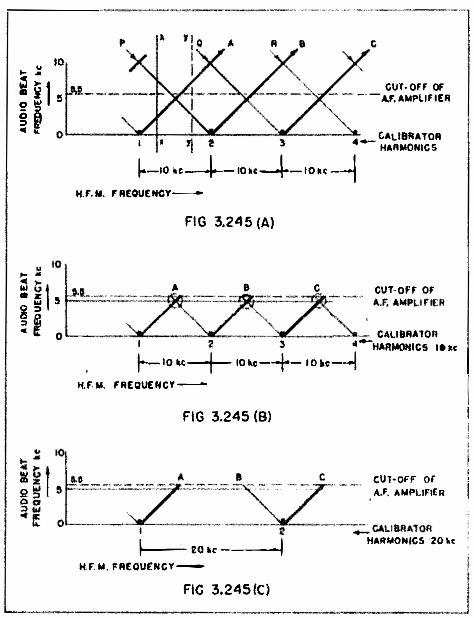


FIGURE 3.245. Diagrams Illustrating the Formation of Beat Frequencies

3.2442 The output transformer, T-101, steps down from the impedance of the output tube, V-109, roughly 10,000 ohms, to the impedance of the telephones, roughly 600 ohms at 1 kc.

3.2443 The voltage developed across the telephones will vary with frequency, even if the frequency-gain characteristic of the amplifier to the telephones is flat, because the telephone impedance is not constant. For low frequencies, the telephone impedance drops to a low value and tends to short-circuit the output. This is not particularly disadvantageous, as far as the telephones are concerned, since the response of both the human ear and the telephones falls off badly. It is troublesome, however, in operating the interpolator, since the input voltage to the telephone transformer, T-101, is used to drive it, via J-103 and R-163. A small amount of resistance at R-144 and R-145 placed in series with the telephones limits this reduction in voltage to the interpolator without noticeably affecting the response from the telephones. The TEL VOLUME control, R-184-A, -B, provides for adjustment of the level of the telephone response.

3.245 *Formation of Beat Frequencies*

3.2451 Referring to Figure 3.245 (*A*), the formation of beat tones, for beats between the heterodyne frequency meter and 10-kc harmonics of the calibrator, may be understood. Points 1, 2, 3, 4 along the horizontal HFM frequency axis represent four harmonics of the calibrator, spaced 10 kc apart. If now the heterodyne frequency meter is set to point No. 1, zero beat with this calibrator harmonic would result. If the frequency of the heterodyne frequency meter is then raised, that is, the point representing the HFM frequency is moved toward the right, a beat tone is heard which increases in frequency as the HFM frequency is raised. This beat tone is represented by the line 1-*A*. At the same time, a beat is obtained between the HFM frequency and that of the next higher calibrator harmonic, No. 2. This beat frequency, indicated by line *P*-2, starts at 10 kc when the heterodyne frequency meter is in zero beat with harmonic No. 1, and decreases to zero when the heterodyne reaches zero beat with harmonic No. 2. This process repeats as the heterodyne frequency meter is advanced, as indicated by lines 2-*B*, *Q*-3, 3-*C*, *R*-4, etc.

3.2452 Consider now a setting of the frequency meter at a frequency just above that of calibrator harmonic No. 1, as indicated by line *X*-*X*. It will be seen that two beat frequencies are obtained, one where *X*-*X* crosses the line 1-*A*, representing the desired or "expected" beat frequency; the second is obtained where *X*-*X* crosses line *P*-2, representing an undesired or "unexpected" beat frequency. If the heterodyne-frequency-meter frequency is increased somewhat from that corresponding to *X-X*, the beat 1-*A* increases and the beat *P*-2 decreases, both becoming 5 kc at the point where these lines cross. In a region near this crossing point, the effect is that of a 5 kc tone with a strong waxing and waning in amplitude, or "flutter." As the frequency of the heterodyne frequency meter is raised still further, to a point corresponding to *Y-Y*, two beat frequencies are again obtained.

3.2453 Since it is necessary to measure the HFM frequency at any point between two calibrator harmonics, it is evident from the diagram that beat frequencies up to at least 5 kc must be available, but also that beat frequencies from 5 to 10 kc are not necessary. The range over which undesired beats are obtained may be greatly reduced by giving the audio amplifier system a sharp cut-off characteristic at a frequency just slightly above 5 kc as shown by the horizontal line, marked CUT-OFF of AF AMPLIFIER, in Figure 3.245 (*A*).

3.2454 With an amplifier having such a cut-off characteristic, the conditions are as shown in Figure 3.245 (*B*). Here no beat frequencies above the cut-off frequency of the amplifier will be heard. The region in which two beat frequencies are heard has been reduced from the whole 10-kc interval, from one calibrator harmonic to the next, to a small region midway between two harmonics, as indicated by the dotted circles, *A*, *B*, *C*.

3.2455 To obtain proper operation of the interpolator, this small region must be eliminated. Because of limitations in the performance of filters, it is not feasible to make the amplifier cut-off exactly 5 kc. A simple change in calibrator frequency from 10 kc to 20 kc produces the desired result, as indicated in Figure 3.245 (*C*). A single beat frequency is obtained from harmonic No. 1, up to the cut-off of the amplifier, as shown by the line 1-*A*. Similarly for

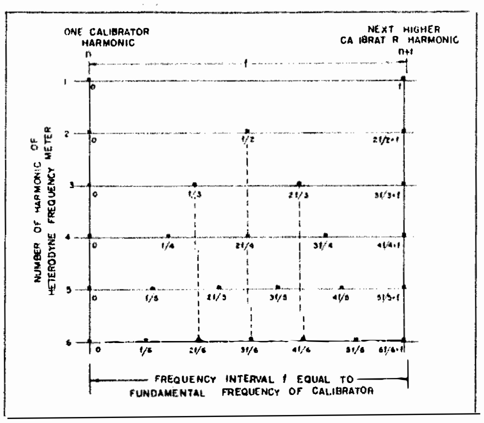


FIGURE 3.246. DIAGRAM ILLUSTRATING THE FORMATION OF EXTRANEOUS BEAT FREQUENCIES

the lines *B*-2 and 2-*C*. By this expedient, proper operation of the interpolator may be obtained throughout the range from one 10-kc calibrator harmonic to the next, if, when the beat frequency *is very near 5 kc* the calibrator be shifted from 10 kc to 20 kc. (This condition is marked by BLUE zones on the interpolator meter, M-101, with instructions to change calibrator from 10 kc to 20 kc.) *CAUTION:* Care should be taken to return CALIBRATOR switch, S-101, to 10 kc position, in accordance with operating instructions, when commencing another measurement.

3.246 *Formation of Extraneous Beat Frequencies*

3.2461 The following brief discussion of the formation of extraneous beats is given so that such beats may be identified. At times an understanding of these beats is very useful, since the extraneous beats provide additional calibration points for the heterodyne frequency meter.

3.2462 The pattern of the extraneous beats is the same no matter what frequency is used for the calibrator. Once this grouping is visualized, and bearing in mind that the heterodyne frequency meter calibration is essentially linear, it is very easy to identify any extraneous beat which may be heard.

3.2463 Consider the interval on the scale of the heterodyne frequency meter from one harmonic, *n*, of the calibrator to the next harmonic, $n+1$, above. See Figure 3.246. This interval is equal to the fundamental frequency *f*, of the calibrator.

3.2464 In line 1, the zero beat points, for beats between the fundamental (harmonic No. 1) of the heterodyne frequency meter and the calibrator harmonics are shown. If we call the lower point zero, the frequency interval on the heterodyne frequency meter scale to the next point will be *f* kilocycles, as shown at the top of the figure.

3.2465 In line 2, the zero beat points, for beats between the second harmonic of the heterodyne frequency meter and higher harmonics of the calibrator are shown. The lowest frequency point, marked zero, occurs when the second harmonic of the heterodyne frequency meter, $2n$, beats zero with twice the original calibrator harmonic frequency, or $2n$. The highest frequency point, marked *f*, occurs when the second harmonic of the heterodyne frequency meter, $2(n+1)$, beats zero with twice the original calibrator harmonic frequency, $2(n+1)$. It will be seen that the interval covered by the second harmonic is twice what it was on the fundamental, that is, from $2n$ to $2(n+1)$, or two harmonics. Consequently, if the heterodyne frequency meter is set half-way between the two original zero beat settings, another zero beat setting is found, where the second harmonic of the heterodyne frequency meter beats zero with the $(2n+1)$ harmonic of the calibrator, lying half-way between the harmonics $2n$ and $2(n+1)$. This point is shown at $f/2$.

3.2466 The net result may be very simply summed up by noting that the interval between one calibrator harmonic and the next is divided into *two* parts by the *second* harmonic of the heterodyne frequency meter; into *three* parts by the *third* harmonic; into *four* parts by the *fourth* harmonic and so on.

3.2467 Suppose the calibrator frequency f is 100 kc. The second harmonic of the heterodyne frequency meter will then give a zero beat point at $f/2$ or $100/2=50$ kc above the lower calibrator harmonic marking the 100-kc interval f. The third harmonic will give zero beat points at $f/3$ or $100/3=33.33$ kc and at $2f/3$ or 66.67 kc above the lower harmonic marking the 100-kc interval f and so on. Similarly, if the calibrator frequency f is 20 kc, the second harmonic point will be 10 kc, the third harmonic points will be 6.67 and 13.33 kc, and so on, above the lower harmonic marking the 20-kc interval, f. For a calibrator frequency, f, of 10 kc, the intervals will be one-tenth those given above for the frequency of 100 kc.

3.2468 Since the heterodyne frequency meter calibration is essentially linear, the dial divisions corresponding to the various zero beat points will lie in the same proportions of the scale interval between calibrator points as the frequency intervals. Thus, if a zero beat point is found half-way between two calibrator settings, it is the second harmonic point. The frequency is accurately known, so this half-way setting becomes another calibrator point.

3.2469 For example, suppose the calibrator frequency is 100 kc and the dial divisions difference between two calibrator harmonics is 120 divisions. Then the second harmonic point will lie approximately 60 divisions above the lower calibrator point, giving a calibration point 50 kc above the lower calibrator harmonic frequency. The fourth harmonic points will lie approximately $120/4=30$ divisions apart, giving calibration points respectively 25, 50 and 75 kc above the lower calibrator harmonic frequency.

3.25 Interpolator

3.251 *Input Amplifier*

3.2511 The input amplifier, V-114, is partially degenerative, to improve the frequency-gain characteristic and to reduce the tendency to overload at high signal levels. Since relatively high signal voltages are applied to the input, a series resistance, R-163, is used to prevent the input impedance from dropping to very low values. A certain minimum voltage is required to trip the gas-triodes, V-115, V-116. On increasing the input voltage above this value, the tripping-voltage waveforms become more sharply squared. For further increases but little change in waveform or in amplitude take place. The increase in input voltage does not affect the performance of the interpolator. As used in the equipment, the input voltage is normally several times the threshold value of approximately three volts, ranging from 15 to 30 volts.

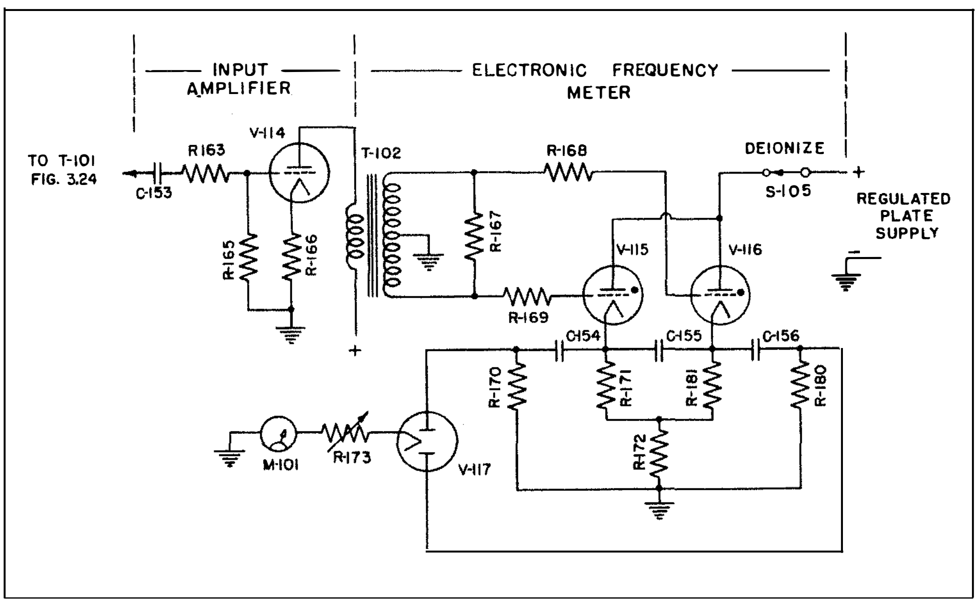


FIGURE 3.25. Schematic Circuit Diagram of Interpolator. For Complete Wiring Diagram, See Page 75

3.252 *Electronic Frequency Meter*

3.2521 The electronic frequency meter consists of the gas-triodes V-115, -116, and associated resistors and capacitors, the switching tube V-117 (full-wave rectifier type) and the indicating meter, M-101. The combination indicates on meter M-101 the *frequency* of an alternating voltage applied to the gas-triode grids, over a frequency range from 0 to 5 kc and *independent of the amplitude of this voltage* provided only that this voltage is appreciably greater than the threshold voltage required to ignite the gas-triodes.

3.2522 Tubes of the gas-triode type possess the property of remaining practically non-conducting while the grid voltage is less than a certain critical value. When the grid voltage is above the critical value the tubes become conductive, and the current through the tubes is practically independent of subsequent values of the control, or grid, voltage. In other words, the gas-discharge cannot be established until the grid voltage has been raised above a certain critical value; once established, the gas-discharge cannot be extinguished by varying the *grid* voltage. If the *plate* voltage is momentarily removed, or dropped to a very low value, the gas-discharge is broken and the tube is rendered non-conducting if the grid voltage is, at the same time, held below the critical value.

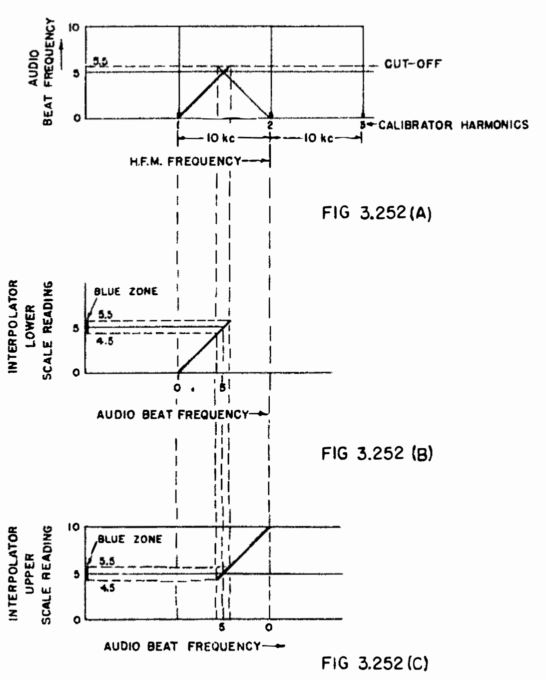


FIGURE 3.252. ILLUSTRATING THE USE OF UPPER AND LOWER SCALES ON INTERPOLATOR

3.2523 The grids of the gas-discharge tubes V-115, -116, are connected to the secondary of transformer T-102 in push-pull. At any instant, one grid will be driven in the positive direction, the other in the negative direction from the normal by the alternating audio-frequency voltage supplied from the input amplifier V-114. Thus at the time that the grid of one of the gas-triodes is driven sufficiently positive to ignite the gas-discharge, the grid of the other tube is held negative, and no gas-discharge through it is possible.

3.2524 On starting of the gas-discharge in one tube, the voltage, to ground, of its cathode is raised abruptly to a value equal to that of the plate supply voltage (drop across V-118) less the drop in the gas-discharge between plate and cathode of the gas-triode. Similar considerations apply to the second gas-triode. The cathode resistors R-171, R-181, serve to limit the plate current. The resistors R-168, -169, serve to prevent excessive grid-current in the gas-triodes V-115, -116. They also reduce the load on the transformer T-102.

3.2525 When the cathode voltage is abruptly raised, the metering capacitor, C-154 or -156, connected to the cathode is charged to the cathode voltage to ground. In so doing, a current pulse passes through the metering resistance, R-170 or R-180, momentarily raising the corresponding plate of V-117 to a positive voltage. A current pulse thus passes through V-117, R-173 and M-101. When the gas discharge is transferred to the other tube, the metering capacitor discharges, but the corresponding plate of V-117 is then driven negative, so no current pulse passes through this tube or through M-101.

3.2526 When the discharge starts in the idle tube (V-115 or V-116), its cathode voltage is abruptly raised. The switching capacitor, C-155, was originally charged to the cathode voltage of the working tube. The immediate effect of the rise in cathode voltage in the tube which has just been ignited is to increase the cathode voltage of the working tube by the amount of this cathode voltage rise. The net rise in cathode voltage of the working tube will be much greater than the supply voltage of the working tube (drop across V-118). The plate-cathode voltage of the working tube is thus not only dropped to a low value, it is actually reversed, which extinguishes the gas-discharge in this tube.

3.2527 While this cathode voltage rise takes place, the grid voltage of the working tube was, and remains, less than the critical voltage, so that when the gas discharge is extinguished, the grid of this tube can regain control. The grid voltage, being below the critical value, prevents the gas-discharge from igniting when the plate-cathode voltage returns to normal, which occurs when the switching capacitor, C-155, becomes fully charged.

3.2528 The operation detailed above may be summarized by saying that for each *alternation* of the input voltage, the gas-discharge in the gas-triodes V-115 or V-116 *is switched from one tube to the other.* At each *transition* of the discharge from one tube to the other, a single positive current pulse is sent through the meter M-101. Each time the gas-discharge starts in the non-conducting tube, the establishment of plate current interrupts the gas-discharge in the other tube, which thereafter remains non-conducting until its grid voltage is again raised above the critical value (by the input voltage).

3.2529 As stated above, for each transition of the gas-discharge from one gas-triode to the other, a single current pulse is sent through the meter M-101. This pulse, within wide limits, is unaffected by the *time* between the transfers of the gas-discharge from one tube to the other, and is also independent of the *duration* of the discharge in the individual gas-triodes. The *average* current, through the meter M-101 (which is what the meter indicates), is therefore proportional to the *number of pulses per second*, that is, to the *frequency* of the input signal voltage.

3.25210 The average current through meter M-101 is thus seen to be inherently proportional to frequency; a standard d-c current meter, with linear scale, is consequently used. By adjustment of R-173 the output current is regulated to fit the scale of the meter M 101, the scale of which is consequently marked directly in frequency.

3.25211 The average current is strictly proportional to frequency only if the successive current pulses are *alike.* In this equipment, these pulses will be alike provided the supply voltage is constant (which is the reason for the elaborate regulation in V 118, -119, -120), the values of the metering resistors and capacitors are constant and the voltage drops in the gas-discharge tubes are independent of grid voltage. All of these conditions are closely realized in practice.

3.25212 If, in warming up, or due to a sudden transient caused by switching, both gas-triodes V-115 and V-116 become conducting, then *neither* tube can regain control regardless of the applied grid voltage. This condition is indicated by the reading of the interpolator meter, M-101, falling to zero (on lower scale) or reading 5.0 kc (on upper scale) even though a normal beat frequency is heard in the telephones. If the plate supply voltage is momentarily removed, by pressing the DEIONIZING button, S-105, both gas-triodes are extinguished. When the button is released, and plate voltage is again applied to the tubes, normal grid control is again obtained.

3.253 *Scales; Scale Test and Scale Selector*

3.2531 As is pointed out in more detail in Section 3.245 the beat frequencies to be indicated by the interpolator vary from 0 to 5 kc, or from 5 kc to 0, as the heterodyne frequency meter is changed continuously in one direction. It would be possible to use a single scale, 0 to 5 kc, if the frequency measurements could be obtained by *addition or subtraction.* Since the results are to be obtained by *addition only*, a special scale must be provided and marked 5 to 10 kc. This scale reads right-handed in the normal way, *to avoid errors in estimating readings,* but the pointer is moved to the right by a frequency which varies from *5 kc down to 0.* This scale is provided by reversing the meter M-101 with the INTERPOLATOR SCALE SELECTOR switch S-104 and introducing an opposing current (adjusted at R-176) equal to normal full-scale current. The pointer of the meter then moves toward the *right* when the beat frequency *decreases,* over a scale (upper) marked 5 to 10 kc.

3.2532 Referring to Section 3.245 on the formation of beat notes, and Figure 3.245, it is seen that the interpolator must indicate from 0 to slightly over 5 kc on one scale, while the beat frequency varies from 0 to slightly over 5 kc along line 1-A, Figure 3.245 (*B*) and must indicate from slightly below 5 kc to 10 kc on the other scale, while the beat frequency varies from slightly above 5 kc down to zero, along line A-2, Figure 3.245 (*B*). The regions enclosed in the dotted circles of Figure 3.245 (*B*), where two beat frequencies may be present, are indicated on the interpolator meter M-101 by blue zones on the meter scale. When the reading comes in these blue zones, change the calibrator frequency from 10 kc to 20 kc.

3.2533 In Figure 3.252 (*A*) the essentials of Figure 3.245 (*B*) are repeated, showing the beat between the HFM and the 10-kc calibrator harmonics as it varies from zero to 5 kc (against calibrator harmonic No. 1) and from 5 kc back to zero (against calibrator harmonic No. 2).

3.2534 The *readings* of the interpolator meter, M-101, with respect to the beat frequencies in (*A*) are indicated in Figure 3.252 (*B*) for the LOWER scale (selected by INTERPOLATOR SCALE SELECTOR switch, S-104). The connection between the blue zone and the double beat section in Figure 3.252 (*A*) is indicated by the dotted lines.

3.2535 The *readings* of the interpolator meter, M-101, with respect to the beat frequencies in (*A*) are indicated in Figure

3.252 (*C*) for the UPPER scale (selected by the INTERPOLATOR SCALE SELECTOR switch, S-104). The connection between the blue zone and the double beat section in Figure 3.252 (*A*) is indicated by the dotted lines.

3.2536 When using the equipment, with a beat frequency difference existing between the heterodyne frequency meter and the calibrator (as heard in the telephones), it is necessary to determine which scale of the interpolator should be used (upper or lower). This is done by use of the INTERPOLATOR SCALE TEST, C-163, which introduces a smoothly controllable *reduction* in the frequency of the heterodyne frequency meter without the necessity of changing the position of the main frequency control C-135-A, -B. See paragraph 3.235.

3.2537 With the INTERPOLATOR SCALE SELECTOR switch, S-104, in the LOWER position, and reading the LOWER scale of the INTERPOLATOR meter, M-101, it is evident that, if the frequency of the heterodyne frequency meter is *above* the calibrator harmonic, *reducing* the heterodyne frequency meter frequency will *reduce* the beat frequency difference, and the needle of M-101 will move *down-scale* to a *lower* reading. This signifies that the LOWER scale should be used.

3.2538 With the INTERPOLATOR SCALE SELECTOR switch, S-104, in the LOWER position, and reading the LOWER scale of the INTERPOLATOR meter, M-101, it is evident that, if the frequency of the heterodyne frequency meter is *below* the calibrator harmonic, *reducing* the heterodyne frequency meter frequency will *increase* the beat frequency difference, and the needle of M-101 will move *up-scale* to a *higher* reading. This signifies that the UPPER scale should be used, so the INTERPOLATOR SCALE SELECTOR switch, S-104, should be thrown to the UPPER position and the reading taken on the upper scale.

3.2539 *CAUTION:* Do not advance the INTERPOLATOR SCALE-TEST control, C-163, too rapidly, and be sure to use the initial indication of pointer on INTERPOLATOR meter, M-101. A too rapid motion of, or too great an angular displacement of, the INTERPOLATOR SCALE-TEST control, C-163, may result in a reversal in the direction of motion of the pointer of the INTERPOLATOR meter, M-101.

3.26 POWER SUPPLY

3.261 *110-115-120 Volt 60-Cycle Supply*

3.2611 The power supply is from a 110-115-120 volt, 60-cycle, a-c line. The fuse F-101 should be inserted in the clips corresponding to the average line voltage. The power supply consists of the power transformer T-103, rectifier V-121 and a smoothing filter (L-108, -109, -110 and C-160, -157, -158, -159). In the filter, one output is obtained at the junction of L-108, -109 for operation of the interpolator only. The normal output is obtained at C-159 for all other circuits. Filament supply and heater power for the crystal temperature control R-101 are obtained from a 6.3-volt winding on the power transformer T-103.

3.262 *Power Switch*

3.2621 The power switch S-106 has three positions: OFF, STAND BY and ON. In the OFF position no power is drawn from the supply. The other positions operate as follows:

3.2622 The STAND BY position energizes the primary of T-103 and power is delivered to the heterodyne oscillator tube V-110 filament, the crystal oscillator tube V-101 filament, and crystal temperature control R-101. The rectifier filament, V-121, circuit is energized, but the plate center tap connection is open so that no plate supply power is taken. The ON position energizes all tube heaters from the 6.3-volt winding. At the same time the plate

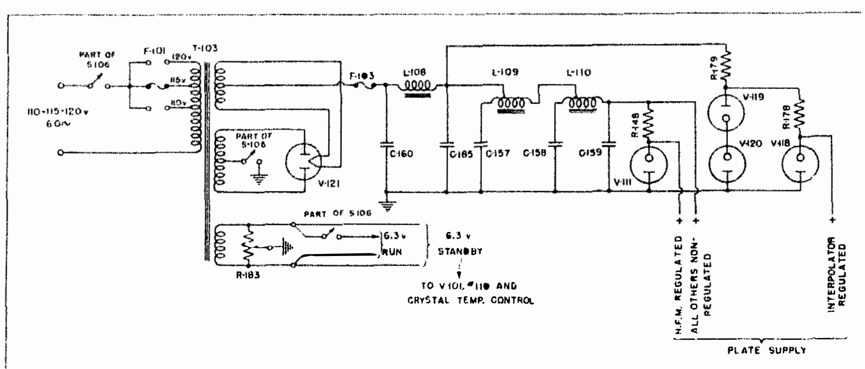


FIGURE 3.26. SCHEMATIC CIRCUIT DIAGRAM OF POWER SUPPLY.
FOR COMPLETE WIRING DIAGRAM, SEE PAGE 76

center tap connection is made, so normal plate voltage is obtained.

3.263 *Voltage Regulator*

3.2631 The voltage regulator, for the plate supply voltage to the interpolator, consists of the regulator tubes V-118, -119, -120 with the resistors R-178, -179.

3.2632 The glow tube regulators have the property of a low dynamic resistance (that is, resistance offered to changing voltages) while having a high static resistance. Over the current range of the tubes the dynamic resistance is approximately 150 ohms. If a tube is connected in series with 1500 ohms to the plate supply, the changes in voltage of the power supply would be reduced by roughly 10 to 1 across the tube. Other things being equal, the higher the supply voltage and the greater the resistance in series with the tube, the smaller will be the voltage variations across the tube.

3.2633 Such voltage regulators may be cascaded, which is done here, with the tubes V-119, -120 and resistor R-139 forming the first stage; R-178 and V-118 form the second stage.

3.264 The adjustable center-tap resistor, R-183, is provided as a "hum-control" for minimizing the hum heard in the telephones. It is advisable to check the setting for minimum hum, occasionally, as the tubes age, or, upon changing any tubes in the equipment. This is easily done by drawing equipment forward on slides, attaching servicing cable, and operating in the ON condition for at least 10 minutes. Then set R-183, located on center of left main frame, for minimum hum in the telephones. This test is most easily made by throwing the DETECTOR INPUT switch, S-103, to MATCH and turning the R. F. INPUT control, R-154, back to zero.

SECTION 4. OPERATING INSTRUCTIONS

4.1 GENERAL

4.11 It is assumed that a general idea of the operation of the circuits has been obtained from Section 3, PRINCIPLES OF OPERATION. This section deals only with SPECIFIC OPERATING INSTRUCTIONS, which are purposely made just as concise as possible. These operating instructions cover the following:

- 4.2 Placing Equipment in Operation
  - 4.21 STAND BY operation
  - 4.22 Full operation
- 4.3 Checking Heterodyne Frequency Meter Against Calibrator
  - 4.31 Full Checking Procedure
  - 4.32 Short Checking Procedure
- 4.4 Setting Up or Measuring a Frequency, QUICK METHOD
  - 4.41 To Set Up a Frequency, QUICK METHOD
  - 4.42 To Measure a Frequency, QUICK METHOD
- 4.5 Setting Up or Measuring a Frequency, EXACT METHOD
  - 4.51 To Set Up a Frequency, EXACT METHOD
  - 4.52 To Measure a Frequency, EXACT METHOD
- 4.6 Checking and Adjusting Calibrator Against Standard-Frequency Transmissions; Use of Calibrator Output in External Circuits
  - 4.61 Crystal and Standard-Frequency Comparisons
  - 4.62 Checking Calibrator
  - 4.63 Adjusting Calibrator
  - 4.64 Using Calibrator Output in External Circuits
- 4.7 Use of Interpolator on Audio Frequencies from an External Source
- 4.8 Use of Equipment as a Source of Known Audio Frequencies
- 4.9 Operation if Part of Equipment is Faulty
  - 4.91 General
  - 4.92 Calibrator Partially or Wholly Faulty
  - 4.93 Heterodyne Frequency Meter Partially Faulty
  - 4.94 Interpolator Partially or Wholly Faulty
  - 4.95 Detector and Audio Amplifier Partially or Wholly Faulty
  - 4.96 Interpolation by Scale of Equal Parts

4.2 TO PLACE EQUIPMENT IN OPERATING CONDITION

4.21 Stand By Operation

4.211 Turn POWER switch, S-106, to STAND BY position at least 30 minutes before exacting use is to be made of the equipment. The POWER and CRYS. HEAT pilot lights, I-101, -102, should light. In some cases, if such time is not available, it will be satisfactory to use the equipment before 30 minutes on STAND BY has elapsed. The error of the calibrator, due to the crystal temperature not having reached its final value, is small since the temperature coefficient of frequency of the crystal is low. At normal room temperatures the crystal heat is on approximately 35 seconds and off 60 seconds, after the STAND BY period of 30 minutes.

4.22 Full Operation

4.221 To place equipment in full operation, turn POWER switch, S-106, to ON position. Wait five minutes for tubes to reach full operating temperature.

4.222 When the POWER switch, S-106, is turned to the ON position, the HFM plate current meter, M-103, should read. If the RANGE SELECTOR switch, S-102, is set on a "dead" point, or, if for any other reason the HFM Oscillator does not oscillate, the meter will indicate approximately 2.6 ma. If the RANGE SELECTOR switch, S-102, is on a working point and the HFM Oscillator is oscillating, the meter, M-103, should indicate approximately 1.5 ma.

4.223 When the POWER switch, S-106, is turned to the ON position, and the CALIBRATOR switch, S-101, is turned to an operating position, the CRYSTAL OSC. plate current meter should read approximately 1.5 ma. If the crystal does not oscillate, the meter should read approximately 2.4 ma. When power is first applied, the multivibrator and amplifier tubes of the calibrator are cold, so that about one-half minute is required for the meter to give its proper indication.

4.3 TEST OF INTERPOLATOR SCALE ALIGNMENT; CHECK OF HETERODYNE FREQUENCY METER (HFM) AGAINST CALIBRATOR

4.31 Full Checking Procedure

4.311 *A quick test of the INTERPOLATOR scale alignment can be made as follows:*

(1) Turn HFM RANGE SELECTOR switch, S-102, to highest frequency range.

(2) Turn CALIBRATOR switch, S-101, to 10-kc position.

(3) Throw DETECTOR INPUT switch, S-103, to MEASURE position.

(4) Throw INTERPOLATOR SCALE-SELECT switch, S-104, to LOWER position.

(5) Turn HFM FREQUENCY control, C-135-A, -B, rapidly. The INTERPOLATOR meter, M-101, should read 2.5 kc$\pm$0.05 kc on LOWER BLACK scale, *while* the frequency control is being turned rapidly.

(6) Repeat (5) with INTERPOLATOR SCALE-SELECT switch, S-104, in UPPER position; the INTERPOLATOR meter, M-1, should read 2.5 kc$\pm$0.05 kc on LOWER BLACK scale, *while* the frequency control is being turned rapidly.

(7) For accurate alignment tests and adjustments for the INTERPOLATOR, see paragraph 5.526, page 29.

4.312 *Full Checking Procedure, for Checking Heterodyne Frequency Meter Against Calibrator*

(1) Throw DETECTOR INPUT switch, S-103, to MEASURE position.

(2) Select range desired on HFM RANGE SELECTOR switch, S-102.

(3) Turn HFM FREQUENCY control, C-135-A, -B, to nearest calibrator harmonic to the required frequency (100 kc, or 0.1 Mc, multiples on BLACK or 200 kc, or 0.2 Mc, multiples on RED scales), setting HFM FREQUENCY dial N-103 carefully to index line at this frequency.

NOTE: On the *BLACK* scales of the direct-reading frequency dial, N-103, the calibrator harmonics of 10, 20 and 100 kc fall at multiples of 10, 20 and 100 kc. On the *RED* scales, the calibrator harmonics of 10, 20 and 100 kc fall at multiples of 20, 40 and 200 kc. On *BOTH* scales *the long dial markings indicate actual calibrator harmonics,* which are multiples of 10 or 20 kc. Long markings, with a cross-bar at the top, underlining the number giving the frequency at that mark, indicate actual calibrator harmonics at multiples of 100 or 200 kc. On any of the scales, very short marks indicate intermediate frequency intervals which are multiples of 5, 10 or 50 kc (all of which can be checked from the calibrator, but which are not principal *zero beat* points) which are of assistance in estimating frequencies lying between calibrator harmonics.

(4) Throw CALIBRATOR switch, S-101, to 100-kc position.

(5) If a beat tone is then heard in the telephones, plugged in at the TEL jacks, J-101 or J-102, reduce this beat to zero by carefully setting COMPENSATOR, C-135-C, making the HFM FREQUENCY dial reading agree with the calibrator.

(6) Throw CALIBRATOR switch, S-101, to 20 kc or to 10 kc position.

(7) Turn HFM FREQUENCY control, C-135-A, -B, to nearest (20 or 10 kc, or 0.02 or 0.01 Mc, multiples on BLACK or 40 or 20 kc, or 0.04 or 0.02 Mc, multiples on RED scale) calibrator harmonic, to the required frequency, setting the HFM FREQUENCY dial, N-103, carefully to index line at this frequency.

(8) If a beat tone is heard in the telephones, plugged in at the TEL jacks, J-101 or J-102, or connected to the REMOTE telephone circuit, reduce this beat to zero by carefully setting COMPENSATOR, C-135-C, making the HFM FREQUENCY dial reading agree with the calibrator.

NOTE: The above gives the full procedure for checking the heterodyne frequency meter against the calibrator, to make the direct reading dial agree exactly with the calibrator at a frequency not over 10 kc away from any desired frequency, and taking all precautions to avoid any possible error or ambiguity. Where the instrument is known to be in good order, this full procedure is not necessary, and the following short checking procedure will serve.

4.32 Short Checking Procedure

(1) Throw DETECTOR INPUT switch, S-103, to MEASURE position.

(2) Select range desired on HFM RANGE SELECTOR switch, S-102.

(3) Turn HFM FREQUENCY CONTROL, C-135-A, -B, to nearest calibrator harmonic, to the required frequency (20 kc, or 0.02 Mc, on BLACK, or 40 kc, or 0.04 Mc, on RED scale), setting the HFM FREQUENCY dial, N-103, carefully to index line at this frequency.

(4) Throw CALIBRATOR switch, S-101, to 20-kc position.

(5) If a beat tone is then heard in the telephones, plugged in at TEL jacks, J-101 or J-102, reduce this beat to zero by carefully setting COMPENSATOR, C-135-C, making the HFM FREQUENCY dial N-103 agree with the calibrator.

4.4 TO SET UP OR MEASURE A FREQUENCY — QUICK METHOD

4.41 To Set Up a Desired Frequency by the Quick Method for Approximate Results

4.411 *Frequency Between 160 kc and 15 Mc*

(1) Check heterodyne frequency meter calibration against CALIBRATOR, as given in Section 4.3, at a setting near desired frequency.

NOTE: If the calibration of the HFM FREQUENCY dial, N-103, has been checked very recently near the desired frequency, step (1) may be omitted. If there is any question, however, *ALWAYS CHECK THE CALIBRATION.*

(2) Set HFM FREQUENCY dial, N-103, to desired frequency.

(3) The desired frequency is then available at the R. F. OUTPUT terminal on panel.

(4) Beats between this desired frequency and the frequency of an external source (connected to the R. F. INPUT terminal, E-102) are obtained by throwing the DETECTOR INPUT switch, S-103, to the MATCH position. The level of the voltage introduced at the R. F. INPUT terminal, E-102, can be adjusted by the R. F. INPUT control, R-154.

The *ACCURACY of the RESULT* obtained above is limited by (1) the accuracy with which the reading of the HFM FREQUENCY dial, N-103, has been made to agree with the CALIBRATOR, and (2) the accuracy with which the desired frequency can be read from the HFM FREQUENCY dial, N-103. This method is useful for a quick set-up of a desired frequency, as in *preliminary* adjustments of transmitters or receivers.

4.412 *Frequency between 15 and 30 Mc*

(1) Take *one-half* of the desired frequency.

(2) Select range 12 or 13 on HFM RANGE SELECTOR switch, S-102, as required for (1). See lines 12×2 and 13×2, heavy sections, on MULTIPLIER chart, N-106.

(3) Proceed as given in paragraph 4.411 above, setting *one-half* the desired frequency in 4.411 (2).

4.413 *Frequency between 30 and 45 Mc*

(1) Take *one-third* of the desired frequency.

(2) Select range 12 or 13 on HFM RANGE SELECTOR switch, S-102, as required for (1). See lines 12×3 and 13×3, heavy sections, on MULTIPLIER chart, N-106.

(3) Proceed as given in 4.411 above, setting *one-third* the desired frequency in 4.411 (2).

4.414 *Frequency between 45 and 60 Mc*

(1) Take *one-quarter* of the desired frequency.

(2) Select range 13 on HFM RANGE SELECTOR switch, S-102, as required for (1). See line 13×4, heavy section, on MULTIPLIER chart, N-106.

(3) Proceed as given in 4.411 above, setting *one-fourth* the desired frequency in 4.411(2).

4.42 To Measure a Frequency by the Quick Method for Approximate Results

4.421 *Frequency between 160 kc and 15 Mc*

(1) Check heterodyne frequency meter calibration against CALIBRATOR, as given in Section 4.3, at a setting near the frequency to be measured.

NOTE: If the calibration of the HFM FREQUENCY dial, N-103, has been checked very recently near the frequency to be measured, step (1) may be omitted. If there is any question, however, ALWAYS CHECK THE CALIBRATION.

(2) Set HFM FREQUENCY dial, N-103, to estimated value of frequency to be measured.

(3) Throw DETECTOR INPUT switch, S-103, to MATCH position.

(4) Vary HFM FREQUENCY control, C-135-A, -B, to obtain zero beat, against the frequency to be measured (introduced at R. F. INPUT terminal, E-102; level controlled at R. F. INPUT control, R-154).

(5) Read value of frequency from HFM FREQUENCY dial, N-103.

The accuracy of the result is limited by the same factors as those given under paragraph 4.411.

4.422 *Frequency between 15 and 30 Mc*

(1) Take *one-half* of the estimated value of the frequency to be measured.

(2) Select range 12 or 13 on HFM RANGE SELECTOR switch, S-102, as required for (1). See lines 12×2 and 13×2, heavy sections, on MULTIPLIER chart, N-106.

(3) Proceed as given in paragraph 4.421 above, setting at *one-half* the estimated value of the frequency for zero beat, in 4.421(2).

(4) *Multiply* reading obtained from HFM FREQUENCY dial, N-103, *by 2*, to obtain value of frequency being measured.

4.423 *Frequency between 30 and 45 Mc*

(1) Take *one-third* of estimated value of the frequency to be measured.

(2) Select range 12 or 13 on HFM RANGE SELECTOR switch, S-102, as required for (1). See lines 12×3 and 13×3, heavy sections, on MULTIPLIER chart, N-106.

(3) Proceed as given in paragraph 4.421 above, setting at *one-third* the estimated value of the frequency for zero beat in 4.421(2).

(4) *Multiply* reading obtained from HFM FREQUENCY dial, N-103, *by 3* to obtain value of frequency being measured.

4.424 *Frequency between 45 and 60 Mc*

(1) Take *one-quarter* of estimated value of frequency to be measured.

(2) Select range 13 on HFM RANGE SELECTOR switch, S-102, as required for (1). See line 13×4, heavy section, on MULTIPLIER chart, N-106.

(3) Proceed as given in paragraph 4.421 above, setting at *one-quarter* the estimated value of the frequency for zero beat in 4.421(2).

(4) *Multiply* reading obtained from HFM FREQUENCY dial, N-103, *by 4* to obtain value of frequency being measured.

4.5 TO SET UP OR MEASURE A FREQUENCY — ACCURATE METHOD

4.51 To Set up a Desired Frequency by the Accurate Method

4.511 *Frequencies from 160 kc to 15 Mc*

(1) Check heterodyne frequency meter calibration against CALIBRATOR, as given in Section 4.3, at a setting near desired frequency.

NOTE: If the calibration of the HFM FREQUENCY dial, N-103, has been checked very recently near the desired frequency, Step (1) may be omitted. If there is any question, however, *ALWAYS CHECK THE CALIBRATION.*

(2) Set HFM FREQUENCY dial, N-103, to desired frequency.

At this point, the heterodyne frequency meter is set to the desired frequency by the QUICK method. The following steps are concerned with setting ACCURATELY to this desired frequency.

(3) Determine the amount that the desired frequency is above the frequency of the calibrator point next below it. For BLACK scales on the HFM FREQUENCY dial, N-103, this FREQUENCY DIFFERENCE will be from 0 to 10 kc, for RED scales on the HFM FREQUENCY dial, N-103, this FREQUENCY DIFFERENCE will be from 0 to 20 kc.

(4) Throw the INTERPOLATOR SCALE SELECTOR switch, S-104, to LOWER or UPPER position, according to the value of the FREQUENCY DIFFERENCE found in (3) above, as tabulated below.

(5) Throw CALIBRATOR switch, S-101, to 10-kc position.

(6) Readjust HFM FREQUENCY control, C-135-A, -B, carefully until correct frequency difference is read on INTERPOLATOR meter, M-101, on correct scale, as tabulated below.

(6*a*) NOTE the correspondence of colors, that is, if the scale in use on the HFM FREQUENCY dial, N-103, is BLACK, frequency differences are read on the BLACK scales on the INTERPOLATOR meter, M-101; if the scale in use on the HFM FREQUENCY dial, N-103, is RED, frequency differences are read on the RED scales on the INTERPOLATOR meter, M-101.

(6*b*) NOTE that when the FREQUENCY DIFFERENCE has been determined the proper scale on the INTERPOLATOR meter, M-101, is evident at once on inspection. The COLOR is determined by the COLOR of the HFM FREQUENCY dial, N-103, scale in use; the LOWER or UPPER portion is determined by the value of the FREQUENCY DIFFERENCE.

(6*c*) NOTE that if the INTERPOLATOR meter, M-101, reads zero (on lower scales) or full scale (on upper scales) even though a strong beat tone can be heard in the telephones, the DEIONIZE button, S-105, should be pressed and then released. See paragraph 3.252(12).

(7) If, in making the readjustment of (6) above, the reading of the INTERPOLATOR meter, M-101, falls in the BLUE zone, follow instruction note on meter scale and change CALIBRATOR switch, S-101, setting to 20-kc position. Complete the readjustment called for in (6).

(8) The desired frequency is then available at the R. F. OUTPUT terminal, E-103.

(9) Beats between this desired frequency and the frequency of an external source (connected to the R. F. INPUT terminal E-102) are obtained by throwing the DETECTOR INPUT switch,

STEP (2)	*STEP* (3)	*STEP* (4)	*STEP* (6)
HFM FREQUENCY DIAL (N-103) SCALE	REQUIRED FREQUENCY DIFFERENCE IN RANGE (kc)	THROW INTERPOLATOR SCALE SELECTOR Switch S-104 to:	READ REQUIRED FREQUENCY DIFFERENCE ON INTERPOLATOR Meter (M-101) SCALE:
BLACK	0–5	LOWER	BLACK–LOWER
BLACK	5–10	UPPER	BLACK–UPPER
RED	0–10	LOWER	RED–LOWER
RED	10–20	UPPER	RED–UPPER

S-103, to the MATCH position. The level of the voltage introduced at the R. F. INPUT terminal, E-102, can be adjusted by the R. F. INPUT control, R-154.

The accuracy of the result obtained above is limited by (1) the accuracy of the calibrator and (2) the accuracy of the interpolator. The calibrator error should be so small as to be negligible. The interpolator error will be small in the final frequency because this error is only a small part of the beat frequency difference between the heterodyne frequency meter and calibrator frequencies.

4.512 *Frequencies from 15 to 30 Mc*

(1) Take *one-half* of the desired frequency.

(2) Select range 12 or 13 on HFM RANGE SELECTOR switch, S-102, as required for (1). See lines 12×2 and 13×2 on MULTIPLIER chart, N-106.

(3) Proceed as given in paragraph 4.511 above, setting to *one-half* the desired frequency in 4.511, (2) through (7).

4.513 *Frequencies from 30 to 45 Mc*

(1) Take *one-third* of the desired frequency.

(2) Select range 12 or 13 on HFM RANGE SELECTOR switch, S-102, as required for (1). See lines 12×3 and 13×3, heavy sections, on MULTIPLIER chart, N-106.

(3) Proceed as given in paragraph 4.511 above, setting to *one-third* the desired frequency in 4.511, (2) through (7).

4.514 *Frequencies from 45 to 60 Mc*

(1) Take *one-quarter* of the desired frequency.

(2) Select range 13 on HFM RANGE SELECTOR switch, S-102, as required for (1). See line 13×4, heavy section, on MULTIPLIER chart, N-106.

(3) Proceed as given in paragraph 4.511 above, setting *one-quarter* the desired frequency in 4.511, (2) through (7).

4.52 To Measure a Frequency by the Accurate Method

4.521 *Frequencies from 160 kc to 15 Mc*

(1) Check heterodyne frequency meter against calibrator, as given in Section 4.3, at a setting near the estimated value of the frequency being measured.

NOTE: If the calibration of the HFM FREQUENCY dial, N-103, has been checked very recently near the desired frequency, Step (1) may be omitted. If there is any question, however, *ALWAYS CHECK THE CALIBRATION.*

(2) Set HFM FREQUENCY dial, N-103, to estimated value of frequency to be measured.

(3) Throw DETECTOR INPUT switch, S-103, to MATCH position.

(4) Vary HFM FREQUENCY control, C-135-A, -B, to obtain zero beat against frequency to be measured (introduced at R. F. INPUT terminal, E-102; level controlled at R. F. INPUT control, R-154).

(5) *At this point, the heterodyne frequency meter reads the value of the frequency being measured by the QUICK METHOD.* The following steps are concerned with measuring this frequency by the ACCURATE method.

(6) Throw DETECTOR INPUT switch, S-103, to MEASURE position.

(7) Turn CALIBRATOR switch, S-101, to 10-kc position.

(8) Throw INTERPOLATOR SCALE SELECTOR switch, S-104, to LOWER position.

(8*a*) If reading of INTERPOLATOR meter, M-101, falls in BLUE zone, follow instruction note on the meter scale and change the calibrator frequency to 20 kc.

(8*b*) NOTE that if the INTERPOLATOR meter, M-101, reads zero (on lower scales) or full scale (on upper scales), even though a strong beat tone can be heard in the telephones, the DEIONIZE button, S-105, should be pressed and then released. See paragraph 3.252(12).

(9) Advance the INTERPOLATOR SCALE-TEST control, C-163, in direction of arrow, until a change in reading of the interpolator meter M-101 takes place. If pointer moves to LOWER scale readings, leave INTERPOLATOR SCALE switch, S-104, in LOWER position. If pointer moves to HIGHER scale readings, throw INTERPOLATOR SCALE SELECTOR switch, S-104, to UPPER position.

(10) The value of the frequency being measured is given by the SUM of the calibrator frequency next below the setting of the HFM FREQUENCY dial, N-103, and the reading on the INTERPOLATOR meter, M-101, taken on the correct scale, as tabulated on page 22. (The HFM FREQUENCY dial, N-103, indicates the approximate value of the frequency being measured.)

NOTE the correspondence of colors, that is, if the scale in use on the HFM FREQUENCY dial, N-103, is BLACK, the INTERPOLATOR meter, M-101, is read on the BLACK scales; if the scale in use on the HFM FREQUENCY dial, N-103, is RED, the INTERPOLATOR meter, M-101, is read on the RED scales.

NOTE that having determined the correct position of the INTERPOLATOR SCALE SELECTOR switch, S-104 (Step 9), the position of the switch indicates which scale of the INTERPOLATOR meter, M-101, should be read. With switch thrown to LOWER position, read LOWER scale; with switch thrown to UPPER position, read UPPER scale.

The accuracy of the result is limited by the same factors as those given under paragraph 4.511.

4.522 *Frequencies Between 15 and 30 Mc*

(1) Take *one-half* of the estimated value of the frequency to be measured.

(2) Select range 12 or 13 on HFM RANGE SELECTOR switch, S-102, as required for (1).

See lines 12×2 and 13×2, heavy sections, on MULTIPLIER chart, N-106.

(3) Proceed as given in paragraph 4.521 above, setting at *one-half* the estimated value of the frequency for zero beat in 4.521, (2) through (10).

(4) *Multiply* final readings *by 2* to obtain value of frequency being measured.

4.523 *Frequencies Between 30 and 45 Mc*

(1) Take *one-third* of the estimated value of the frequency to be measured.

(2) Select range 12 or 13 on HFM RANGE SELECTOR switch, S-102, as required for (1). See lines 12×3 and 13×3, heavy sections, on MULTIPLIER chart, N-106.

(3) Proceed as given in paragraph 4.251 above, setting at *one-third* the estimated value of the frequency for zero beat in 4.251, (2) through (10).

(4) *Multiply* final readings *by 3* to obtain value of frequency being measured.

4.524 *Frequencies Between 45 and 60 Mc*

(1) Take *one-quarter* of the estimated value of the frequency to be measured.

(2) Select range 13 on HFM RANGE SELECTOR switch, S-102, as required for (1). See line 13×4, heavy section, on MULTIPLIER chart, N-106.

(3) Proceed as given in paragraph 4.251 above, setting at *one-quarter* the estimated value of the frequency for zero beat in 4.251, (2) through (10).

(4) *Multiply* final readings *by 4* to obtain value of frequency being measured.

4.6 CHECKING AND ADJUSTING CALIBRATOR AGAINST STANDARD FREQUENCY TRANSMISSIONS; USING CALIBRATOR OUTPUT IN EXTERNAL CIRCUITS

4.61 Crystal and Standard Frequency Comparisons

4.611 In this equipment the stability and accuracy of the crystal oscillator frequency (rated value 100 kc±1 cycle) are such that the necessity for applying corrections to the crystal frequency harmonics or for making adjustments to the crystal frequency by means of control C-102 (see paragraph 3.2211) should rarely be encountered.

4.612 While the procedure of paragraph 4.63 has been given to cover the possibility of crystal frequency adjustment, *a special report, including all the standard frequency transmission check measurements, should be sent through the proper authorities to the Bureau*, if there is evidence over a period of a month that the average crystal frequency differs from its rated value of 100 kc by more than 2 cycles.

4.62 Checking Calibrator

4.621 The frequency of the crystal controlled calibrator may be checked in terms of standard frequency transmissions, through the use of an external receiver. (Refer to BEI-117, October 1, 1940.) Pick up the standard frequency transmission in the receiver, which is preferably of the oscillating type. Introduce the output of the calibrator into the receiver circuits by coupling from the CAL. OUT terminal to the antenna circuit of the receiver. *NOTE:* Keep snap cover on CAL. OUT concentric jack, E-104, when this output is not in use to provide shielding of circuits from noise and radio frequencies.

4.622 The CALIBRATOR 100-kc output is obtained at the CAL. OUT terminal, E-104, as follows:

(1) Turn CALIBRATOR switch, S-101, to 100-kc position.

STEP (5)	*STEP* (9)	*STEP* (10)
Scale of HFM FREQUENCY DIAL (N-103) in use:	INTERPOLATOR SCALE SELECTOR Switch S-104 thrown to:	READ following INTERPOLATOR SCALE on Meter, M-101:
BLACK	LOWER	BLACK–LOWER
BLACK	UPPER	BLACK–UPPER
RED	LOWER	RED–LOWER
RED	UPPER	RED–UPPER

(2) Throw DETECTOR INPUT switch, S-103, to MEASURE position.

(3) If a beat is obtained with the heterodyne frequency meter, simply turn the HFM FREQUENCY control, C-135-A, -B, until the heterodyne frequency is outside the response range of the receiver, or turn the RANGE SELECTOR switch, S-102, to another range.

4.623 The difference in frequency between the standard frequency and the calibrator frequency will be heard in the receiver output as a "flutter" of noise or hum (or of the beat tone, if the receiver is oscillating and set for a beat tone against the standard frequency) or as a very low beat tone.

4.63 Adjusting Calibrator

4.631 If the CALIBRATOR is to be set into agreement with the standard frequency transmission, proceed as follows:

(1) Release the four fasteners near the four corners of the panel by turning one-quarter turn to left.

(2) Draw equipment forward on slides.

(3) Insert service cable between the two parts of the automatic connector in the lower left front corner of instrument. The service cable is stored in the compartment under the top of the cabinet. It is readily accessible when the instrument is drawn forward on the slides.

(4) While listening to the "flutter" or low beat tone heard in the receiver output, release the lock on dial of C-102 (located at rear of top shelf) with a screw driver, and with the screw driver, turn the dial slowly, one way or the other, to make the "flutter" become a very slow waxing and waning.

(5) Lock dial of C-102.

(6) Remove service cable and store in place.

(7) Push equipment back into place.

(8) Lock the four fasteners, near the four corners of the panel, by turning one-quarter turn to right.

4.632 Refer to Figure 4.632 for average curve of the change in frequency of the crystal oscillator as a function of the dial setting of C-102.

4.64 Using Calibrator Output in External Circuits

4.641 The output of the calibrator is available at the CAL. OUT terminal, E-104, following the procedure given below, and may be used directly in calibrating receivers, etc. The output frequency can be 10, 20 or 100 kc, with harmonics. Key frequencies, to identify the harmonic frequencies, can be obtained by setting up frequencies on the heterodyne frequency meter in the usual way.

4.642 To obtain the output of the calibrator at the CAL. OUT terminal, E-104, proceed as follows:

(1) Turn CALIBRATOR switch, S-101, to desired frequency.

(2) Throw DETECTOR INPUT switch, S-103, to MEASURE position.

(3) Connect external circuit to CAL. OUT terminal, E-104.

(4) If the output of the heterodyne frequency meter produces an undesired beat, simply move the HFM FREQUENCY control, C-135-A, -B, until no interference remains, or turn the RANGE SELECTOR switch, S-102, to another range.

4.7 USE OF INTERPOLATOR ON AUDIO FREQUENCIES FROM AN EXTERNAL SOURCE

4.71 The interpolator may be used as a frequency meter for indicating or measuring the frequency of an external audio frequency source. *The frequency range which can be covered is 0 to 5.5 kc.*

4.72 Connect the audio frequency source to a telephone plug and insert this at the jack, J-103, marked INTERP. INPUT. The tip of the plug should be connected to the "high" side of the source; the sleeve should be connected

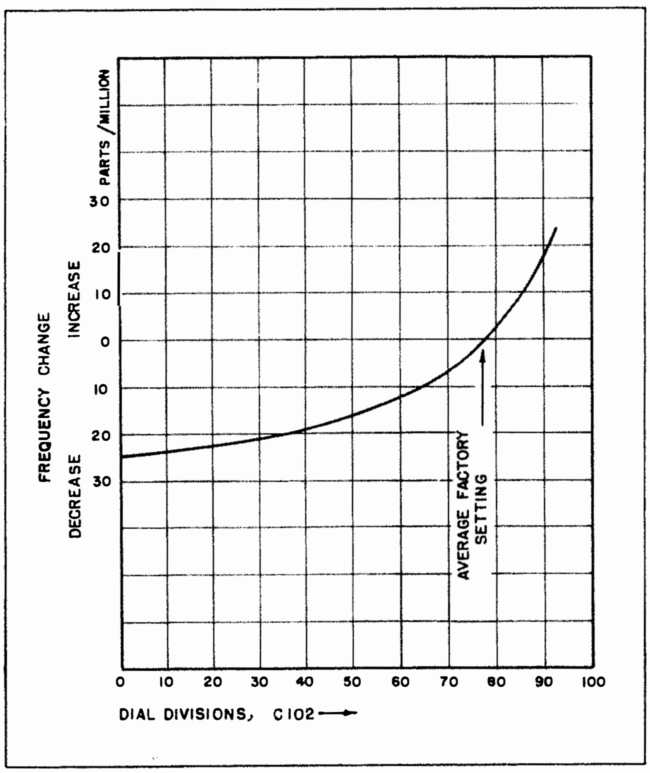


FIGURE 4.632. Plot of Frequency Change vs. Dial Setting of C-102 for Crystal-Controlled Calibrator

to the "low" (ground) side of the source. On inserting the plug in the jack, J-103, the "low" side of the source will be grounded. The source voltage should be at least five volts, and may be up to 100 volts.

4.73 The input impedance of the interpolator is high, 0.5 megohm approximately, so a step-up audio-frequency transformer may be used to advantage between the source and the interpolator. If the source is balanced to ground, the transformer may have a balanced primary connection, with the secondary unbalanced. If a transformer with a step-up ratio is used, the minimum source voltage which is required to operate the interpolator is reduced from the figure of 5 volts given above, depending on the step-up ratio.

4.74 Throw the INTERPOLATOR SCALE SELECTOR switch, S-104, to the LOWER position. Read the frequency of the audio-frequency source on the LOWER BLACK scale. No attention need be paid to the BLUE zone on the INTERPOLATOR meter scale, M-101, when the interpolator is being used as described in this section.

4.8 USE OF EQUIPMENT AS A SOURCE OF KNOWN AUDIO FREQUENCIES

4.81 The beat frequency obtained between the heterodyne frequency meter and the crystal calibrator may be used as a source of known audio frequencies over a range from 0 to 5.5 kc as described below:

(1) Turn CALIBRATOR switch, S-101, to 20-kc position.

(2) Turn HFM RANGE SELECTOR switch, S-102, to range 1, 160–232 kc.

(3) Throw DETECTOR INPUT switch, S-103, to MEASURE position.

(4) Throw INTERPOLATOR SCALE SELECTOR switch, S-104, to LOWER position.

(5) Adjust HFM FREQUENCY control, C-135-A, -B, to obtain zero beat against any calibrator harmonic near the middle of the range.

(6) Advance the HFM FREQUENCY control, C-135-A, -B, to increase the beat frequency. The INTERPOLATOR meter, M-101, indicates the audio frequency at all times. Read the LOWER BLACK scale. No attention need be paid to the BLUE zone on the INTERPOLATOR meter scale, M-101, when it is being used as described in this section.

(7) The audio-frequency output is obtained at either of the TEL jacks, J-101 or J-102, and at REMOTE telephone connection. If no telephones are plugged in, while the equipment is being used as an audio-frequency source, the output voltage will be somewhat greater and the waveform at low frequencies will be greatly improved. The output impedance of this audio-frequency source is 600 ohms, approximately, balanced to ground. The audio output voltage is approximately 3.0 volts into a 600-ohm load. The output voltage may be adjusted by means of the TEL VOLUME control, R-184-A, -B.

4.9 OPERATION IF PART OF EQUIPMENT IS FAULTY

4.91 The following paragraphs outline methods of using this equipment in cases where parts of the circuits are faulty. In such cases it will be appreciated that the convenience of operation or the accuracy of the result may be adversely affected. However, it may be better to have some approximate result or somewhat restricted coverage than to have no results at all.

4.92 Calibrator Partially or Wholly Faulty

4.921 10 kc position normal; 20 kc position normal or faulty; 100 kc position normal or faulty. Full operation by QUICK METHOD (Sections 4.41, 4.42) can be obtained. Only partial operation by EXACT METHOD can be obtained. INTERPOLATOR readings are restricted to ranges outside of BLUE zones giving ranges 0–4.5 kc, 5.5–10 kc, 0–9 kc and 11–12 kc for the respective scales. Interpolation by the use of the scale of equal parts (N-103, N-104) may be used. (See Section 4.96.)

4.922 10 kc position faulty; 20 kc position normal; 100 kc position faulty or normal. Full operation by QUICK METHOD (Sections 4.41, 4.42) can be obtained. Somewhat over 50% coverage can be obtained by EXACT METHOD (5.5 kc on either side of every 20 kc CALIBRATOR point on BLACK scales; 11 kc on either side of every 40 kc CALIBRATOR point on RED scales. Interpolation by the use of the scale of equal parts (N-103, N-104) may be used. (See Section 4.96.)

4.923 10 kc and 20-kc positions faulty; 100-kc position normal. Practically full operation may still be obtained by the QUICK METHOD, the only difficulty being encountered in the LOW FREQUENCY ranges of the Heterodyne Frequency Meter. Interpolation by the use of the scale of equal parts (N-103, N-104) may be used. (See Section 4.96.)

4.924 If the calibrator is faulty on all three positions, 10, 20 and 100 kc, no accurate operation is possible. Results can still be obtained by the QUICK METHOD (see Sections 4.41, 4.42) but only by relying upon the accuracy with which the heterodyne frequency meter keeps its calibration.

4.93 Heterodyne Frequency Meter Partially Faulty

4.931 If one or more of the fundamental ranges of the heterodyne frequency meter are faulty, no results can be obtained on such faulty ranges, *or on their second harmonic ranges.* (See table, paragraph 3.232.) Normal results can, of course, be obtained for the ranges showing no fault.

4.94 Interpolator Partially or Wholly Faulty

4.941 If the interpolator is faulty in one position, full operation is of course possible by the QUICK METHOD (see Sections 4.41, 4.42) and is also possible by the EXACT METHOD *provided* the readings are properly interpreted.

4.942 UPPER scale faulty; LOWER scale normal. In this case results must be obtained by adding *or* subtracting the interpolator reading to or from the frequency of the calibrator point. It is probably simplest, for most cases, to note which way the frequency of the heterodyne frequency meter must be varied to go from the nearest calibrator point to the desired frequency or the frequency being measured on HFM FREQUENCY dial, N-103. If the HFM frequency is *increased,* ADD the INTERPOLATOR reading on LOWER scale to the frequency of the CALIBRATOR point; if the HFM frequency is *decreased,* SUBTRACT the INTERPOLATOR reading on LOWER scale from the frequency of the CALIBRATOR point.

4.943 LOWER scale faulty; UPPER scale normal. The principle of operation is just as given in 4.942. Note which way the frequency of the heterodyne frequency meter must be varied to go from the nearest calibrator point to the desired frequency, or the frequency being measured, on HFM FREQUENCY dial, N-103. If the HFM frequency is *increased,* SUBTRACT the INTERPOLATOR reading on UPPER scale from the frequency of the calibrator point *next above the reference calibrator point;* if the HFM frequency is *decreased,* ADD the INTERPOLATOR reading on UPPER scale to the frequency of the calibrator point *next below the reference calibrator point.*

4.944 If BOTH scales are faulty, no operation is possible by the EXACT METHOD. Use the QUICK METHOD (see Sections 4.41, 4.42) or interpolation by scale of equal parts N-103, N-104. (See Section 4.96.)

4.95 Detector and Audio Amplifier Partially or Wholly Faulty

4.951 If the detector and audio amplifier are partially faulty, so that the output is much below normal level, the interpolator may not function because of insufficient input voltage. In such a case, results cannot be obtained by the EXACT METHOD. Use the QUICK METHOD (see Sections 4.41, 4.42) or interpolation by scale of equal parts, N-103, N-104. (See Section 4.96.)

4.952 If the detector and audio amplifier are wholly faulty, operation can be obtained by using an external receiver. Couple the receiver to the CAL. OUT terminal, E-104, and to the R. F. OUTPUT terminal, E-103. Beats between the Heterodyne Frequency Meter and the calibrator may then be obtained in the receiver. Full operation by the QUICK METHOD (see Sections 4.41, 4.42) can then be obtained. Because of the absence of filters in the audio frequency circuits of the receiver, it is not recommended that operation by the EXACT METHOD be attempted unless the operator is thoroughly familiar with the problem. If sufficient audio output is available from the receiver, the INTERPOLATOR can be operated by plugging the receiver output into the INTERP. INPUT jack, J-103.

4.96 Interpolation by Scale of Equal Parts

4.961 The accuracy of results may be improved in cases where the QUICK METHOD only can be used, by interpolating on the scale of equal parts, N-103, N-104, instead of interpolating by estimating reading on the HFM FREQUENCY dial, N-103.

4.962 Refer to Figure 4.962. Let the frequency f_1 represent the calibrator point next below the desired frequency f_x (or the frequency to be measured, f_x) and S_1 represent the corresponding scale setting read on the equal parts scale. Let f_2, similarly, represent the frequency of the calibrator point next above f_x, and S_2 represent the corresponding scale setting. $(f_2 - f_1)$ represents the frequency difference between the two calibrator harmonics used and is equal to the fundamental frequency selected by the CALIBRATOR switch, S-101.

4.963 The calibrator frequencies can be immediately identified from the direct-reading HFM FREQUENCY dial, N-103. Set to zero beat against f_1 and note the scale reading, in divisions, corresponding; this is S_1. Set to zero beat against f_2 and note the scale reading, in divisions, corresponding; this is S_2. Find the "divisions per kilocycle" factor D from

$$D = \frac{S_2 - S_1}{f_2 - f_1}$$

where $(S_2 - S_1)$ is the number of scale divisions between the settings for f_1 and f_2. $(f_2 - f_1)$ is 10, 20 or 100 kc, depending upon the CALIBRATOR

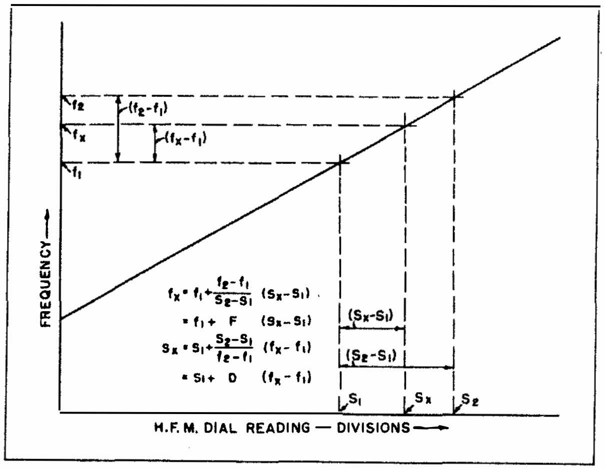


FIGURE 4.962. DIAGRAM ILLUSTRATING INTERPOLATION BY SCALE OF EQUAL PARTS

switch setting, S-101. Find the "kilocycles per division" factor F from

$$F = \frac{f_2 - f_1}{S_2 - S_1}$$

where $(S_2 - S_1)$ and $(f_2 - f_1)$ are as above.

4.964 To set up a frequency, determine the value of $(f_x - f_1)$, that is, the number of kilocycles f_x is above f_1. Then this frequency difference $(f_x - f_1)$ multiplied by the "divisions per kilocycle" factor D gives the scale difference $(S_x - S_1)$ or the number of divisions S_x lies above S_1.

$$(f_x - f_1)D = (S_x - S_1)$$

4.965 To measure a frequency, find the scale difference $(S_x - S_1)$, that is, the number of divisions S_x lies above S_1. Then this scale difference $(S_x - S_1)$ multiplied by the "kilocycles per division" factor F gives the frequency differences $(f_x - f_1)$ or the number of kilocycles that f_x lies above f_1.

$$(S_x - S_1)F = (f_x - f_1).$$

SECTION 5

PROBABLE TROUBLES: LOCATING; OVERCOMING

5.1 GENERAL STATEMENT

5.11 There is little likelihood of troubles developing from failure of circuit components, other than vacuum tubes. Whatever the cause of difficulty may be, the first step in overcoming any trouble is localization of the fault or failure. In general, the portion of the circuit affected is either known by the manner in which the equipment operates or by simple methodical tests. Having established the portion of the circuit at fault, the following outlines of possible sources of difficulty should be helpful.

5.12 If a circuit analyzer is available, check readings should be made for the tubes involved in the portion of the circuit in question and compared with those given on page 70. If no analyzer is available, then ohmmeter tests, point-to-point in the portion of the circuit in question may disclose any serious circuit fault. It must be borne in mind that neither the analyzer nor ohmmeter tests will always quickly disclose open-circuits, particularly those in series with capacitors or within capacitors.

5.13 If the difficulty may be traceable to old or defective tubes, systematically replace tubes in the affected section. If replacing a tube makes no change, return to the original tube. If a tube-tester or tube-checker is available, the tubes involved may be checked, though such checks do not always disclose a defective tube. *CAUTION:* If the tube-tester or tube-checker does not have complete directions and provision for testing tubes of special types, such as the 38205 (VR-105) and 38884 (884), DO NOT ATTEMPT TO CHECK SUCH TUBES. Gas tubes such as these can be permanently damaged if connected in circuits not provided with appropriate resistance in series with the source of plate supply voltage.

5.2 CALIBRATOR

5.21 CRYSTAL OSCILLATOR

5.211 The performance of the crystal oscillator can be judged from the readings of the CRYS. OSC. meter, M-102, and from the control of the multivibrator. If the crystal oscillator fails to oscillate, M-102 will read 2.4 ma and the multivibrator will not control on any position of the CALIBRATOR switch, S-101. When operating correctly, M-102 reads 1.5 ma approximately, the reading depending on the calibrator frequency and somewhat on the line voltage. The reading, in general, will be slightly higher with a new crystal oscillator tube, V-101, than with an old tube. Check by replacing V-101 and using analyzer or ohmmeter, if circuit defects are suspected.

5.22 TEMPERATURE CONTROL

5.221 Failure of the temperature control system would be indicated by (1) abnormally high or low readings of thermometer, M-104, or (2) by the HEAT signal lamp, I-101, not lighting at all or staying lighted. If the HEAT signal lamp fails to light, first check reading of thermometer, M-104, mounted on the top of the temperature control box, rear left of top shelf in equipment (by drawing equipment forward on slides).

5.222 If thermometer reads 50°C±2.5°C, the control is functioning properly. The trouble is then a burned out HEAT signal lamp, I-101, or poor connections in the lamp socket.

5.223 If the thermometer shows an abnormally low reading, or no reading, the fault is in the heater circuits. Check HEAT fuse, F-102; check heater circuit for resistance or for continuity. A thermostat which fails to close the circuit when cold, or an open-circuit in the thermostat or heater connections, is indicated.

5.224 If the thermometer, M-104, shows an abnormally high reading, either a faulty thermostat, S-107, which fails to open-circuit when hot, or a short-circuit across the thermostat connections is indicated, at S-107 or C-101.

5.23 MULTIVIBRATOR

5.231 If the multivibrator controls properly on one or two positions of the CALIBRATOR switch, S-101, the difficulty is most probably within the multivibrator itself — those circuits associated with V-103 and V-104, but such difficulty may possibly be contingent on subnormal output from the amplifier V-102.

5.232 If the crystal oscillator is normal (see 5.21) the input and output of the amplifier may be easily checked if a vacuum-tube voltmeter is available. Remove multivibrator tubes V-103, -104. Throw CALIBRATOR switch, S-101, to 100-kc position. With the vacuum-tube voltmeter measure the voltage from the grid terminal of V-102 to ground. This should be approximately 6.0 volts. Then measure the voltage across R-111 (or the voltage from the junction of R-112, -113, -114 to ground). This should be 12.0 volts±0.5 volt, at normal line voltage. If it is not, adjust R-109 to obtain this value.

5.233 To check for faults or to check the alignment of the multivibrator V-103, -104, replace these tubes and remove amplifier V-102. Throw CALIBRATOR switch, S-101, to 100-kc position. Using the heterodyne frequency meter direct-reading dial, N-103, check the frequency of the multivibrator harmonic obtained near 200 kc. This frequency should be 200 kc±1 kc. If it is not, adjust R-114 to bring the frequency close to 200 kc. *NOTE:* The beat tone will sound rough and unsteady, the frequency varying somewhat with line voltage. An approximate setting for the frequency can be made, however, which is sufficient for this test. Next, insert the amplifier V-102 and let it reach operating temperature. Using the heterodyne frequency meter, set it for a beat of, say, 0.5 kc, near 200 kc. Next vary R-114, noting if the beat tone changes from 0.5 kc. Normally, the multivibrator remains in control over the entire range of R-114. Set R-114 at the mid-point of the range.

5.234 To check the 20-kc position, throw the CALIBRATOR switch, S-101, to the 100-kc position. Throw the heterodyne frequency meter RANGE SELECTOR switch, S-102, to the 1.33−1.87 Mc range. Vary the heterodyne frequency meter frequency control, C-135, A-B, noting the dial division reading (on the equal parts scale) for two *successive* 100-kc harmonics. Next throw the CALIBRATOR switch, S-101, to the 20-kc position. Then, starting at the lower of the 100-kc harmonic settings noted previously, call it zero, and count the number of zero beat points passed over in going to and including the higher of the two 100-kc harmonics. This count should be 0, 1, 2, 3, 4, 5. If the count is more than 5, the multivibrator frequency is too low. Adjust R-113 in the clockwise direction until a new control range is obtained and recheck until the correct count is obtained. If the count is less than 5, the multivibrator frequency is too high. Adjust R-113 in the counterclockwise direction until a new control range is obtained and recheck until the correct count is obtained. When the correct count has been obtained, set the heterodyne frequency meter to one of the 20-kc harmonics *in between* the two 100-kc harmonics previously noted. Set a beat of, say, 0.5 kc. Then vary R-113 each way until the beat note suddenly changes, noting the position of R-113. Make final setting of R-113 in middle of this range.

5.235 To check the 10-kc position, proceed as in 5.234 to spot two successive 100-kc harmonics on heterodyne frequency meter dial. Throw CALIBRATOR switch to 10-kc position. Make count of zero beat points, as described in 5.233, which should give 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. If the count is more or less than 10, correct by adjusting R-112, as described for R-113 in 5.234, and make final setting in same manner.

5.236 If the beat output at the telephones for beats between the CALIBRATOR and the heterodyne-frequency meter is below normal, the difficulty may be due, among other

20 KC

possibilities, to a subnormal calibrator output. Try replacing V-105.

5.3 HETERODYNE FREQUENCY METER

5.31 Heterodyne Oscillator Circuit

5.311 The general performance of the oscillator of the heterodyne frequency meter can be judged from the readings of the HFM PLATE meter, M-103, on any range. If the circuit fails to oscillate, the meter reading is approximately 2.6 ma; if the circuit oscillates normally, the reading is approximately 1.5 ma. If normal readings are obtained on all but one or two positions of the HFM RANGE SELECTOR switch, S-102, the difficulty is either in the switch, S-102, or in the coil associated with the defective range or ranges.

5.312 If the circuit fails to oscillate on all ranges, the difficulty may be a defective tube, V-110, or a fault in the oscillating circuit connections between tube and tuned circuit, or in the tuned circuit.

5.313 If the frequency of the heterodyne frequency meter does not check the dial readings, and is in error by a large amount, with the frequency much lower than the correct value, a coil shield has come off or was not replaced properly after having been removed.

5.32 HFM Input Signal Amplifier

5.321 If difficulty is encountered in getting good beats between the heterodyne frequency meter and a frequency introduced at the R. F. INPUT terminal, E-102, with the DETECTOR INPUT switch, S-103, in the MATCH position, it may signify a defective tube at V-112, or a fault in the circuits involving the DETECTOR INPUT switch, S-103, the plate output circuits of the tube V-112, or a fault in the INPUT control, R-154. Such a condition may also result from incorrect coupling to the source of the frequency being measured.

5.33 HFM Coupling Tube

5.331 If difficulty is encountered in obtaining good beats between the heterodyne frequency meter and the calibrator, with the DETECTOR INPUT switch S-103 in the MEASURE position, the fault may lie in the HFM coupling tube, V-113, or in the circuits involving the switch, S-103.

5.34 To Align Direct-Reading Dial, N-103

5.341 Set condenser C-135 to 0 or 2500 divisions on scale of equal parts.

5.342 If necessary, set index line on direct-reading dial into vertical position. To do this, remove cover by removing the two clamps. Remove mask by removing the staking screw in the edge of the spider; remove three screws at center; remove ring; rotate mask one tooth at edge of spider and remove. Loosen setscrews behind the dial assembly which are accessible with a screw driver put through the arms of the spider. Set index against a straight edge placed between center of zero corrector on M-101 and center of direct-reading dial N-103. Lock setscrews firmly.

5.343 Replace mask and dial cover. Align cover index with index line of direct-reading scale. Secure cover firmly by tightening clamps.

5.344 Check adjustments by setting RANGE SELECTOR switch, S-102, on Range 13 ; setting C-135 to 0 or 2500 divisions on scale of equal parts; see that dial and cover indexes are in alignment.

5.345 Check mask and window opening alignment by turning S-102 to Range 13 and making certain that the right and left edges of mask opening are in alignment with the sides of the window opening in the dial cover. If the edges are not aligned, loosen the setscrews in the sprocket hub on the shaft of the RANGE SELECTOR switch, S-102, advance or retard the mask by turning the sprocket until the edges are aligned. Set up setscrews firmly.

5.346 Check the alignment of the knob indicator on the RANGE SELECTOR switch, S-102, with the engraving on the panel. If not in alignment, loosen setscrews in knob, turn knob into alignment and tighten setscrews.

5.4 DETECTOR AND A. F. AMPLIFIER

5.41 Detector

5.411 If the audio-frequency output is low, it may be due to a faulty detector tube. If so, replacing V-106 should result in improved output. If no improvement is found, replace original tube and see if the trouble is in the circuits of S-103, or is beyond the detector in the audio amplifier.

5.42 Audio Amplifier

5.421 Difficulties which may be due to poor tubes are best localized by successively replacing the tubes with new ones. If an audio-frequency voltmeter or output meter is available, it may be used to advantage. Adjust the heterodyne frequency meter for a beat of, say, 1 kc against a calibrator harmonic. Connect the audio-frequency voltmeter across the telephones at J-101 or J-102. As the successive tubes are replaced, note the meter readings. A sudden increase, following replacement of a given tube, discloses the faulty tube.

5.422 If the above tests fail to disclose a fault in the audio amplifier, an audio-frequency source may be connected to the grid of each stage of the amplifier in turn, V-109, V-108, V-106, beginning at the *last* stage. For each stage note that a substantial gain in output occurs. If the oscillator is calibrated, the required input voltage at each stage can be noted, for constant output. If any stage shows no appreciable gain, the trouble is probably in that stage, either in the tube or its associated circuits.

5.423 After applying the audio-frequency voltage to the grid of V-108, note that on applying the voltage between cathode and ground of V-107 a small loss in gain may occur, due to filter LC-101. Similarly, applying the voltage at the grid of V-107, a slight loss in gain may be expected. In either case, however, if no output is obtained, the trouble is localized in LC-101 and its connections, or in V-107 and its connections.

5.5 INTERPOLATOR

5.51 Input Amplifier

5.511 If failure of the input amplifier is suspected, replace V-114 with another tube and see if proper performance results. If not, check circuits from T-101 through V-114 to T-102.

5.52 Electronic Frequency Meter

5.521 Failure of the electronic frequency meter may be caused by defective tubes, particularly V-115, V-116, lack of plate voltage, lack of audio-frequency input voltage or defective switching at S-104, the INTERPOLATOR SCALE SELECT Switch. Verify the operation of V-119, -120, and V-118 by inspection to see that they glow, to be certain that proper plate supply voltage is obtained. Check input amplifier as in 5.511 above. Replace V-115 and/or V-116. If proper performance is obtained with S-104 in one position, but not in the other, the trouble is localized in the circuits associated with S-104. V-117, the switching tube, is not likely to cause complete failure unless its heater is burned out.

5.522 Erratic or irregular readings on the Interpolator Meter, M-101, may be caused by failure of plate voltage regulator system, V-118, -119, -120; irregular or variable audio frequency supplied to interpolator input, too low an audio-frequency voltage applied to interpolator input or faulty gas triode tubes V-115, -116. The plate voltage regulator system may be checked as given in Section 5.6 on Power Supply. If the frequency of the audio voltage applied to the interpolator is irregular or variable, the interpolator indication will attempt to follow such fluctuations *and the fault is not in the interpolator.* Check by listening in telephones. If insufficient audio-frequency voltage is applied to the interpolator input, reliable firing of the gas-triodes V-115, -116 will not be obtained. The check for audio input may be quickly made with a vacuum-tube voltmeter connected across the telephones (at least 1.0 volt should be obtained with TEL VOLUME control, R-184-A, -B, fully advanced in direction of arrow), or at input to V-114 (at least 10 volts should be obtained). Find the cause of this subnormal input. With normal audio-frequency input, irregular interpolator readings may be obtained through faulty gas triodes. Replace V-115 and/or V-116.

5.523 If the interpolator meter readings, M-101, vary with line voltage changes, the cause may be a defective regulator tube at V-119, -120, or, less likely, at V-118. If the *source frequency varies with supply line voltage,* the change of interpolator meter readings is *not due to any fault in the interpolator.* Check V-119, -120, and see that the glow discharge covers practically the whole electrode area and that it does not go out when the line voltage drops momentarily. If it does, replace one or both tubes.

5.524 Faulty gas-triodes, V-115, -116, can sometimes be detected by noting the color of the gas discharge. Normal tubes show a pinkish glow. Faulty tubes sometimes show a bluish or purplish glow.

5.525 *Quick Test for INTERPOLATOR Scale Adjustment*

5.5251 If the interpolator appears to be operating normally, but the calibration on one or both scales is not accurate, the following tests and adjustments can be made. Turn HFM Range Selector, S-102, to the highest frequency range. Turn Calibrator Switch, S-101, to 10-kc position. Throw DETECTOR INPUT switch, S-103, to MEASURE position. Throw INTERPOLATOR SCALE SELECT Switch, S-104, to LOWER position. Turn HFM FREQUENCY control, C-135-A, -B, rapidly. The Interpolator Meter, M-101, should read 2.5 kc on LOWER BLACK scale, *while* the frequency control is being turned rapidly. Repeat with the INTERPOLATOR SCALE SELECT switch, S-104, in the UPPER position; the Interpolator Meter, M-101, should read 2.5 kc on LOWER BLACK scale, *while* the frequency control is being turned rapidly.

5.526 *Accurate Alignment of INTERPOLATOR Scales*

5.5261 To align the LOWER scales of Interpolator proceed as follows, after sliding instrument out of cabinet on slides, attaching servicing cable, and operating in ON condition for ten minutes or more.

(a) Throw Interpolator Scale Selector Switch, S-104, to center (OFF) position. Check mechanical zero of Interpolator Meter, M-101. Reset, if necessary, by using zero adjuster on face of meter case.

(*b*) This next adjustment is not necessary (unless the setting of R-175 has been changed) *for routine alignment of calibration.* Remove V-114. Keep INTERPOLATOR SCALE SELECT Switch, S-104, in LOWER position. Turn R-175 back to zero (clockwise end), by screw driver adjustment on top of lower left-hand shelf. Meter M-101 will then read about one-tenth full scale. With a high resistance voltmeter, connected between the clockwise end of R-175 (located at center of lower left-hand shelf) and the arm, adjust R-175 to obtain a reading of 5.0 volts. (If a voltmeter cannot be obtained, adjust R-175 as follows: Proceeding as above, turn R-175 back to zero, then advance carefully in the counterclockwise direction until the reading of M-101 has been brought just to zero. Throw POWER switch, S-106, to STAND BY position. With an ohmmeter measure the resistance included between the arm of R-175 and the clockwise end (ground). Then advance R-175 in the counterclockwise direction until the resistance has been increased by 750 ohms. Remove ohmmeter. Throw POWER SWITCH, S-106, to ON position. If neither a voltmeter nor an ohmmeter is available, proceed as above, setting R-175 so that M-101 just reads zero. Note position of arm of R-175, then advance in counterclockwise direction by ¾ inch along winding.)

(*c*) Replace V-114 removed above.

(*d*) Set HFM RANGE SELECTOR switch, S-102, to lowest frequency range. Set CALIBRATOR switch, S-101, to 10-kc position. Throw DETECTOR INPUT switch, S-103, to MEASURE position. Adjust the HFM FREQUENCY control, C-135-A, -B, carefully, half-way between two 10-kc calibrator harmonics. This setting can be made accurately by bringing the flutter heard on the 5-kc note to a very slow waxing and waning. Throw calibrator switch, S-101, to 20-kc position. The audio output heard will then be a single tone of 5 kc. Keep INTERPOLATOR SCALE SELECTOR switch, S-104, in LOWER position. Adjust R-173 (screw driver adjustment on top, rear, of lower left-hand shelf) carefully, until the reading of the INTERPOLATOR Meter, M-101, is exactly 5 kc on the LOWER black scale. Both LOWER scales are then aligned.

5.5262 To align the UPPER scales of the INTERPOLATOR proceed as follows, after sliding instrument out of cabinet on slides, attaching servicing cable and operating in RUN condition for ten minutes or more.

(*a*) FIRST ALIGN the LOWER scales as given in Section 5.5261 above.

(*b*) Remove V-114. Throw the INTERPOLATOR SCALE SELECTOR switch, S-104, to UPPER position. Meter M-101 will then read near full scale.

(*c*) Adjust R-176 (by screw driver adjustment on top, rear, of lower left-hand shelf) until Interpolator Meter, M-101, reads just 10 kc on UPPER BLACK scale. Both UPPER scales are then aligned. Replace V-114 removed above.

5.6 POWER SUPPLY

5.61 The only likely sources of trouble in the power supply are the rectifier tube V-121, and fuses. If power supply fails entirely, first check fuses, then check operation of rectifier. If tube is defective, replace with another. If fuses blow, check the plate circuit on the filter side of F-103, and the output sides of L-108 and L-110, for short-circuits or broken down capacitors. Also check C-192A, B for defects. If the trouble appears as a blow-out of F-101, and the fault is not in the plate supply circuits, check for a short-circuit in the tube heater circuits, removing all tubes, the POWER pilot light I-102, and F-102 (to open the heaters of the temperature-control system). If the rectifier tube filament lights, and the remaining tube heaters and temperature control operate normally, but there is no plate supply voltage, check F-103. If the fuse F-103 is normal, then the trouble is likely an open circuit in L-108, -109 or -110.

5.62 The plate supply voltage which is regulated by V-119, -120 and V-118 is taken from the junction of L-108, -109. If the total supply voltage is normal and the regulator tubes V-119, -120 and V-118 do not light up, the trouble is in R-179 or associated wiring, or is due to a fault in the interpolator causing an abnormally large current to flow from the junction of R-178 and V-118 to S-105, the DEIONIZE switch. If the line voltage is abnormally low, or the fuse F-101 is not inserted in the correct position (suitable for the average line voltage) the regulators V-119, -120 may not light, but regulator V-118 should light. Check line voltage and position of F-101. Finally, if line voltage is normal, replace any regulator tube in which the glow discharge does not cover practically the whole electrode surface or any in which the discharge goes out if the line voltage drops momentarily.

5.7 LOCATING TROUBLE

These notes cover a number of maintenance problems that may be encountered in field use. Since most of these troubles are of a specific nature, knowledge of the symptoms and location of the troubles will be helpful to those charged with servicing these equipments. These notes are intended to expedite repairs that may occasionally be necessary in service operation.

SYMPTOM	CAUSE	REASON
Extraordinarily high hum in telephones, when checking against calibrator.	Open grid circuit.	Open grid in V-105, output tube of calibrator. Hum pick-up modulates calibrator output.
Steady audio note in phones, regular beats against calibrator heard in background.	Improper by-passing in audio amplifier.	Open common ground return of by-pass condenser bank of audio amplifier. Condenser bank mounted on power supply shelf.
No normal beat tones when checking against calibrator; steady very low frequency "popping."	Shorted diode detector.	Bus leads, at front of socket of V-106, shorted together.
No audio output.	Volume control set at minimum.	Incorrect operation.
No audio output.	Shorted plate voltage supply to detector and audio amplifier shelf.	Heavy shielded cables pull down B+ bus wire at left underside of shelf, shorting plate supply. Replace bus with insulated wire. Occurs only in serial numbers below 300.
High hum in audio output. Abnormal heating of hum-control R-183.	Abnormal voltage on part of R-183.	Ground on one side of heater circuits of tubes.
Low audio output.	Poor detection.	Faulty detector, V-106.
Noisy audio output when making zero-beat settings.	External noise pick-up or faulty detector.	Try replacing V-106, if noise continues with coupling lead disconnected.
Buzz in audio output. (Sounds like R. F. buzz from mercury rectifier.)	Sparking in buffer condensers.	If a foil in C-161, 162 or 190 is open, sparking may take place across gap. Condensers do *not* break down on voltage test.
Noise in audio output.	Poor contact in connections of power filter and audio by-pass condensers (bottom shelf).	Loosened soldering to condenser connections. Resolder.
Het. Freq. Meter calibration does not agree with calibrator.	Multivibrator out of control.	All calibrator adjustments had been turned to end of range. Reset according to instructions.
Unsteady beat tones; wobbly reading of interpolation meter.	Multivibrator out of control.	Readjust according to instructions.
Erratic operation of interpolator. Reads OK if DEIONIZE switch is pressed and released after switching instrument to ON.	Improper plate supply voltage to interpolator shelf.	Defective V-118; replace. Tube glows on first switching instrument ON; then goes out as tubes warm up (Normal) but fails to light up again unless deionize switch is pressed and released.
Erratic interpolator operation.	Improper bias.	Leads from power plug P-101 (lower left corner of panel) bear against R-172, on front lower side of interpolator shelf, grounding R-172.

SYMPTOM	CAUSE	REASON
Interpolator does not operate, with SCALE SELECTOR switch in upper position.	Improper bias.	R-173, 175 shorted by bare bus wire being bent in handling. (This lead is located at left of instrument near latch-bar.)
Interpolator meter snaps off-scale on approaching zero beat between HFM and calibrator.	10 KC or 20 KC passed through audio filters.	Faulty audio filter LC-101 or LC-102. See NOTE.

NOTE: This fault can be quickly detected by putting the HFM RANGE SELECTOR switch on a dead point. Set CALIBRATOR to 10 KC and then to 20 KC. If interpolator meter reads off-scale, instead of zero, one of the filters is faulty. Using a cathode-ray oscillograph check input and output voltages of each filter, setting gain to get a good deflection on the input voltage. If the filter is normal, no noticeable deflection will be obtained on the output voltage using the same gain. If the filter is faulty the trouble is probably an open-circuited condenser.

SYMPTOM	CAUSE	REASON
Erratic operation of interpolator, or a steady reading at about mid-scale.	Grounded interpolator meter.	Shield can of V-121 (power rectifier) on top shelf touches interpolator meter minus terminal.
Interpolator meter reads about 1/5th full scale continuously, with SCALE SELECTOR switch in lower position.	No bias voltage.	Open-circuit in deionize switch, or other failure in plate voltage supply to interpolator shelf.
Interpolator reading erratic, reads mid-scale at zero beat or with no signal. Small change in reading for 5 KC change in input frequency.	Incorrect bias.	Open at one end of R-175.
Crystal oscillator plate current low (0.6 ma approx.).	Low plate voltage to calibrator shelf.	C-120 on calibrator shelf short-circuited. Plate supply shorted through R-160.
Het. Freq. Meter does not oscillate.	Short-circuit in R.F. tuned circuit.	Ground on bus leads from coil assembly through top shelf.
Erratic oscillation of Het. Freq. Meter, ranges 10, 12.	Poor contact.	Loosened solder joint in L-106. Remove can and resolder joint just inside lip of coil form.
Het. Freq. Meter calibration does not agree with calibrator on two ranges.	Improper inductance.	Coil shield not in place.
Plate fuse blows (on turning to RUN from STAND BY).	Arc of plate voltage to ground.	High lead of C-185 (or other power filter condensers) very near case; breaks down under high voltage but tests open with ohmmeter.
Line fuse blows (on turning to STAND BY from OFF).	Abnormal load on high voltage winding.	Short-circuited buffer condenser C-192A, 192B.
Het. Freq. Meter plate current higher than normal 1.5 ma on Range 1; Frequency on Range 1 higher than normal.	Improper Het. Freq. Meter Coupling Condensers.	C-134 or C-136 open-circuited. Oscillator operates on residual capacity. Frequency error is greatest at low frequency, decreases at high frequencies.
Loss of HFM output on high frequencies (15–30 Mc).	Too high HFM oscillator grid-leak.	R-147 defective; resistance increased from normal of 0.1 meg. to nearly one megohm.

SECTION 6. ACCESS

6.1 GENERAL STATEMENT

6.11 The equipment is designed with the intention of having immediate access to as great a number of circuit elements as possible when drawn out of the cabinet on the slides. If the equipment is so installed as to give access to the sides of the instrument when it is drawn out of the case on the slides, immediate access is obtained for all vacuum tube replacements. If either side is blocked by adjacent bulkheads or other obstructions, access to a majority of the tubes is still obtained. When the equipment is lifted out of the slide carriage (see paragraph 2.2) and placed on a bench, access is obtained to practically all portions of the equipment except the power supply. The following instructions give details of access to specific parts of the equipment.

6.2 ACCESS TO POWER SUPPLY AND BY-PASS CAPACITORS OF AUDIO-FREQUENCY AMPLIFIER

6.21 Lift the equipment out of the slide carriage and place it on its *back* on a bench. Remove the eight screws exposed on the bottom of the instrument, four along each side. Slack is provided in the cables so that the power supply shelf may be drawn away from the bottom of the instrument and turned, giving access to all units mounted on this shelf.

6.22 To remount the power shelf, lay the cables in place as the shelf is brought into position; then fasten the shelf securely with the eight screws provided.

6.3 ACCESS TO CRYSTAL MOUNTING; HEATERS OF TEMPERATURE CONTROL. REMOVAL OF CRYSTAL MOUNTING OR THERMOSTAT

6.31 To obtain access to the crystal or the heaters of the temperature-control system, release the flat spring over the temperature box exposing the thermometer, M-104. Slide a piece of fine wire, or a strip of paper, under the thermometer and lift it up out of the temperature box. Lift up the entire balsa box (the "lid" is on the bottom, mounted on the shelf). This exposes the aluminum temperature-control unit. The aluminum box is held by snap catches to the base. Draw the box upward, and then tilt toward the interior of the equipment. Sufficient slack is provided in wiring so that the crystal mounting may be uncovered, or the interior of the temperature-control unit may be inspected or repaired without disconnecting any heater or thermostat connections.

6.32 To remove the thermostat, S-107, first remove balsa box as in 6.31 above, then disconnect the thermostat leads from terminals of C-101, mounted under top shelf at rear. Draw the thermostat out of the aluminum box. The thermostat may be withdrawn for inspection without disconnecting its leads.

6.33 To remove crystal monnting, Y-101, first remove the balsa and aluminum boxes, as in 6.31 above. Next disconnect the two leads to the crystal mounting. Next remove the screws in the corners of the isolantite base of the crystal mounting. Lift up the crystal mounting from the aluminum base. In replacing, make certain that the piece of felt is in position between the crystal base and the aluminum plate.

6.4 ACCESS TO CONNECTIONS OF MAIN TUNING CAPACITOR, C-135; HETERODYNE FREQUENCY METER OSCILLATOR CIRCUITS

6.41 Remove instrument from slides and place on bench. Turn so that back and left side are accessible. As viewed from back, looking below top shelf, access to many parts of the Heterodyne Oscillator sub-assembly is obtainable. Some access and some view is possible also through left side frame.

6.42 For greater access, place instrument as directed in Paragraph 6.21 and remove power supply shelf. Remove eight screws, four along each side casting, which secure the middle shelf in position. Slide middle shelf out of instrument. Access may then be had, from the bottom of the instrument, to the connections of the main tuning capacitor, C-135, and the circuits of the heterodyne frequency meter oscillator, V-110.

6.43 If the heterodyne oscillator sub-assembly must be removed, proceed as in 6.42. Disconnect the two wires from C-135, left side, to the oscillator sub-assembly at C-134 (right) and C-136 (right). Disconnect wire from C-163 (on panel) to sub-assembly at C-163 (left). Disconnect coupling wire going through top shelf at C-139, left. Disconnect wire from R-183 arm.

6.44 Remove four mounting screws on under side of top shelf, two near V-110 and two below shield base of V-121. The heterodyne oscillator sub-assembly can then be dropped to extent of slack in cable, giving access to all parts.

6.5 TO REMOVE MAIN TUNING CAPACITOR, C-135

6.51 Place instrument and remove shelves as directed in Paragraph 6.41.

6.52 Remove the direct-reading dial, N-103, in accordance with the instructions in Section 6.6. Remove control knob, E-123.

6.53 Unsolder the connections on the right-hand pair of terminals of C-135. These are accessible through the right-hand main frame. Unsolder the connections to the left-hand terminals of C-135 at the points where they attach to the Capacitor.

6.54 Loosen the four mounting screws in the top shelf, one in each corner of the main casting of C-135. These are accessible from the top of the instrument. Holding the casting, turn the screws out free of the casting.

6.55 Lower the casting, at the same time moving the left-hand edge away from the top shelf and past the Heterodyne Oscillator sub-assembly. Then lower the casting straight down to the bench. The casting can then be removed from between the side frames.

6.6 TO REMOVE THE MAIN DIRECT-READING DIAL, N-103

6.61 Remove cover of main dial.

6.62 Remove staking screw and lock-nut in edge of mask spider. Remove three screws in center ring. Remove ring. Turn mask, by grasping at edge, the amount of one tooth in the spider. Mask can then be drawn forward out of the spider. CAUTION: Do not scratch the mask by placing on a dirty surface.

6.63 Turn control knob, E-123, until the set-screws holding the dial plate and spider are accessible through the arms of the spider. Loosen these two screws, with a screw driver held parallel with the panel.

6.64 Grasping the edge of the dial plate, work it forward, and out of the assembly. CAUTION: Do not dirty the dial plate or scratch it by placing on a dirty surface.

6.65 After removal of the dial plate, with its shaft sleeve, the spider will be very loose on the dial shaft of C-135. Depress the tension arm, behind the panel, near the RANGE SELECTOR Switch, S-102, to take the tension off the chain. Lift chain off of sprocket on spider. Remove spider.

6.66 Reassemble dial mechanism in reverse order.

6.67 For alignment of main dial, N-103, see Paragraph 5.34.

6.7 TO REMOVE RANGE SELECTOR SWITCH, S-102, AND COIL ASSEMBLY

6.71 Disconnect the two bus leads from the middle and rear switch decks from C-140 (rotor) and C-135 (right rear terminal) respectively.

6.72 Remove two screws in left-hand support casting of coil assembly (on top shelf). Remove lock-nuts on two screws in right-hand support casting; then remove the screws.

6.73 Remove knob, E-115, of RANGE SELECTOR switch, S-102.

6.74 Loosen two set-screws in collar of sprocket on shaft of S-102.

6.75 Lifting up slightly on coil assembly, move assembly straight back from panel, until sleeve on shaft comes clear of panel bearing. The coil assembly can then be lifted up out of the instrument.

6.76 Reassemble in reverse order. See Paragraph 5.34 for instructions on alignment of direct-reading dial, N-103, and switch, S-102.

6.8 ACCESS TO POWER SWITCH, S-106

6.81 Remove the three mounting screws in the fuse plate, located just behind left edge of panel. Drop fuse plate on the flexible cable leads attached to it.

6.82 The panel mounting screws of the POWER switch, S-106, are accessible on removing the knob, E-119.

6.83 If necessary, dismount the POWER switch, S-106. The switch can then be drawn out of the side frame, and all connections reached, without disconnecting any wires.

6.9 ACCESS TO SUB-ASSEMBLY UNDER TUBE SHELF MOUNTED ON MAIN TOP SHELF

6.91 Unsolder lead, coming up through main top shelf near V-110, from sub-assembly. This point can be reached by removing V-110.

6.92 Disconnect lead running from C-120 to V-113, along rear edge of shield base on V-121.

6.93 Remove five mounting screws in the tube shelf.

6.94 Remove tubes from tube-shelf sockets.

6.95 Raise left-hand edge of tube shelf, to stand shelf on edge, exposing components mounted under shelf. If necessary, after raising the tube shelf, disconnect the lead between S-103 and R-161, at point under V-113, to obtain further access to sub-assembly.

PARTS LISTS

TABLE I

LIST OF MAJOR UNITS FOR MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER

Name	Symbol Group Designation
Combined Crystal Controlled Calibrator and Heterodyne Frequency Meter	101-199

TABLE II

PARTS LIST BY SYMBOL DESIGNATION FOR MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT

LOCATION CODE

Approximate locations of items in the equipment are indicated in Column 11 of Table II, "Parts List by Symbol Designation" in accordance with the following code.

The *section* of the equipment is indicated by *numerals:*

1. Main top shelf
2. Tube shelf, mounted on (1)
3. HFM oscillator sub-assembly, mounted under (1)
4. Main bottom shelf
5. Front panel
6. Upper left side shelf assembly
7. Lower left side shelf assembly
8. Lower right side shelf assembly
9. Main frame, left side
10. Main support base (fixed)

The *approximate position* of an item within a section of the equipment is indicated by *letters:*

B. Back
C. Center
F. Front
R. Right
L. Left

TABLE II

PARTS LIST BY SYMBOL DESIGNATION FOR MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT

Symbol Desig'n	Function	Description	Navy Type Number	Navy DWG. or SPEC. Number	Style	MFR.	MFR'S Desig'n	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Approximate Location (See P. 35)
			CAPACITORS							
*C-101	Thermostat Spark Filter	Mica; 0.02μf ± 10%; 600v DC wkg.	−48428-10	RE-48A-221A		2 or 19	4-11020 1445			1-BC below
C-102	Crystal Osc. Frequency Adjustment	Air; Var.; 320$\mu\mu$f max.; 500v DC wkg.	−481138			3	MC-325-1S			1-BC
C-103	Not used									
C-104	Crystal Osc. Fixed Tuning	Air; Var.; 320 $\mu\mu$f max. 500v DC wkg.	−481138			3	MC-325-S	Locked at max. cap.	1CA6	1-BL below
*C-105	Crystal Osc. Grid Capacitor	Mica; 0.0005μf ± 10% 600v DC wkg.	−48665-10	RE-48A-221-A		2 or 19	4-13050 1445			6-B
*C-106	Crystal Osc. Plate Blocking Capacitor	Same as C-101	−48428-10							6-B
*C-107	Crystal Osc. Plate R.F. By-pass Cap.	Same as C-101	−48428-10							6-B
*C-108	Crystal Osc. Screen R.F. By-pass Cap.	Same as C-101	−48428-10							6-B
*C-109	Crystal Osc. Amplifier Grid Capacitor	Same as C-105	−48665-10							6-B
*C-110	Crys. Osc. Amplifier Plate Blocking Cap.	Same as C-101	−48428-10							6-B
*C-111	Multivibrator Freq. Setting Capacitor	Mica; 0.00162μf ± 2% 600v DC wkg.	−481128-C2	RE-48A-221A		2 or 19	4LTS-120162 1445-LTS			6-B
*C-112	Multivibrator Freq. Setting Capacitor	Mica; 0.000750μf ± 2% 600v DC wkg.	−481125-C2	RE-48A-221A		2 or 19	4LTS-13075 1445-LTS			6-B
*C-113	Multivibrator Freq. Setting Capacitor	Mica; 0.000152μf ± 2% 600v DC wkg.	−481123-C2	RE-48A-221A		2 or 19	4LTS-130152 1445-LTS			6-B
*C-114	Multivibrator Freq. Setting Capacitor	Same as C-111	−481128-C2							6-F
*C-115	Multivibrator Freq. Setting Capacitor	Same as C-112	−481125-C2							6-F
*C-116	Multivibrator Freq. Setting Capacitor	Same as C-113	−481123-C2							6-F
*C-117	MV. Harmonic Ampl. Grid Capacitor	Mica; 0.00005μf ± 10% 600v DC wkg.	−48893-10	RE-48A-221A	C	2 or 19	4-14050 1445			6-C
*C-118	MV. Harm. Ampl. Cathode By-pass	Same as C-105	−48665-10							6-F
*C-119	Calibrator Plate Supply By-pass	Paper; 1.0μf +10% −3% 600v DC wkg. Oil Filled	−481004	RE-48A-147A		2 or 22	VC-1430 EUC-10498		1CL5	1-BL below
C-120	Calibrator R.F. Output Coupling Cap.	Air; Var.; 4 to 50$\mu\mu$f	−48787-A			3	APC-50-C		1CA2	6-F
*C-121	Detector R.F. Coupling Capacitor	Mica; 0.0001μf ± 10% 600v DC wkg.	−48666-10	RE-48A-221A	C	2 or 19	4-13010 1445			8-F
*C-122	Detector A.F. Coupling Capacitor	Same as C-101	−48428-10					Two 0.02μf cond. in parallel		8-F
*C-123	Impedance Transf. Tube Plate By-pass	Paper; 4.0μf +10% −3% 600v DC wkg. Oil Filled	−48865	RE-48A-147A		2 or 22	TDF-6040 EUC-10600		1CL8	4-CR
*C-124	First A.F. Stage Plate By-pass Cap.	Same as C-123	−48865							4-CR
*C-125	Imped. Transf. Tube Grid Capacitor	Same as C-101	−48428-10					Two 0.02 μf cond. in parallel		8-F
*C-126	Second A.F. Stage Grid Capacitor	Same as C-101	−48428-10					Two 0.02 μf cond. in parallel		8-C

* Spares furnished, for quantities refer to Table IV.

TABLE II (*Continued*)

PARTS LIST BY SYMBOL DESIGNATION FOR MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT

Symbol Desig'n	Function	Description	Navy Type Number	Navy DWG. or SPEC. Number	and Style	MFR.	MFR'S Desig'n	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Approximate Location (See P. 35)
		CAPACITORS (*Continued*)								
*C-127	First A.F. Stage High Freq. Suppressor	Mica; 0.000250μf ± 10% 600v DC wkg.	−48431-10	RE-48A-221A	C	2 or19	4-13025 1445			8-C
*C-128	Second A.F. Stage Cathode By-pass	Same as C-123	−48865							4-CR
*C-129	Second A.F. Stage Screen By-pass	Same as C-119	−481004							4-FR
*C-130	Second A.F. Stage Plate By-pass	Same as C-119	−481004							4-FR
*C-131	Second-Third A.F. Stages Coupling Cap.	Same as C-101	−48428-10					Two 0.02 μf cond. in parallel		8-B
*C-132	Third A.F. Stage Cathode By-pass	Same as C-123	−48865							4-FR
C-133	Not used									
*C-134	H.F.M. Osc. Grid Capacitor	Mica; 0.001μf ± 10% 600v DC wkg.	−48645-10	RE-48A-221A	C	2 or19	4-12010 1445			3-F
C-135	A H.F.M. Tuning Cap. Front Section	Air; Var.; 127 to 307μμf wkg.				1		Complete		
	B H.F.M. Tuning Cap Rear Section	Air; Var.; 132 to 312μμf wkg.						Assembly		
	C H.F.M. Tuning Cap., Compensator	Air; Var.; 3 to 15μμf						General		
*	D H.F.M. Tuning Cap., Trimmer Front	Air; Var.; 3 to 35μμf	−481196			3	APC-35C	Radio	1CA-14	1-FC
*	E H.F.M. Tuning Cap., Trimmer Rear	Air; Var.; 3 to 25μμf	−481195			3	APC-25C	Type	1CA-13	
*	F H.F.M. Tuning Cap., Temp. Comp. Front	Ceramicon, 25μμf	−481197-10			17	N680K	622-Z		
	G H.F.M. Tuning Cap., Temp. Comp. Rear	Same as C-135-F								
*C-136	H.F.M. Osc. Screen Blocking Cap.	Same as C-101	−48428-10							3-C
*C-137	H.F.M. Osc. Screen By-pass Capacitor	Same as C-101	−48428-10							3-B
*C-138	H.F.M. Osc. Plate By-pass Capacitor	Same as C-101	−48428-10							3-B
*C-139	H.F.M. Harmonic Output Coupling	Same as C-117	−48893-10							3-B
C-140	H.F.M. Fundamental Output Coupling	Air; Var.; 3 to 25μμf	−48628A			3	APC-25-C		1CA1	1-FR below
*C-141	Automatic Detector Coupling	Mica; 0.003μf ± 10% 600v DC wkg.	−481188-10	RE-48A-221A	C	2 or19	4-12030 1445			1-FR
*C-142	Automatic Detector Coupling	Mica; 0.0025μf ± 10% 600v DC wkg.	−481187-10	RE-48A-221A	C	2 or19	4-12025 1445			1-FR
*C-143	Automatic Detector Coupling	Mica; 0.0015μf ± 10% 600v DC wkg.	−481127-10	RE-48A-221A	C	2 or19	4-12015 1445			1-FR
*C-144	Automatic Detector Coupling	Mica; 0.0008μf ± 10% 600v DC wkg.	−481126-10	RE-48A-221A	C	2 or19	4-13080 1445			1-FR
*C-145	Automatic Detector Coupling	Mica; 0.0002μf ± 10% 600v DC wkg.	−481186-10	RE-48A-221A	C	2 or19	4-13020 1445			1-FR
*C-146	R.F. Input Blocking Capacitor	Same as C-105	−48665-10							5-L upper
*C-147	R.F. Input Amplifier Grid. Capacitor	Same as C-105	−48665-10							2-F
*C-148	R.F. Input Amplifier Cathode By-pass	Same as C-101	−48428-10							2-F
*C-149	R.F. Input Amplifier Plate By-pass	Same as C-119	−481004							2-F

* Spares furnished, for quantities refer to Table IV.

TABLE II (*Continued*)

PARTS LIST BY SYMBOL DESIGNATION FOR MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT

Symbol Desig'n	Function	Description	Navy Type Number	Navy DWG. or SPEC. Number and Style	MFR.	MFR'S Desig'n	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Approximate Location (See P. 35)
				CAPACITORS (*Continued*)					
*C-150	R.F. Output Blocking Capacitor	Mica; 0.00001μf ± 10% 600v DC wkg.	−481121-10	RE-48A-221A C	2 or 19	4-14010 1445			5-R upper
*C-151	H.F.M. Coupling Tube Plate By-pass	Same as C-119	−481004						2-B
C-152	H.F.M. Switching Compensator	Same as C-120	−48787A						1-FR below
*C-153	Interpolator Amplifier Grid Capacitor	Same as C-101	−48428-10						7-F
*C-154	Interpolator Metering Capacitor	Mica; 0.0015μf ± 2% 600v DC wkg.	−481127-C2	RE-48A-221A C	2 or19	4LTS-12015 1445-LTS			7-C
*C-155	Interpolator Switching Capacitor	Mica; 0.002μf ± 2% 600v DC wkg.	−48668-C2	RE-48A-221A C	2 or19	4LTS-12020 1445-LTS			7-C
*C-156	Interpolator Metering Capacitor	Same as C-154	−481127-C2						7-C
*C-157	Power Supply Filter Capacitor	Same as C-123	−48865						4-C
*C-158	Power Supply Filter Capacitor	Same as C-123	−48865						4-FC
*C-159	Power Supply Filter Capacitor	Same as C-123	−48865						4-FC
*C-160	Power Supp. H. F. Transient Suppr.	Paper; 0.5μf +10% −3% 1000v DC wkg. Oil Filled	−481139	RE-48A-147A	2 or 22	VC-1819 EUC-10499		1CL24	4-C
*C-161	Power Supply Buffer Capacitor	Mica; 0.001μf ± 10% 1200v DC wkg.	−48641-10	RE-48A-221A	2 or19	4-22010 1445			4-BL
*C-162	Power Supply Buffer Capacitor	Same as C-161	−48641-10						4-BL
C-163	Interpolator Scale-Test Capacitor	Air; Var.; ΔC 0 to 4μμf						P-400-454	5-LC
*C-164	Detector, A.F. Amplifier Plate By-pass	Same as C-123	−48865						4-FR
C-165	Not used								
C-166	Not used								
C-167	Not used								
C-168	Not used								
C-169	Not used								
C-170	Not used								
C-171	Not used								
C-172	Not used								
*C-173	Interpolator Suppressor, Plate	Same as C-101	−48428-10						7-B
*C-174	Interpolator Suppressor, Bias	Same as C-101	−48428-10						7-C
*C-175	Interpolator Suppressor, Cathode	Mica; 0.01μf ± 10% 600v DC wkg.	−48487-10	RE-48A-221A C	2 or19	4-11010 1445			7-B
C-176	H.F.M. Switching Compensator	Same as C-120	−48787A						1-FR below
*C-177	Local Tel. U.H.F. Filter Capacitor	Mica; 0.0001μf ± 10% 500v DC wkg.	−481042-10	RE-48A-218A	19	1465			5-C lower
*C-178	Local Tel. U.H.F. Filter Capacitor	Same as C-177	−481042-10						5-C lower
*C-179	Remote Tel. U.H.F. Filter Capacitor	Same as C-177	−481042-10						10-LB
*C-180	Remote Tel. U.H.F. Filter Capacitor	Same as C-177	−481042-10						10-LB

* Spares furnished, for quantities refer to Table IV.

TABLE II (*Continued*)

PARTS LIST BY SYMBOL DESIGNATION FOR MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT

Symbol Desig'n	Function	Description	Navy Type Number	Navy DWG. or SPEC. Number and Style	MFR.	MFR'S Desig'n	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Approximate Location (See P. 35)
				CAPACITORS (*Continued*)					
*C-181	Supply Line U.H.F. Filter Cap.; Output	Same as C-177	—481042-10						10-LB
*C-182	Supply Line U.H.F. Filter Cap.; Output	Same as C-177	—481042-10						10-LB
*C-183	Supply Line U.H.F. Filter Cap.; Input	Same as C-177	—481042-10						10-LB
*C-184	Supply Line U.H.F. Filter Cap.; Input	Same as C-177	—481042-10						10-LB
*C-185	Power Supply Filter Capacitor	Same as C-123	—48865						4-RB
*C-186	Interpolator Filament R.F. By-pass	Same as C-101	—48428-10						7-F
*C-187	Interpolator Filament R.F. By-pass	Same as C-101	—48428-10						7-F
*C-188	Calibrator Filament R.F. By-pass	Same as C-101	—48428-10						6-B
*C-189	Calibrator Filament R.F. By-pass	Same as C-101	—48428-10						6-B
*C-190	Power Supply Buffer Capacitor	Same as C-161	—48641-10						4-BL
*C-191	A.F. Output Blocking Capacitor	Same as C-101	—48428-10						8-B
*C-192A C-192B	Power Supply Surge Buffer Capacitor	Paper; 0.02 mfd., +10%-10%, 1500 volts d-c working. Oil filled; 2 sections	—481478-10	RE-13A-488C	23	2XDRTMW-15-.02		COLB-13	4-LB
				MISCELLANEOUS ELECTRICAL PARTS					
E-101	Anchor Terminal	Anchor Terminal			10	No. 3	Replace Eyelet and Washers		5-R upper
E-102 A	R.F. Input Connection	Concentric Jack	—49120	RA-49F-215A	1	774-400			5-L upper
E-102 B		Concentric Plug	—49121	RA-49F-216A	1	774-401			§S.P.B. 89
E-102 C		Binding Post Adapter			1			P-400-451	§S.P.B. 90
E-103 A	R.F. Output Connection	Same as E-102-A	—49120						5-R upper
E-103 B		Same as E-102-B	—49121						§S.P.B. 89
E-103 C		Same as E-102-C							§S.P.B. 90
E-104 A	Calibrator Output Connection	Same as E-102-A	—49120		1	139-58			5-C lower
E-104 B		Same as E-102-B	—49121						§S.P.B. 89
E-104 C		Same as E-102-C							§S.P.B. 90
E-105	Anchor Terminal	Cable Terminal on Strip			1	139-58			3-B
E-106	Anchor Terminal	Same as E-105							3-B
E-107	Anchor Terminal	Same as E-105							2-B below
E-108	Anchor Terminal	Same as E-105							2-B below
E-109	Anchor Terminal	Same as E-105							2-B below
E-110	Anchor Terminal	Same as E-105							2-B below
E-111	Anchor Terminal	Same as E-105							2-B below
E-112	Anchor Terminal	Same as E-105							2-B below
E-113	Anchor Terminal	Same as E-105							3-B
E-114	Knob for Calibrator Switch S-101	Insulating Knob, Skirted			1			137-117E	5-L upper
E-115	Knob for Het. Freq. Meter S-102	Insulating Knob, Skirted			1			P-400-318	5-R upper
E-116	Handle Knob for Key Switch, S-103	Insulating Handle			11	On #1424Sw.			5-RC
E-117	Handle Knob for Key Switch, S-104	Same as E-116							5-LC

* Spares furnished, for quantities refer to Table IV.

§ S.P.B. = Spare Parts Box No.

TABLE II (*Continued*)

PARTS LIST BY SYMBOL DESIGNATION FOR MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT

Symbol Desig'n	Function	Description	Navy Type Number	Navy DWG. or SPEC. Number and Style	MFR.	MFR'S Desig'n	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Approximate Location (See P. 35)
	MISCELLANEOUS ELECTRICAL PARTS (*Continued*)								
E-118	Knob for DEIONIZE Switch, S-105	Insulating Knob			1			P-400-319-1	5-R upper
E-119	Knob for POWER Switch, S-106	Insulating Knob, Skirted			1			P-400-317	5-LC
E-120	Knob for R.F. Input Control, R-154	Insulating Knob			1	137-105EF			5-L upper
E-121	Knob for Interp. Scale Test, C-163	Insulating Knob			1	137-104EF			5-LC
E-122	Knob for Compensator, C-135-C	Same as E-120					Engraved Arrow		5-RC
E-123	Knob for Het. Freq., Meter, C-135A, B	Insulating Knob with Handle			1	222-37			5-RC
E-124	Knob for Crys. Osc. Dial, N-105	Hex. Metal Knob			1			P-400-614	1-BC
E-125	Dial Lock for Crys. Osc. Dial, N-105	Clamps and Hex. Knob			1			P-400-315	1-BC
E-126	Indicator for Crys. Osc. Dial, N-105	Metal Coplanar.			1	139-84A			1-BC
E-127	Socket for Heat Pilot Light	Bayonet Base Socket			12	25A-CSP		139-981	5-L upper
E-128	Jewel for Heat Pilot Light	Red Jewel Assembly			12	32-CSP		139-982	5-L upper
E-129	Socket for Power Pilot Light	Same as E-127							5-R upper
E-130	Jewel for Power Pilot Light	Same as E-128							5-R upper
E-131	Tube Shield Base, Rectifier V-121	Aluminum Shield Base			1			P-400-853	1-LF
E-132	Tube Shield Can, Rectifier V-121	Aluminum Shield			1			P-400-871	1-LF
E-133	Grounding Strap	Flexible, Copper, with Terminals			1			P-400-312	10-LB
*E-134	Capacitor Insulator, C-135-A, B	Isolantite Insulator	RE-13A-317F		20			539-75A	
*E-135	Capacitor Insulator, C-135-A, B	Isolantite Insulator	RE-13A-317F		20			622-709	
*E-136	Insulator for C-135-C	Isolantite Insulator	RE-13A-317F		20			368-75	
*E-137	Terminal Bushing for C-135-A, B	Isolantite Insulating Bushing	RE-13A-317F		20			539-75	
E-138 A	Insulating Washer for Tel. Jacks	Duck bakelite			1			P-400-761	5-C lower
E-138 B	Insulating Plate for Tel. Jacks	Duck bakelite			1			P-400-760	5-C lower
E-139 A	Insulating Washer for Tel. Jacks	Same as E-138A							5-C lower
E-139 B	Insulating Plate for Tel. Jacks	Same as E-138B							5-C lower
E-140	Not used								
E-141	Anchor Terminal	Same as E-101							1-LB below
E-142	Cable Terminal on R-184-A, B	Hook Terminal			1	1302			5-C lower
E-143	Cable Terminal on R-184-A, B	Same as E-142							5-C lower
E-144	Insulator for C-163				1			P-400-74	
E-145	Tel. Vol. Control Knob, R-184	Insulating Knob			1			P-400-319-2	5-C lower
E-146	Tube Shield Base (For V-117)	Tube Shield Base			1	139-451-M			7-B
E-147	Tube Shield Can (For V-117)	Tube Shield Can			1	139-451-N			7-B
E-148	Tube Shield Cover (For V-117)	Tube Shield Cover			1	139-451-P			7-B
	FUSES								
*F-101	Line Fuse, 60-cycle Supply	Glass Cartridge Fuse, 2 Amp.		17-F2G	13	3-AG			9-FC
*F-102	Heat Fuse	Same as F-101							9-FC
*F-103	Plate Fuse	Glass Cartridge Fuse, 0.25 Amp.		17-F2G	13	3-AG			9-FC

* Spares furnished, for quantities refer to Table IV.

TABLE II (*Continued*)

PARTS LIST BY SYMBOL DESIGNATION FOR MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT

Symbol Desig'n	Function	Description	Navy Type Number	Navy DWG. or SPEC. Number and Style	MFR.	MFR'S Desig'n	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Approximate Location (See P. 35)
			HARDWARE						
H-101	Handles	Panel handles			1	139–140A			5-C lower
H-102	Dzus Fastener, Small	Panel fastener, upper corners			7	AJW-60		P-400-304	5-L,R upper
H-103	Dzus Fastener, Large	Panel fastener, lower corners			7	AJW7-80		P-400-305	5-L.R lower
H-104	Stop Latch	Slide assembly stop latch			1			P-400-308	sides, lower
H-105	Handle	Inside, main frame, left rear			1	139–140A			9-BC
			INDICATING DEVICES						
I-101	Crys. Temp. Control Pilot Light	Bayonet Base, 6-8v			21	Mazda #44		139-939	5-L upper
I-102	Power Supply Pilot Light	Same as I-101							5-R upper
			JACKS						
J-101	Connection for Telephone Receivers	Telephone Jack, Circuit Closing	—49021A	RE-13A-481E	14		Insulated from Ground		5-C lower
J-102	Connection for Telephone Receivers	Same as J-101	—49021A				Insulated from Ground		5-C lower
J-103	Connection to Interpolator Input	Same as J-101	—49021A				Frame Grounded		5-C lower
			INDUCTORS						
L-101	H.F.M. Oscillator Coil	Special Radio Frequency Coil; low-loss ceramic form; adj., wax impregnated.			1			P-400-L-101	1-FR
L-102	H.F.M. Oscillator Coil	Special Radio Frequency Coil; low-loss ceramic form; adj., wax impreganted.			1			P-400-L-102	1-FR
L-103	H.F.M. Oscillator Coil	Special Radio Frequency Coil; low-loss ceramic form; adj., wax impregnated.			1			P-400-L-103	1-FR
L-104	H.F.M. Oscillator Coil	Special Radio Frequency Coil; low-loss ceramic form; adj., wax impregnated.			1			P-400-L-104	1-FR
L-105	H.F.M. Oscillator Coil	Special Radio Frequency Coil; low-loss ceramic form; adj., wax impregnated.			1			P-400-L-105	1-FR
L-106	H.F.M. Oscillator Coil	Special Radio Frequency Coil; low-loss ceramic form; adj., wax impregnated.			1			P-400-L-106	1-FR
L-107	H.F.M. Oscillator Coil	Special Radio Frequency Coil; low-loss ceramic form; adj., wax impregnated.			1			P-400-L-107	1-FR
*L-108	Power Supply Filter Swing Choke	Core: General Radio 485–88 laminations, interleaved, with 0.016 inch air gap in center leg. Winding: 2400 turns No. 28 enameled wire. Vacuum impregnate in glyptal Case: General Radio 285–85 heavy cadmium plate. Potted in pure ozite.			1	485-424			4-LC

* Spares furnished, for quantities refer to Table IV.

TABLE II (*Continued*)

PARTS LIST BY SYMBOL DESIGNATION FOR MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT

Symbol Desig'n	Function	Description	Navy Type Number	Navy DWG. or SPEC. Number and Style	MFR.	MFR'S Desig'n	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Approximate Location (See P. 35)
		INDUCTORS (*Continued*)							
*L-109	Power Supply Filter Choke	Core: General Radio 485-80 laminations, butt joint, 3-0.006″ air gaps. Winding: 3400 turns No. 29 enameled wire tapped at 3300 turns; vacuum impregnate in glyptal. Case: General Radio 285-85 heavy cadmium plate. Potted in pure ozite.			1	485-425			4-RB
*L-110	Power Supply Filter Choke	Same as L-109			1				4-LF
L-111	Not Used								
L-112	Local Tel. U.H.F. Filter Choke	54 turns No. 26 D.S.C. on 63288 1 meg. resistor; impregnated in Superla			1	P-400-356			5-C lower
L-113	Local Tel. U.H.F. Filter Choke	Same as L-112							5-C lower
L-114	Remote Tel. U.H.F. Filter Choke	Same as L-112							9-LB
L-115	Remote Tel. U.H.F. Filter Choke	Same as L-112							9-LB
L-116	Supply Line U.H.F. Filter Choke	41 turns No. 20 D.S.C. on 63474 1 meg. resistor; impregnated in Superla			1	P-400-357			9-LB
L-117	Supply line U.H.F. Filter Choke	Same as L-116							9-LB
		A. F. FILTERS							
LC-101	Audio Frequency Filter	Low-pass, 600 ohm, sharp cut-off above 5.5 kc.			1	830-403			1-RB
LC-102	Audio Frequency Filter	Low-pass, 10,000 ohm, cut-off 5 kc.			1	830-404			8-B
		METERS, THERMOMETERS							
*M-101	Interpolator Indicating Meter	D.C. microammeter, 600μa D.C.	-22313	17-I-12A	8	271	Special scale	P-400-M101	5-C upper
*M-101 A	Interpolator Indicating Meter	Scale for M-101			8			P-400-M101A	
*M-102	Crystal Oscillation Indicator	D.C. milliammeter, 3ma.	-22312	17-I-12A	8	506	Navy Case		5-L upper
*M-103	Het. Freq. Meter Oscillation Ind.	Same as M-102	-22312	17-I-12A					5-R upper
*M-104	Thermometer for Crys. Temp. Control	Right angle; 50°C. center scale	-40036		{9A 9B}			139-181-2	1-LB
		NAMEPLATES, DIALS, CHARTS, etc.							
N-101	Name Plate	Equipment Model Plate			1			P-400-950	Cabinet, left
N-102	Name Plate	Patent License Plate			1			P-400-99	1-RB
N-103	Het. Freq. Meter Main Dial	Direct Reading Frequency Dial			1		Individual Calibration	P-400-90	5-C
N-104	Het. Freq. Meter Vernier Dial	Vernier for Equal Parts Scale N-103			1	222-520			5-RC
N-105	Crys. Osc. Tuning Dial	Crys. Osc. Freq. Adjustment Dial			1			P-400-314	1-BC
N-106	Het. Freq. Meter Range Chart	Diagram Chart of Harmonic Ranges			1			P-400-96	5-C

* Spares furnished, for quantities refer to Table IV.

TABLE II (*Continued*)

PARTS LIST BY SYMBOL DESIGNATION FOR MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT

Symbol Desig'n	Function	Description	Navy Type Number	Navy DWG. or SPEC. Number and Style	MFR.	MFR'S Desig'n	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Approximate Location (See P. 35)
				PLUGS AND SOCKETS					
P-101	Automatic Power Connector	6 point Multiple Plug			10			P-400-309	5-L lower
P-102	Automatic Power Connector	6 point Multiple Socket			10			P-400-311	10-FL
P-103	Servicing Cable Connector	6 point Multiple Plug and Cover			10			139-1269-6	
P-104	Servicing Cable Connector	6-point Multiple Socket and Cover			10			139-469-6	
				RESISTORS					
*R-101	Crystal Temperature Control Heater	Fixed, molded, wire wound, metal clad, 2Ω ±10% 2 watts	−63789		5	MW1½	Two 2Ω units in series		1-LB
*R-102	Crystal Oscillator Plate Resistor	Fixed, composition, pigtail; 3,000Ω ±10% 1 watt	−63288	RE-13A-372G	5	BT-1			6-B
*R-103	Crystal Oscillator Grid Leak	Fixed, composition, pigtail; 1,000,000Ω ±10% 1 watt	−63288	RE-13A-372G	5	BT-1			6-B
*R-104	Crystal Oscillator Screen Resistor	Fixed, composition, pigtail; 75,000Ω ±10% 1 watt	−63288	RE-13A-372G	5	BT-1			6-B
*R-105	Crystal Osc. Screen Voltage Divider	Fixed, composition, pigtail; 30,000Ω ±10% 2 watt	−63474	RE-13A-372G	5	BT-2			6-C
*R-106	Crystal Osc. Screen Voltage Divider	Fixed, composition, pigtail; 50,000Ω ±10% 2 watt	−63474	RE-13A-372G	5	BT-2			6-C
R-107	Crystal Osc. Ampl. Grid Leak	Same as R-103	−63288						6-B
*R-108	Crystal Osc. Ampl. Cathode Resistor	Fixed, molded, wire-wound, pigtail; 1,000Ω ±10% 1 watt	−63703-10	RE-13A-372G	5	BW-1			6-B
*R-109	Crystal Osc. Ampl. Cathode Resistor	Rheo, no taper, resistance decreases with clockwise rotation 5,000Ω ±10% 6 watt	−63849		1	410–406			6-B
*R-110	Crystal Osc. Ampl. Plate Resistor	Fixed, composition, pigtail; 20,000Ω ±10% 1 watt	−63288	RE-13A-372G	5	BT-1			6-B
*R-111	Multivibrator Input Coupling	Fixed, wire wound, 5,000Ω ±1% 1 watt	−63786-1		5	WW-4			6-C
*R-112	Multivibrator Freq. Adj. 10 kc.	Rheo, no taper, resistance decreases with clockwise rotation 5,000Ω ±10% 6 watt	−63847		1	410–407		LR-2	6-B
*R-113	Multivibrator Freq. Adj. 20 kc.	Same as R-109	−63849						6-B
*R-114	Multivibrator Freq. Adj. 100 kc.	Same as R-112	−63847						6-B
*R-115	Multivibrator Grid Resistor	Same as R-111	−63786-1						6-C
*R-116	Multivibrator Plate Resistor	Fixed, wire wound. 20,000Ω ±1% 1 watt	−63788-1		5	WW-4			6-C

* Spares furnished, for quantities refer to Table IV.

TABLE II (*Continued*)

PARTS LIST BY SYMBOL DESIGNATION FOR MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT

Symbol Desig'n	Function	Description	Navy Type Number	Navy DWG. or SPEC. Number	Navy DWG. or SPEC. Style	MFR.	MFR'S Desig'n	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Approximate Location (See P. 35)
		RESISTORS (*Continued*)								
*R-117	Multivibrator Plate Resistor	Same as R-116	−63788–1							6-C
*R-118	Multivibrator Grid Resistor	Same as R-111	−63786–1							6-C
*R-119	Multivibrator Grid Resistor	Fixed, wire-wound, 10,000Ω ±1% 1 watt	−63787–1			5	WW-4			6-C
*R-120	Multivibrator Plate Resistor	Same as R-116	−63788–1							6-F
*R-121	Multivibrator Plate Resistor	Same as R-116	−63788–1							6-F
*R-122	Multivibrator Output 100 kc.	Fixed, composition, pigtail; 750Ω ±10% 0.5 watt	−63360	RE-13A-372G		5	BT-½			6-F
*R-123	Multivibrator Output 20 kc.	Fixed, composition, pigtail; 680Ω ±10% 0.5 watt	−63360	RE-13A-372G		5	BT-½			6-F
*R-124	Multivibrator Output 10 kc	Fixed, composition, pigtail; 1,000Ω ±10% 0.5 watt	−63360	RE-13A-372G		5	BT-½			6-F
*R-125	M.V. Amplifier Bias	Fixed, composition, pigtail; 1,000Ω ±10% 1.0 watt	−63288	RE-13A-372G		5	BT-1			6-F
*R-126	M.V. Amplifier Plate Resistor	Same as R-102	−63288							6-F
*R-127	Crys. Osc. and M.V. Decoupling	Fixed, wire wound, ferrule; 5,000Ω ±5% 24 watt	−63085-E	RE-13A-372J Grade I, Class 2	D	5	FB-7-C			1-RB
*R-128	Diode Plate Resistor	Fixed, composition, pigtail; 4,000,000Ω ±10% 1 watt	−63288	RE-13A-372G		5	BT-1			8-F
*R-129	Diode Bias Voltage Divider	Fixed, composition, pigtail; 2,500Ω ±10% 1 watt	−63288	RE-13A-372G		5	BT-1			8-F
*R-130	Diode Bias Voltage Divider	Fixed, composition, pigtail; 100,000Ω ±10% 1 watt	−63288	RE-13A-372G		5	BT-1			8-F
*R-131	Impedance Transf. Tube Grid Leak	Fixed, composition, pigtail; 500,000Ω ±10% 1 watt	−63288	RE-13A-372G		5	BT-1			8-C
*R-132	Impedance Transf. Tube Plate Resistor	Fixed, composition, pigtail; 250,000Ω ±10% 2 watt	−63474	RE-13A-372G		5	BT-2			8-C
*R-133	Impedance Transf. Tube Cathode Res.	Fixed, molded, wire-wound, pigtail; 3,000Ω ±10% 1 watt	−63703–10	RE-13A-372G		5	BW-1			8-C
*R-134	1st Stage A.F. Ampl. Grid Leak	Same as R-103	−63288			5	BT-1			8-F
*R-135	1st Stage A.F. Ampl. Decoupling	Same as R-131	−63288							8-F
*R-136	1st Stage A.F. Ampl. Plate Resistor	Same as R-131	−63288							8-F
*R-137	2d Stage A.F. Ampl. Grid Leak	Same as R-130	−63288							8-C
*R-138	2d Stage A.F. Ampl. Bias Resistor	Fixed, molded, wire-wound, pigtail; 500Ω ±10% 1 watt	−63703–10	RE-13A-372G		5	BW-1			8-C
*R-139	2d Stage A.F. Ampl. Screen Suppr. Res.	Same as R-103	−63288							8-B
*R-140	2d Stage A.F. Ampl. Plate Suppr. Res.	Same as R-130	−63288							8-B

* Spares furnished, for quantities refer to Table IV.

TABLE II (*Continued*)

PARTS LIST BY SYMBOL DESIGNATION FOR MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT

Symbol Desig'n	Function	Description	Navy Type Number	Navy DWG. or SPEC. Number	Style	MFR.	MFR'S Desig'n	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Approximate Location (See P. 35)
		RESISTORS (*Continued*)								
*R-141	2d Stage A.F. Ampl. Plate Resistor	Same as R-130	−63288							8-C
*R-142	3d Stage A.F. Ampl. Grid Leak	Same as R-103	−63288							8-B
*R-143	3d Stage A.F. Ampl. Bias Resistor	Same as R-108	−63703–10							8-B
*R-144	3d Stage A.F. Ampl. Unloading Res.	Fixed, molded, wire-wound, pigtail; 100Ω ±10% 1 watt	−63703–10	RE-13A-372G		5	BW-1			5-C lower
*R-145	3d Stage A.F. Ampl. Unloading Res.	Same as R-144	−63703–10							5-C lower
*R-146	Detector, A.F. Ampl. Decoupling	Fixed, wire-wound, ferrule; 10,000Ω ±5%	−63090-E	RE-13A-372J Grade I, Class 2	D	5	FB-7-C			1-RB
*R-147	Het. Freq. Meter Osc. Grid Leak	Same as R-130	−63288							3-F
*R-148	H.F.M. Voltage Regulator Series Res.	Fixed, wire-wound, ferrule; 20,000Ω ±5% 28 watt	−63485-E	RE-13A-372J	C	5	FD-7-C			1-RB
*R-149	H.F.M. Osc. Screen Resistor	Same as R-106	−63474							3-C
*R-150	H.F.M. Osc. Plate Voltage Divider	Same as R-105	−63474							3-B
*R-151	H.F.M. Osc. Plate Voltage Divider	Same as R-106	−63474							3-B
*R-152	H.F.M. Osc. Plate Resistor	Fixed, composition, pigtail; 5,000Ω ±10% 1 watt	−63288	RE-13A-372G		5	BT-1			3-C
*R-153	H.F.M. Osc. Harmonic Output Resistor	Same as R-125	−63288							3-C
*R-154	R.F. Input Volume Control	Pot'r, tapered, resistance increases with clockwise rotation; counter clockwise end grounded; 0 to 10,000Ω ±10% 1.5 watt	−63756	RE-13A-492B		6	P-58-10,000-U			5-L upper
*R-155	R.F. Input Amplifier Grid Leak	Same as R-110	−63288							2-C
*R-156	R.F. Input Amplifier Bias Resistor	Same as R-138	−63703–10							2-C
*R-157	R.F. Input Amplifier Decoupling	Same as R-146	−63090-E							1-RB
*R-158	R.F. Input Amplifier Plate Res.	Same as R-129	−63288							2-C
*R-159	R.F. Output Coupling	Same as R-129	−63288							5-R upper
*R-160	Het.Freq.Meter Coupling Tube Grid Leak	Same as R-129	−63288							2-F
*R-161	H.F.M. Coupling Tube Cathode Res.	Fixed, composition, pigtail; 2,000Ω ±10% 1 watt	−63288	RE-13A-372G		5	BT-1			2-F
*R-162	H.F.M. Coupling Tube Decoupling	Same as R-148	−63485-E							1-RB
*R-163	Interp. Input Ampl. Series Grid Resistor	Same as R-130	−63288							7-F
*R-164	Not used									
*R-165	Interpolator Input Amplifier Grid Leak	Fixed, composition, pigtail; 250,000Ω ±10% 1 watt	−63288	RE-13A-372G		5	BT-1			7-F
*R-166	Interp. Input Ampl. Cathode Resistor	Same as R-138	−63703–10							7-F
*R-167	Interp. Freq. Meter Phasing Resistor	Same as R-165	−63288							7-C

* Spares furnished, for quantities refer to Table IV.

TABLE II (*Continued*)

PARTS LIST BY SYMBOL DESIGNATION FOR MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT

Symbol Desig'n	Function	Description	Navy Type Number	Navy DWG. or SPEC. Number	Navy DWG. or SPEC. Style	MFR.	MFR'S Desig'n	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Approximate Location (See P. 35)
		RESISTORS (*Continued*)								
*R-168	Interp. Freq. Meter Gas Triode Series Grid Resistor	Same as R-130	−63288							7-C
*R-169	Interp. Freq. Meter Gas Triode Series Grid Resistor	Same as R-130	−63288							7-C
*R-170	Interp. Freq. Meter Metering Resistor	Fixed, wire-wound, ferrule; 3,000Ω ±2% 6 watt		RE-13A-372J Grade I, Class 2	F	5	GS-5-C	±2% at 25° C.		7-C
*R-171	Interp. Freq. Meter. Cathode Resistor	Same as R-170								7-F
*R-172	Interp. Freq. Meter Common Cath. Res.	Fixed, wire-wound, ferrule; 1,000Ω ±2% 6 watt		RE-13A-372J Grade I, Class 2	F	5	GS-5-C	±2% at 25° C.		7-F
*R-173	Interp. Freq. Meter Calibration Adj.	Rheo; no taper; resistance decreases with clockwise rotation; 2,500Ω ±10% 6 watt	−63846			1	410–409			7-B
*R-174	Interp. Freq. Meter Opposing Voltage Series Resistor	Same as R-110	−63288							7-B
*R-175	Interp. Freq. Meter Initial Velocity Bias Adjustment	Rheo-Pot'r, no taper; resistance increases with clockwise rotation; counterclockwise end grounded 5,000Ω ±10% 6 watt	−63848			1	410–408		LR-2	7-C
R-176	Interp. Freq. Meter Opposing Voltage Adjustment	Same as R-175	−63848							7-B
R-177	Interp. Freq. Meter Voltage Divider	Same as R-110	−63288							7-B
*R-178	Interp. Freq. Meter Voltage Regulator Second Stage Series Resistor	Fixed, wire-wound, ferrule; 2,150Ω ±2% 24 watt		RE-13A-372J	D	5	FB-7-C	±2% at 25° C.		1-RB
*R-179	Interp. Freq. Meter Voltage Regulator First Stage Series Resistor	Fixed, wire-wound, ferrule; 2,850Ω ±2% 28 watt		RE-13A-372J	C	5	FD-7-C	±2% at 25° C.		1-RB
R-180	Interp. Freq. Meter Metering Resistor	Same as R-170								7-C
R-181	Interp. Freq. Meter Cathode Resistor	Same as R-170								7-F
R-182	Interp. Freq. Meter Shunt Compensator	Same as R-110	−63288							9-FC
*R-183	Hum Control	Potentiometer, no taper, 25ohm ±10%	−63845			1	410–410		LR-2	9-C
*R-184 A	Tel. Volume Control (Front)	Pot'r, L taper, 1,250Ω ±10%	−63850			} 1	{ 301–451 }		LR-3	5-C lower
* B	Tel. Volume Control (Rear)	Pot'r, R taper, 1,250Ω ±10%	−63850				{ 301–452 }		LR-6	5-C lower
*R-185	Interpolator Freq. Meter Compensator	Fixed, molded, wire-wound, pigtail; 285Ω ±2%	−63703–2	RE-13A-372G		5	BW-1			9-FC
*R-186	Interpolator Bucking Voltage Divider	Fixed, composition, pigtail; 10,000Ω ±10% 1 watt	−63288	RE-13A-372G		5	BT-1			7-C

* Spares furnished, for quantities refer to Table IV.

TABLE II (*Continued*)

PARTS LIST BY SYMBOL DESIGNATION FOR MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT

Symbol Desig'n	Function	Description	Navy Type Number	Navy DWG. or SPEC. Number and Style	MFR.	MFR'S Desig'n	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Approximate Location (See P. 35)
				SWITCHES					
S-101	Calibrator Switch	8 pole, 5 position, rotary			8		Silver Contacts	139-1259	5-L upper
S-102	Het. Freq. Meter Range Selector	3 pole, 13 position, rotary			1		Silver Contacts	P-400-47	5-R upper
S-103	Detector Input Switch	4 pole, 3 position, key, locking	−24043	RN-10A-133	11	1424		139-930	5-RC
S-104	Interpolator Scale Selector	Same as S-103	−24043	Sheet 10C					5-LC
S-105	Interpolator Deionize Switch	1 pole, 2 position, push, normally closed			15	3392-C	Silver Contacts	139-809A	5-R upper
S-106	Power Switch	3 pole, 3 position, rotary			15	80156 Spec.		139-1429	5-LC
*S-107	Thermostat, Crys. Temp. Control	1 pole, 2 position, thermal	−40040		16	D1-2A	50° C. ±2° C.	139-508	1-LB
				TRANSFORMERS					
*T-101	Audio Output Transformer	Core: General Radio 345–90 laminations, butt joint, 3–0.002″ air-gaps. Primary: 5750 turns No. 37 enameled wire. Secondary: 1140 turns No. 30 enameled wire, tapped at 570 turns. Discontinuous 0.002″ copper shield between windings grounded to case. Vacuum impregnated in glyptal. Hermetically sealed case, type 345–813. 1000 volt test between windings and between windings and case. Secondary center tap grounded to case.			1			345-431	8-B
*T-102	Interpolator Transformer	Core: General Radio 345–90 laminations, interleaved. First secondary, 8625 turns No. 40 enameled wire. Primary, 5750 turns No. 40 enameled wire; second secondary, 8625 turns No. 40 enameled wire. Secondaries in series, mid-point grounded to case. 1000 volt test between windings and between windings and case. Vacuum impregnated in glyptal. Hermetically sealed case type 345–813.			1			345-432	7-C

* Spares furnished, for quantities refer to Table IV.

TABLE II (*Continued*)

PARTS LIST BY SYMBOL DESIGNATION FOR MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT

Symbol Desig'n	Function	Description	Navy Type Number	Navy DWG. or SPEC. Number and Style	MFR.	MFR'S Desig'n	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Approximate Location (See P. 35)
		TRANSFORMERS (*Continued*)							
*T-103	Power Supply Transformer	Core: General Radio 365-90 laminations, interleaved. Primary: 312 turns, No. 20 enameled, tapped at 0, 286, 299, 312 turns. Secondary No. 1, 18 turns 0.057×0.097 rectangular wire. Secondary No. 2, 14 turns, 4 number 22 enameled wires in parallel. Center tap at 7 turns. Secondary No. 3, 2811 turns. No. 29 enameled wire; center tap 1405 turns. Discontinuous 0.002 inch copper shield between Primary and Secondary No. 1. Vacuum impregnated in glyptal.			1			365-429	4-LB
		VACUUM TUBES							
*V 101	Crystal Oscillator	Triple Grid Detector, Amplifier	(−6C6)−38636	RE-13A-600B	4	6C6			6-B
*V-102	Crystal Oscillator Amplifier	Super-Triode Amplifier, Detector	(−76)−38076	RE-13A-600B	4	76			6-B
*V-103	Multivibrator (1)	Same as V-102	(−76)−38076						6-C
*V-104	Multivibrator (2)	Same as V-102	(−76)−38076						6-F
*V-105	Multivibrator Output Amplifier	Same as V-102	(−76)−38076						6-F
*V-106	Diode Det. and 1st Stage Audio Ampl.	Duplex-Diode High-Mu Triode	(−75)−38075	RE-13A-600B	4	75			8-F
*V-107	Impedance Transforming	Same as V-102	(−76)−38076						8-F
*V-108	2d Stage A.F. Amplifier	Same as V-101	(−6C6)−38636						8-C
*V-109	3d Stage A.F. Amplifier	Same as V-102	(−76)−38076						8-C
*V-110	Het. Freq. Meter Oscillator	Triple Grid Super Control Amplifier	−6SK7	RE-13A-600B	4	6SK7			1-LC
*V-111	H.F.M. Plate Voltage Regulator	Voltage Regulator	−38205	RE-13A-600B	4	VR-105-30			1-C
*V-112	R.F. Input Amplifier	Same as V-102	(−76)−38076						1-C
*V-113	H.F.M. Coupling	Same as V-102	(−76)−38076						1-FC
*V-114	Interpolator Input Amplifier	Same as V-102	(−76)−38076						7-F
*V-115	Interpolator Freq. Meter	Gas Triode, Hot-Cathode, Control-Grid	(−884)−38884	RE-13A-600B	4	884			7-C
*V-116	Interpolator Freq. Meter	Same as V-115	(−84)−38884						7-C
*V-117	Interpolator Switching	Full-Wave High-Vacuum Rectifier	(−84)−38184	RE-13A-600B	4	84			7-B
*V-118	Interp. 2d Stage Plate Voltage Reg.	Same as V-111	−38205						1-C
*V-119	Interp. 1st Stage Plate Voltage Reg.	Same as V-111	−38205						1-C
*V-120	Interp. 1st Stage Plate Voltage Reg.	Same as V-111	−38205						1-C
*V-121	Plate Supply Rectifier	Full-Wave Mercury Vapor Rectifier	(−83)−38183	RE-13A-600B	4	83			1-LF

* Spares furnished, for quantities refer to Table IV.

TABLE II (*Continued*)

PARTS LIST BY SYMBOL DESIGNATION FOR MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT

Symbol Desig'n	Function	Description	Navy Type Number	Navy DWG. or SPEC. Number and Style	MFR.	MFR'S Desig'n	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Approximate Location (See P. 35)
			CABLES						
*W-101	Servicing Cable	With plug and socket			1			P-400-W-101	
			V.T. SOCKETS						
X-101	V.T. Socket for V-121	Ceramic, wafer, 4-prong	—49362	RE-49AA-314-A	18	224			1-LF
X-102	V.T. Socket for V-102	Ceramic, wafer, 5-prong	—49363	RE-49AA-314-A	18	225			6-B
X-103	V.T. Socket for V-101	Ceramic, wafer, 6-prong	—49364	RE-49AA-314-A	18	226			6-B
X-104	V.T. Socket for V-110	Ceramic, wafer, octal	—49367	RE-49AA-314-A	18	228			1-LC
X-105	V.T. Socket for V-103	Same as X-102	—49363						6-C
X-106	V.T. Socket for V-104	Same as X-102	—49363						6-F
X-107	V.T. Socket for V-105	Same as X-102	—49363						6-F
X-108	V.T. Socket for V-107	Same as X-102	—49363						6-F
X-109	V.T. Socket for V-109	Same as X-102	—49363						8-C
X-110	V.T. Socket for V-112	Same as X-102	—49363						1-C
X-111	V.T. Socket for V-113	Same as X-102	—49363						1-FC
X-112	V.T. Socket for V-114	Same as X-102	—49363						7-F
X-113	V.T. Socket for V-117	Same as X-102	—49363						7-B
X-114	V.T. Socket for V-106	Same as X-103	—49364						6-F
X-115	V.T. Socket for V-108	Same as X-103	—49364						8-C
X-116	V.T. Socket for V-111	Same as X-104	—49367						1-C
X-117	V.T. Socket for V-115	Same as X-104	—49367						7-C
X-118	V.T. Socket for V-116	Same as X-104	—49367						7-C
X-119	V.T. Socket for V-118	Same as X-104	—49367						1-C
X-120	V.T. Socket for V-119	Same as X-104	—49367						1-C
X-121	V.T. Socket for V-120	Same as X-104	—49367						1-C
			CRYSTALS						
Y-101	Calibrator Crystal	Quartz Bar; 100 kc. ±1c at 50°C.			1			476-LR	1-LB

*Spares furnished, for quantities refer to Table IV.

TABLE III

PARTS LIST BY NAVY TYPE NUMBERS
MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER

Quantity	Navy Type No.	All Symbol Designations Involved
MISCELLANEOUS PARTS (CLASS 10)		
1		E-101, 141
9		E-105, 106, 107, 108, 109, 110, 111, 112, 113
1		E-114
1		E-115
2		E-116, 117
1		E-118
1		E-119
1		E-120, 122
1		E-121
1		E-123
1		E-124
1		E-125
1		E-126
2		E-127, 129
2		E-128, 130
1		E-131
1		E-132
1		E-133
2		E-138, 139
1		E-142, 143
1		E-144
1		E-145
1		E-146
1		E-147
1		E-148
1		H-101
1		H-102
1		H-103
1		H-104
1		H-105
1		I-101, 102
1		N-101
1		N-102
1		N-103
1		N-104
1		N-105
1		N-106
ELECTRICAL INDICATING INSTRUMENTS (CLASS 22)		
2	−22312	M-102, 103
1	−22313	M-101
SWITCHES (CLASS 24)		
1		S-101
1		S-102
2	−24043	S-103, 104
1		S-105
1		S-106
FUSES (CLASS 28)		
2		F-101, 102
1		F-103

TABLE III (*Continued*)

PARTS LIST BY NAVY TYPE NUMBERS
MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER

Quantity	Navy Type No.	All Symbol Designations Involved
A-F REACTORS AND TRANSFORMERS (CLASS 30)		
1		L-108
2		L-109, 110
1		T-101
1		T-102
1		T-103
VACUUM TUBES (CLASS 38)		
1	−75(−38075)	V-106
9	−76(−38076)	V-102, 103, 104, 105, 107, 109, 112, 113, 114
1	−83(−38183)	V-121
1	−84(−38184)	V-117
4	−38205	V-111, 118, 119, 120
2	−6C6(−38636)	V-101, 108
2	−884(−38884)	V-115, 116
1	6SK7	V-110
THERMOMETERS, THERMOSTATS, CRYSTALS (CLASS 40)		
1	−40036	M-104
1	−40040	S-107
1		Y-101
R-F INDUCTORS (CLASS 47)		
7		L-101, 102, 103, 104, 105, 106, 107
4		L-112, 113, 114, 115
2		L-116, 117

Quantity	Navy Type No.	All Symbol Designations Involved
CAPACITORS (CLASS 48)		
24	−48428-10	C-101, 106, 107, 108, 110, 122(2), 125(2), 126(2), 131(2), 136, 137, 138, 148, 153, 173, 174, 186, 187, 188, 189
1	−48431-10	C-127
1	−48487-10	C-175
1	−48628A	C-140
3	−48641-10	C-161, 162, 190
1	−48645-10	C-134
5	−48665-10	C-105, 109, 118, 146, 147
1	−48666-10	C-121
1	−48668-C2	C-155
3	−48787A	C-120, 152, 176
8	−48865	C-123, 124, 128, 132, 157, 158, 159, 164, 185
2	−48893-10	C-117, 139
5	−481004	C-119, 129, 130, 149, 151
8	−481042-10	C-177, 178, 179, 180, 181, 182, 183, 184
1	−481121-10	C-150
2	−481123-C2	C-113, 116
2	−481125-C2	C-112, 115
1		C-163
1	−481126-10	C-144
2	−481127-C2	C-154, 156
1	−481127-10	C-143
2	−481128-C2	C-111, 114
2	−481138	C-102, 104
1	−481139	C-160
1	−481186-10	C-145
1	−481187-10	C-142
1	−481188-10	C-141
1	−481195	C-135-E
1	−481196	C-135-D
1	−481197	C-135-F, G
1		C-135ABC
1	−481473-10	C-192A, B

TABLE III (*Continued*)

PARTS LIST BY NAVY TYPE NUMBERS
MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR
AND HETERODYNE FREQUENCY METER

Quantity	Navy Type No.	All Symbol Designations Involved
JACKS, PLUGS, AND RECEPTACLES (CLASS 49)		
3	−49021A	J-101, 102, 103
3	−49120	E-102A, 103A, 104A
3	−49121	E-102B, 103B, 104B
1		P-101
1		P-102
1		P-103
1		P-104
1	−49362	X-101
10	−49363	X-102, 105, 106, 107, 108, 109, 110, 111, 112, 113
3	−49364	X-103, 114, 115
7	−49367	X-104, 116, 117, 118, 119, 120, 121
FILTERS (CLASS 53)		
1		LC-101
1		LC-102
INSULATORS (CLASS 61)		
1		E-134
1		E-135
1		E-136
1		E-137
CABLES (CLASS 62)		
1		W-101
RESISTORS (CLASS 63)		
1	−63085-E	R-127
2	−63090-E	R-146, 157
2	−63288	R-125, 153
1	−63288	R-161
4	−63288	R-129, 158, 159, 160
3	−63288	R-102, 126
1	−63288	R-152
1	−63288	R-177
5	−63288	R-110, 155 ,174, 182, 186
1	−63288	R-104
7	−63288	R-130, 140, 141, 147, 163, 168, 169
2	−63288	R-165, 167
3	−63288	R-131, 135, 136
6	−63288	R-103, 107, 134, 137, 139, 142
1	−63288	R-128
1	−63288	R-123
1	−63360	R-122
1	−63360	R-124
2	−63474	R-105, 150
3	−63474	R-106, 149, 151
1	−63474	R-132
2	−63485-E	R-148, 162
2	−63703-10	R-144, 145
1	−63703-10	R-185
3	−63703-10	R-138, 156, 166
2	−63703-10	R-108, 143
1	−63703-10	R-133
1	−63756	R-154
3	−63786-1	R-111, 115, 118
1	−63787-1	R-119
4	−63788-1	R-116, 117, 120, 121
2	−63789	R-101
1	−63845	R-183
1	−63846	R-173
2	−63847	R-112, 114
2	−63848	R-175, 176
2	−63849	R-109, 113
1	−63850	R-184A
1	−63850	R-184B
4		R-170, 171, 180, 181
1		R-172
1		R-178
1		R-179

TABLE IV
MODEL LR-1 COMBINED CRYSTAL CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT
SPARE PARTS LIST BY NAVY TYPE NUMBERS

Quant.	Navy Type Number	All Symbol Designations Involved	Description	Navy DWG. or Spec Number and Style	MFR.	MFR'S Design	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Spare Parts Box, Item Number
			MISCELLANEOUS PARTS (CLASS 10)						
4		I-101, 102	Pilot Lights		21	Mazda #44	T-3¼ bulb; Min. Bayonet base	139-939	92
			ELECTRICAL INDICATING INSTRUMENTS (CLASS 22)						
1	−22312	M.102, 103	D.C. Milliammeter, 3 ma.	17-I-12A	8	506	Navy Case		1
1	−22313	M-101	D.C. Microammeter, 600 μa	17-I-12A	8	271	Special Scale	P-400 M-101	2
			FUSES (CLASS 28)						
10		F-101, 102	Glass cartridge fuse 2.0 amp.	17-F-2G	13	3AG			83
5		F-103	Glass cartridge fuse 0.25 amp.	17-F-2G	13	3AG			84
			A-F REACTORS AND TRANSFORMERS (CLASS 30)						
1		T-101	Audio Output Transformer Core: General Radio 345–90 laminations, butt joint, 3–0.002″ air-gaps. Primary: 5750 turns No. 37 enameled wire. Secondary: 1140 turns No. 30 enameled wire, tapped at 570 turns. Discontinuous 0.002″ copper shield between windings grounded to case. Vacuum impregnated in glyptal. Hermetically sealed case, type 345–813. 1000 volt test between windings and between windings and case. Secondary center tap grounded to case.		1			345-431	93
1		T-102	Interpolator Transformer Core: General Radio 345–90 laminations, interleaved. First secondary, 8625 turns No. 40 enameled wire. Primary, 5750 turns No. 40 enameled wire; second secondary, 8625 turns No. 40 enameled wire. Secondaries in series, mid-point grounded to case. 1000 volt test between windings and between windings and case. Vacuum impregnated in glyptal. Hermetically sealed case type 345–813.		1			345-432	94
1		T-103	Power Supply Transformer Core: General Radio 365–90 laminations, interleaved. Primary: 312 turns, No. 20 enameled, tapped at 0, 286, 299, 312 turns. Secondary No. 1, 18 turns 0.057×0.097 rectangular wire. Secondary No. 2, 14 turns, 4 number 22 enameled wires in parallel. Center tap at 7 turns. Secondary No. 3, 2811 turns, No. 29 enameled wire; center tap 1405 turns. Discontinuous 0.002 inch copper shield between Primary and Secondary No. 1. Vacuum impregnated in glyptal.		1			365-429	95

TABLE IV (*Continued*)
MODEL LR-1 COMBINED CRYSTAL CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT
SPARE PARTS LIST BY NAVY TYPE NUMBERS

Quant.	Navy Type Number	All Symbol Designations Involved	Description	Navy DWG. or Spec Number and Style	MFR.	MFR'S Design	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Spare Parts Box, Item Number
			A-F REACTORS AND TRANSFORMERS (CLASS 30) — (*Continued*)						
1		L-108	Power Supply Filter Swing Choke		1			485-424	96
1		L-109, 110	Power Supply Filter Choke		1			485-425	97
			VACUUM TUBES (CLASS 38)						
1	(−75)−38075	V-106	Duplex-diode High Mu Triode	RE-13A-600B	4	75			4
9	(−76)−38076	V-102, 103, 104, 105, 107 -109, 112, 113, 114	Super Triode Amplifier-Detector	RE-13A-600B	4	76			5
1	(−83)−38183	V-121	Full wave Mercury Vapor Rectifier	RE-BA-600B	4	83			6
1	(−84)−38184	V-117	Full wave High Vacuum Rectifier	RE-13A-600B	4	84			7
4	−38205	V-111, 118, 119, 120	Voltage Regulator	RE-13A-600B	4	VR-105-30			8
2	(−6C6)−38636	V-101, 108	Triple grid Detector Amplifier	RE-13A-600B	4	6C6			9
2	(−884)−38884	V-115, 116	Gas Triode, hot cathode, control grid	RE-13A-600B	4	884			10
1	−6SK7	V-110	Triple grid supercontrol amplifier	RE-13A-600B	4	6SK7			11
			THERMOMETERS AND THERMOSTATS (CLASS 40)						
1	−40036	M-104	Thermometer, right angle, 50° C. center scale		9A 9B			139-181-2	3
1	CEE-40040	S-107	1-Pole 2-Position, Thermal		16	D1-2A		139-508	12
			CAPACITORS (CLASS 48)						
1	−48428-10	C-101, 106, 107, 108, 110, -122, 125, 126, 131, 136, -137, 138, 148, 153, 173, 174, 186, 187, 188, 189, -191	Mica; 0.02 μf ± 10% 600V DC wkg.	RE-48A-221A C	2 or 19	4-11020 1445			13
1	−48431-10	C-127	Mica; 0.00025 μf ± 10% 600V DC wkg.	RE-48A-221A C	2 or 19	4-13025 1445			14
1	−48487-10	C-175	Mica; 0.01 μf ± 10% 600V DC wkg.	RE-48A-221A C	2 or 19	4-11010 1445			15
1	−48641-10	C-161, 162, 190	Mica; 0.001 μf ± 10% 1200V DC wkg.	RE-48A-221A	2 or 19	4-22010 1445			16
1	−48645-10	C-134	Mica; 0.001 μf ± 10% 600V DC wkg.	RE-48A-221A C	2 or 19	4-12010 1445			17
1	−48665-10	C-105, 109, 118, 146, 147	Mica; 0.0005 μf ± 10% 600V DC wkg.	RE-48A-221A C	2 or 19	4-13050 1445			18
1	−48666-10	C-121	Mica; 0.0001 μf ± 10% 600V DC wkg.	RE-48A-221A C	2 or 19	4-13010 1445			19
1	−48668-C2	C-155	Mica; 0.002 μf ± 2% 600V DC wkg.	RE-48A-221A C	2 or 19	4 LTS-12020 1445-LTS			20

TABLE IV (*Continued*)
MODEL LR–1 COMBINED CRYSTAL CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT
SPARE PARTS LIST BY NAVY TYPE NUMBERS

Quant.	Navy Type Number	All Symbol Designations Involved	Description	Navy DWG. or Spec Number and Style		MFR.	MFR'S Design	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Spare Parts Box, Item Number
			CAPACITORS (CLASS 48)—(*Continued*)							
1	—48865	C-123, 124, 128, 132, 157 -158, 159, 164, 185	Paper; 4.0 µf +10%-3% 600 V DC wkg.	RE-48A-147A		2 or 22	TDF-6040 EUC-10600		1CL8	21
1	—48893-10	C-117, 130	Mica; 0.00005 µf ±10% 600V DC wkg.	RE-48A-221A	C	2 or 19	4-14050 1445			22
1	—481004	C-119, 129, 130, 149, 151	Paper; 1.0 µf +10%-3% 600V DC. wkg.	RE-48A-147A		2 or 22	VC-1430 EUC-10498		1CL5	23
1	—481042-10	C-177, 178, 179, 180, 181 -182, 183, 184	Mica; 0.0001 µf ±10% 500V DC wkg.	RE-48A-154E		19	1465			24
1	—481121-10	C-150	Mica; 0.00001 µf ±10% 600V DC. wkg.	RE-48A-221A	C	2 or 19	4-14010 1445			25
1	—481123-C2	C-113, 116	Mica; 0.000152 µf ± 2% 600V DC wkg.	RE-48A-221A	C	2 or 19	4 LTS-130152 1445-LTS			26
1	—481125-C2	C-112, 115	Mica; 0.000750 µf ± 2% 600V DC wkg.	RE-48A-221A	C	2 or 19	4 LTS-13075 1445-LTS			27
1	—481126-10	C-144	Mica; 0.0008 µf ±10% 600V DC wkg.	RE-48A-221A	C	2 or 19	4-13080 1445			28
1	—481127-C2	C-154, 156	Mica; 0.0015 µf ± 2% 600V DC wkg.	RE-48A-221A	C	2 or 19	4 LTS-12015 1445-LTS			29
1	—481127-10	C-143	Mica; 0.0015 µf ±10% 600V DC wkg.	RE-48A-221A	C	2 or 19	4-12015 1445			30
1	—481128-C2	C-111, 114	Mica; 0.00162 µf ± 2% 600V DC wkg.	RE-48A-221A	C	2 or 19	4 LTS-120162 1445-LTS			31
1	—481139	C-160	Paper; 0.5 µf +10%-3% 1000V DC wkg.	RE-48A-147A		2 or 22	VC-1819 EUC-10499		1CL24	32
1	—481186-10	C-145	Mica; 0.0002 µf ±10% 600V DC wkg.	RE-48A-221A	C	2 or 19	4-13020 1445			33
1	—481187-10	C-142	Mica; 0.0025 µf ±10% 600V DC wkg.	RE-48A-221A	C	2 or 19	4-12025 1445			34
1	—481188-10	C-141	Mica; 0.003 µf ±10% 600V DC wkg.	RE-48A-221A	C	2 or 19	4-12030 1445			35
1	—481195	C-135-E	Air; variable, 3-25 µµf			3	APC-25C		1CA13	36
1	—481196	C-135-D	Air; variable, 3-35 µµf			3	APC-35C		1CA14	37
1	—481197	C-135-F, G	Ceramicon, temp. comp., 25 µµf			17	N 680K			38
1	—481473-10	C-192A, B	Paper 0.02 µf, +10%-10%, 1500 volts d-c working; 2 sections	RE-13A-488-C		23	2XDRTMW-15-.02		COLB-13	98
			JACKS, PLUGS, AND RECEPTACLES (CLASS 49)							
3	—49121	E-102B, 103B, 104B	Concentric Plug	RA-49F-216A					774-401	89
3		E-102C, 103C, 104C	Binding Post Adapter			1			P-400-451	90

TABLE IV (*Continued*)
MODEL LR-1 COMBINED CRYSTAL CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT SPARE PARTS LIST BY NAVY TYPE NUMBERS

Quant.	Navy Type Number	All Symbol Designations Involved	Description	Navy DWG. or Spec Number and Style	MFR.	MFR'S Design	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Spare Parts Box, Item Number
			INSULATORS (CLASS 61)						
1		E-134	Isolantite, insulator for C-135A, B		20			539-75A	85
1		E-135	Isolantite, insulator for C-135A, B		20			622-709	86
1		E-136	Isolantite, insulator, for C-135C		20			368-75	87
1		E-137	Isolantite, insulator for C-135A, B		20			539-75	88
3			Binding Post Adapter Insulators		1			P-400-751	91
			CABLES (CLASS 62)						
1		W-101	Servicing cable, with plug and socket		1			P-400-W-101	82
			RESISTORS (CLASS 63)						
1	−63085E	R-127	Fixed, wire-wound, ferrule 5,000 Ω ±5% 24 watt	RE-13A-372J D Grade I, Class 2	5	FB-7C			39
1	−63090E	R-146, 157	Fixed, wire-wound, ferrule 10,000 Ω ±5% 24 watt	RE-13A-372J D Grade I, Class 2	5	FB-7C			40
1	−63288	R-125, 153	Fixed, composition, pigtail 1,000 Ω ±10% 1 watt	RE-13A-372G	5	BT-1			41
1	−63288	R-161	Fixed, composition, pigtail 2,000 Ω ±10% 1 watt	RE-13A-372G	5	BT-1			42
1	−63288	R-129, 158, 159, 160	Fixed, composition, pigtail 2,500 Ω ±10% 1 watt	RE-13A-372G	5	BT-1			43
1	−63288	R-102, 126	Fixed, composition, pigtail 3,000 Ω ±10% 1 watt	RE-13A-372G	5	BT-1			44
1	−63288	R-152	Fixed, composition, pigtail 5,000 Ω ±10% 1 watt	RE-13A-372G	5	BT-1			45
1	−63288	R-186	Fixed, composition, pigtail 10,000 Ω ±10% 1 watt	RE-13A-372G	5	BT-1			46
1	−63288	R-110, 155, 174, 177, 182	Fixed, composition, pigtail 20,000 Ω ±10% 1 watt	RE-13A-372G	5	BT-1			47
1	−63288	R-104	Fixed, composition, pigtail 75,000 Ω ±10% 1 watt	RE-13A-372G	5	BT-1			48
1	−63288	R-130, 137, 140, 141, 147 -163, 168, 169	Fixed, composition, pigtail 100,000 Ω ±10% 1 watt	RE-13A-372G	5	BT-1			49
1	−63288	R-165, 167	Fixed. composition, pigtail 250,000 Ω ±10% 1 watt	RE-13A-372G	5	BT-1			50
1	−63288	R-131. 135, 136	Fixed, composition, pigtail 500,000 Ω ±10% 1 watt	RE-13A-372G	5	BT-1			51
1	−63288	R-103, 107, 134, 139 -142	Fixed, composition, pigtail 1,000,000 Ω ±10% 1 watt	RE-13A-372G	5	BT-1			52

TABLE IV (*Continued*)
MODEL LR-1 COMBINED CRYSTAL CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT
SPARE PARTS LIST BY NAVY TYPE NUMBERS

Quant.	Navy Type Number	All Symbol Designations Involved	Description	Navy DWG. or Spec Number and Style	MFR.	MFR'S Design	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Spare Parts Box, Item Number
			RESISTORS (CLASS 63) — (*Continued*)						
1	−63288	R-128	Fixed, composition, pigtail 4,000,000Ω ±10% 1 watt	RE-13A-372G	5	BT-1			53
1	−63360	R-123	Fixed, composition, pigtail 680Ω ±10% ½ watt	RE-13A-372G	5	BT-½			54
1	−63360	R-122	Fixed, composition, pigtail 750Ω ±10% ½ watt	RE-13A-372G	5	BT-½			55
1	−63360	R-124	Fixed, composition, pigtail 1,000Ω ±10% ½ watt	RE-13A-372G	5	BT-½			56
1	−63474	R-105, 150	Fixed, composition, pigtail 30,000Ω ±10% 2 watt	RE-13A-372G	5	BT-2			57
1	−63474	R-106, 149, 151	Fixed, composition, pigtail 50,000Ω ±10% 2 watt	RE-13A-372G	5	BT-2			58
1	−63474	R-132	Fixed, composition, pigtail 250,000Ω ±10% 2 watt	RE-13A-372G	5	BT-2			59
1	−63485E	R-148, 162	Fixed, wire-wound, ferrule 20,000Ω ±5% 28 watt	RE-13A-372J C Grade I, Class 2	5	FD-7C			60
1	−63703-2	R-185	Fixed, molded, wire-wound, pigtail 285Ω ±2% 1 watt	RE-13A-372G	5	B-W1			61
1	−63703-10	R-144, 145	Fixed, molded, wire-wound, pigtail 100Ω ±10% 1 watt	RE-13A-372G	5	BW-1			62
1	−63703-10	R-138, 156, 166	Fixed, molded, wire-wound, pigtail 500Ω ±10% 1 watt	RE-13A-372G	5	BW-1			63
1	−63703-10	R-108, 143	Fixed, molded, wire-wound, pigtail 1,000 Ω ±10% 1 watt	RE-13A-372G	5	BW-1			64
1	−63703-10	R-133	Fixed, molded, wire-wound, pigtail 3,000Ω ±10% 1 watt	RE-13A-372G	5	BW-1			65
1	−63756	R-154	Rheo-Pot'r, wire-wound, tapered 10,000Ω ±10% 2 watt	RE-13A-492B	6	P-58-10,000-U			66
1	−63786-1	R-111, 115, 118	Fixed, wire-wound, precision 5,000Ω ±1% 1 watt		5	WW-4			67
1	−63787-1	R-119	Fixed, wire-wound, precision 10,000Ω ±1% 1 watt		5	WW-4			68
1	−63788-1	R-116, 117, 120, 121	Fixed, wire-wound, precision 20,000Ω ±1% 1 watt		5	WW-4			69
1	−63789	R-101	Fixed, molded, wire-wound, metal clad 2Ω ±10% 3 watt		5	MW-1½	Two 2 Ω units in series		70
1	−63845	R-183	Rheo-Pot'r, wire-wound, no taper 25 Ω ±10% 6 watt		1	410-410		LR-2	71
1	−63846	R-173	Rheo-Pot'r, wire-wound, no taper 2,500Ω ±10% 6 watt		1	410-409		LR-3	72

TABLE IV (*Continued*)
MODEL LR-1 COMBINED CRYSTAL CALIBRATOR AND HETERODYNE FREQUENCY METER EQUIPMENT SPARE PARTS LIST BY NAVY TYPE NUMBERS

Quant.	Navy Type Number	All Symbol Designations Involved	Description	Navy DWG. or Spec Number and Style		MFR.	MFR'S Design	Special Tolerance, Rating or Modification	General Radio DWG. or Part Number	Spare Parts Box, Item Number
			RESISTORS (CLASS 68) — (*Continued*)							
1	−63847	R-112, 114	Rheo-Pot'r, wire-wound, no taper 5,000Ω ±10% 6 watt			1	410-407		LR-2	73
1	−63848	R-175, 176	Rheo-Pot'r, wire-wound, no taper 5,000Ω ±10% 6 watt			1	410-408		LR-2	74
1	−63849	R-109, 113	Rheo-Pot'r, wire-wound, no taper 5,000Ω ±10% 6 watt			1	410-406		LR-2	75
1	−63850	R-184A (front)	Rheo-Pot'r, wire-wound, left taper 1,250Ω ±10% 6 watt			1	301-451		LR-3	76
1	−63850	R-184B (rear)	Rheo-Pot'r, wire-wound, right taper 1,250Ω ±10% 6 watt			1	301-452		LR-6	77
1		R-170, 171, 180, 181	Fixed, wire-wound, ferrule 3,000Ω ±2% 6 watt	RE-13A-372J Grade I, Class 2	F	5	GS-5-C	±2%@25° C		78
1		R-172	Fixed, wire-wound, ferrule 1,000Ω ±2% 6 watt	RE-13A-372J Grade I, Class 2	F	5	GS-5-C	±2%@25° C		79
1		R-178	Fixed, wire-wound, ferrule 2,150Ω ±2% 24 watt	RE-13A-372J Grade I, Class 2	D	5	FB-7-C	±2%@25° C		80
1		R-179	Fixed, wire-wound, ferrule 2,850Ω ±2% 28 watt	RE-13A-372J	C	5	FD-7-C	±2%@25° C		81

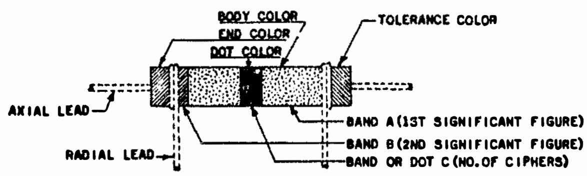
TABLE V

APPLICABLE RMA COLOR CODES FOR RESISTORS

STANDARD METHODS FOR COLOR CODING FIXED MOLDED RESISTORS ORDER OF READING COLOR CODE

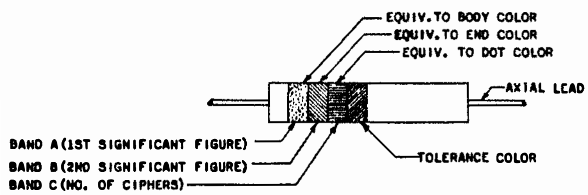
METHOD 1

USED FOR BOTH RADIAL-LEAD AND AXIAL-LEAD RESISTORS



METHOD 2

USED FOR AXIAL-LEAD RESISTORS ONLY



RMA COLOR CODE

WHEN COLOR USED ON BODY, END OR BANDS IS	1ST OR 2ND SIGNIFICANT FIGURE IS	NO. OF CIPHERS AFTER THE FIRST TWO SIGNIFICANT FIGURES IS
BLACK	0	NONE
BROWN	1	0
RED	2	00
ORANGE	3	000
YELLOW	4	0000
GREEN	5	00000
BLUE	6	000000
VIOLET	7	
GRAY	8	
WHITE	9	

EXAMPLE: Take the number 62,000, 6 is the first significant figure, 2 is the 2d significant figure and the number of ciphers after the first two significant figures is 3.

EXAMPLES

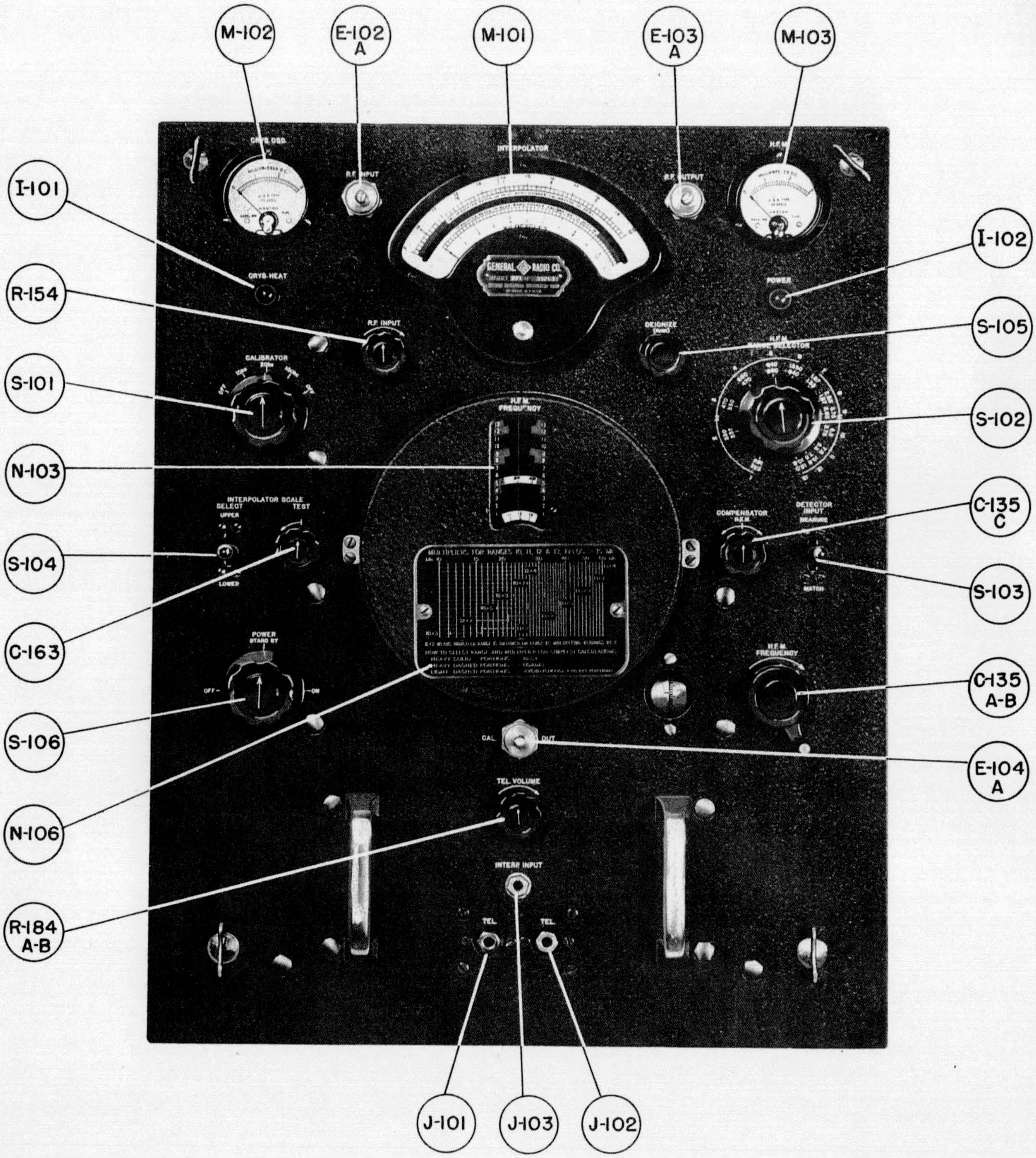
RESISTANCE (OHMS)	BAND A	BAND B	BAND C
20	RED	BLACK	BLACK
390	ORANGE	WHITE	BROWN
4700	YELLOW	VIOLET	RED
56000	GREEN	BLUE	ORANGE
680000	BLUE	GRAY	YELLOW
7500000	VIOLET	GREEN	GREEN
10000000	BROWN	BLACK	BLUE

TABLE VI

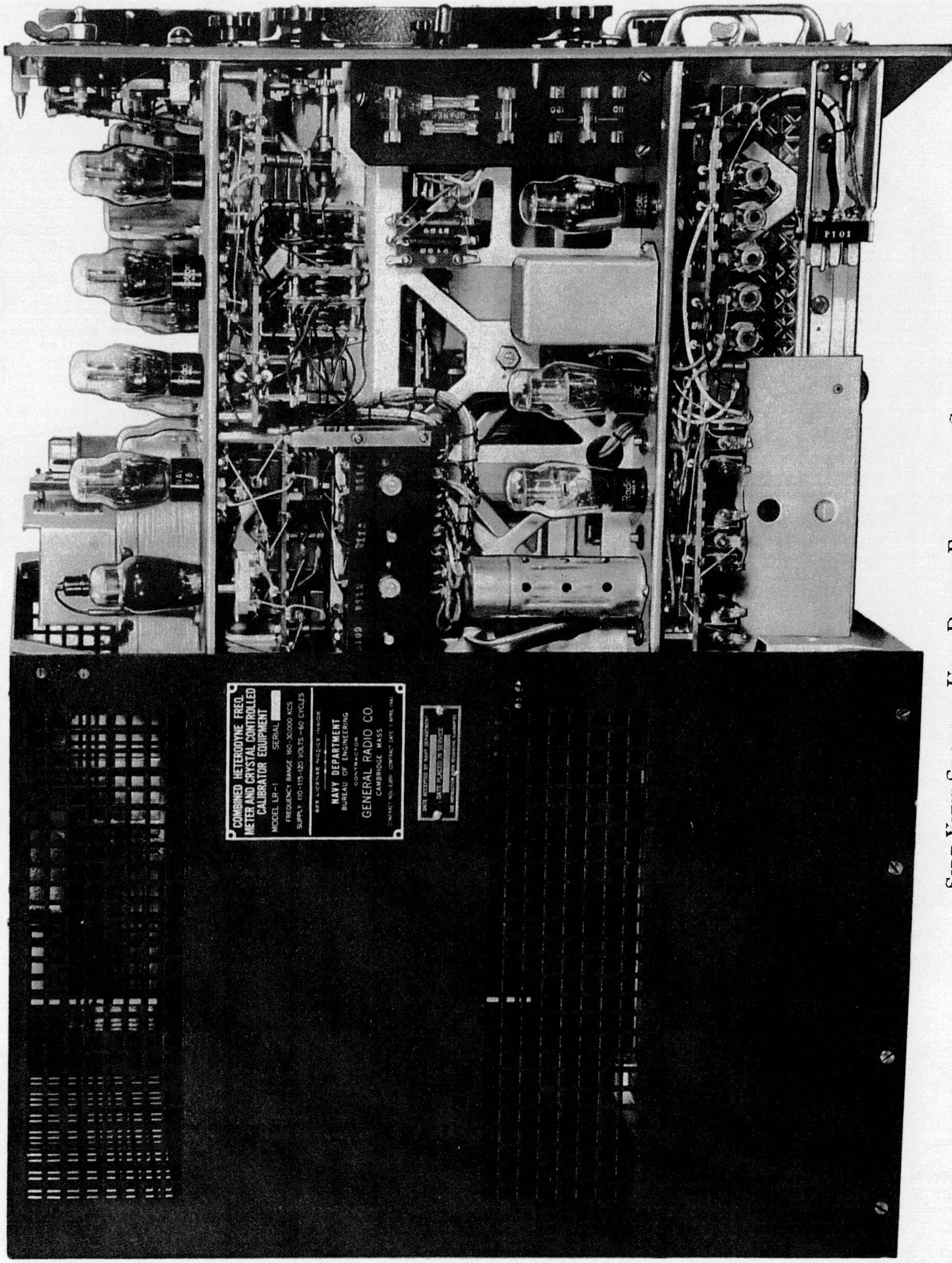
LIST OF MANUFACTURERS

Code Number	Mfrs. Prefix	Name	Correspondence Address
1	CAG	General Radio Company	30 State Street, Cambridge, Mass.
2	CD	Cornell-Dubilier Electric Corp.	South Plainfield, N. J.
3	CHC	Hammarlund Manufacturing Company, Inc.	424 West 33d Street, New York, N. Y.
4	CRC	RCA Manufacturing Company, Inc.	Harrison, N. J.
5	CIR	International Resistance Company	401 North Broad Street, Philadelphia, Pa.
6	CMC	Clarostat Manufacturing Co., Inc.	285 North Sixth Street, Brooklyn, N. Y.
7		Dzus Fastener Company, Inc.	Babylon, N. Y.
8	CV	Weston Electrical Instrument Co.	Newark, N. J.
9A	CPA	The Palmer Company	Cincinnati (Norwood), Ohio
9B	CPT	Precision Thermometer and Instrument Co.	Philadelphia, Pa.
10		Howard B. Jones	2300 Wabansia Avenue, Chicago, Ill.
11	CFS	Federal Corporation	42 Laird Avenue, Buffalo, N. Y.
12		Drake Manufacturing Company	1713 West Hubbard Street, Chicago, Ill.
13		Bussmann Manufacturing Company	St. Louis, Mo.
14	CN	National Electrical Machine Shops, Inc.	2014 Fifth Street, N.E., Washington, D. C.
15	CHH	The Arrow-Hart & Hegeman Electric Company	103 Hawthorn Street, Hartford, Conn.
16	CEE	Thomas A. Edison, Inc.	West Orange, N. J.
17	CER	Erie Resistor Corporation	Erie, Pa.
18	CEJ	E. F. Johnson Company	Waseca, Minn.
19	CAW	Aerovox Corporation	New Bedford, Mass.
20	CBU	Isolantite, Inc.	Belleville, N. J.
21	CG	General Electric Company	Schenectady, N. Y.
22	CEU	Electrical Utilities Company	2900 South Michigan Avenue, Chicago, Ill.
23	CSL	Solar Manufacturing Corp.	Bayonne, N. J.
24		Industrial Condenser Corp.	Chicago, Ill.

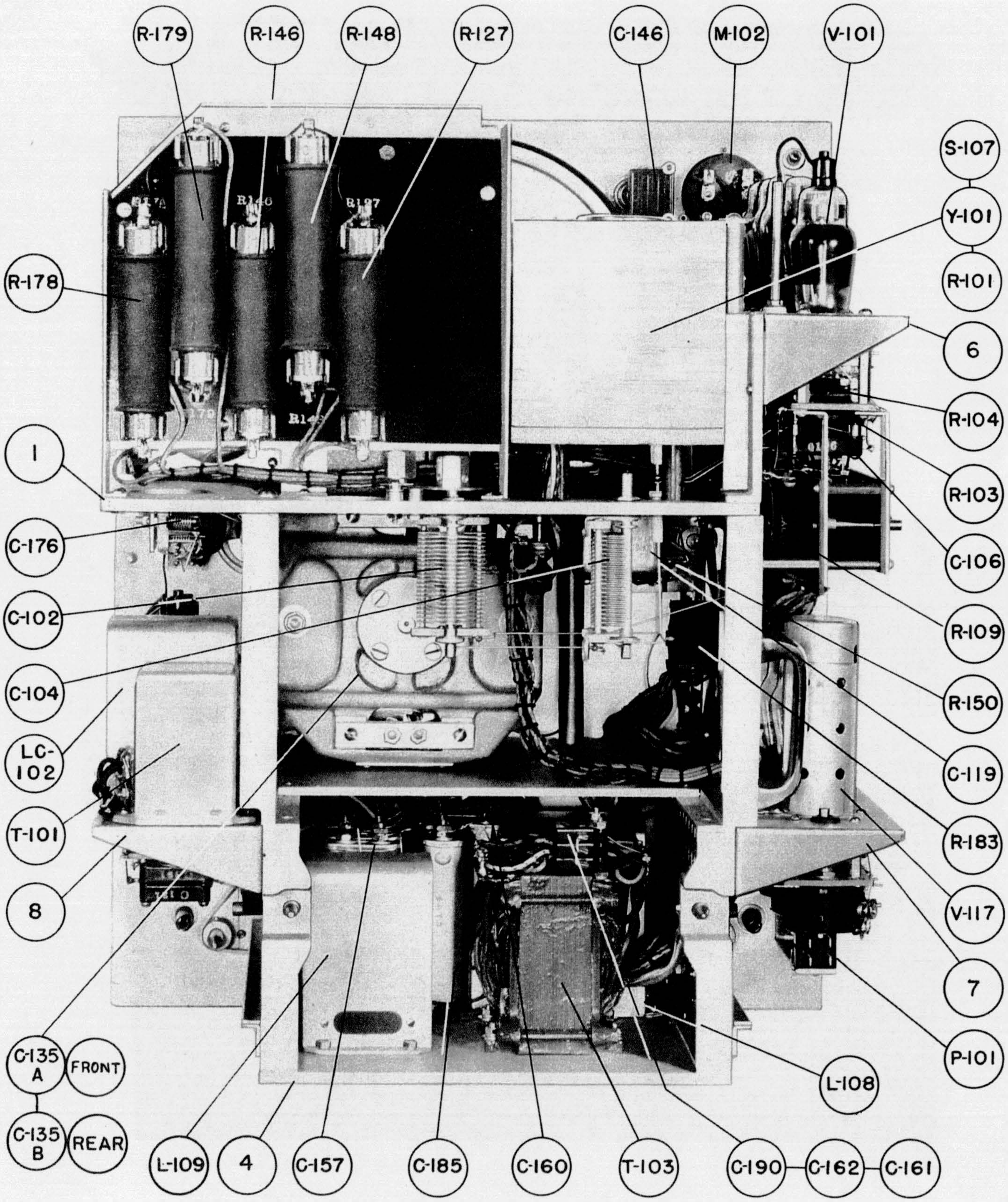
PHOTOGRAPHS


M-102
E-102 A
M-101
E-103 A
M-103
I-101
R-154
S-101
N-103
S-104
C-163
S-106
N-106
R-184 A-B
I-102
S-105
S-102
C-135 C
S-103
C-135 A-B
E-104 A
J-101
J-103
J-102

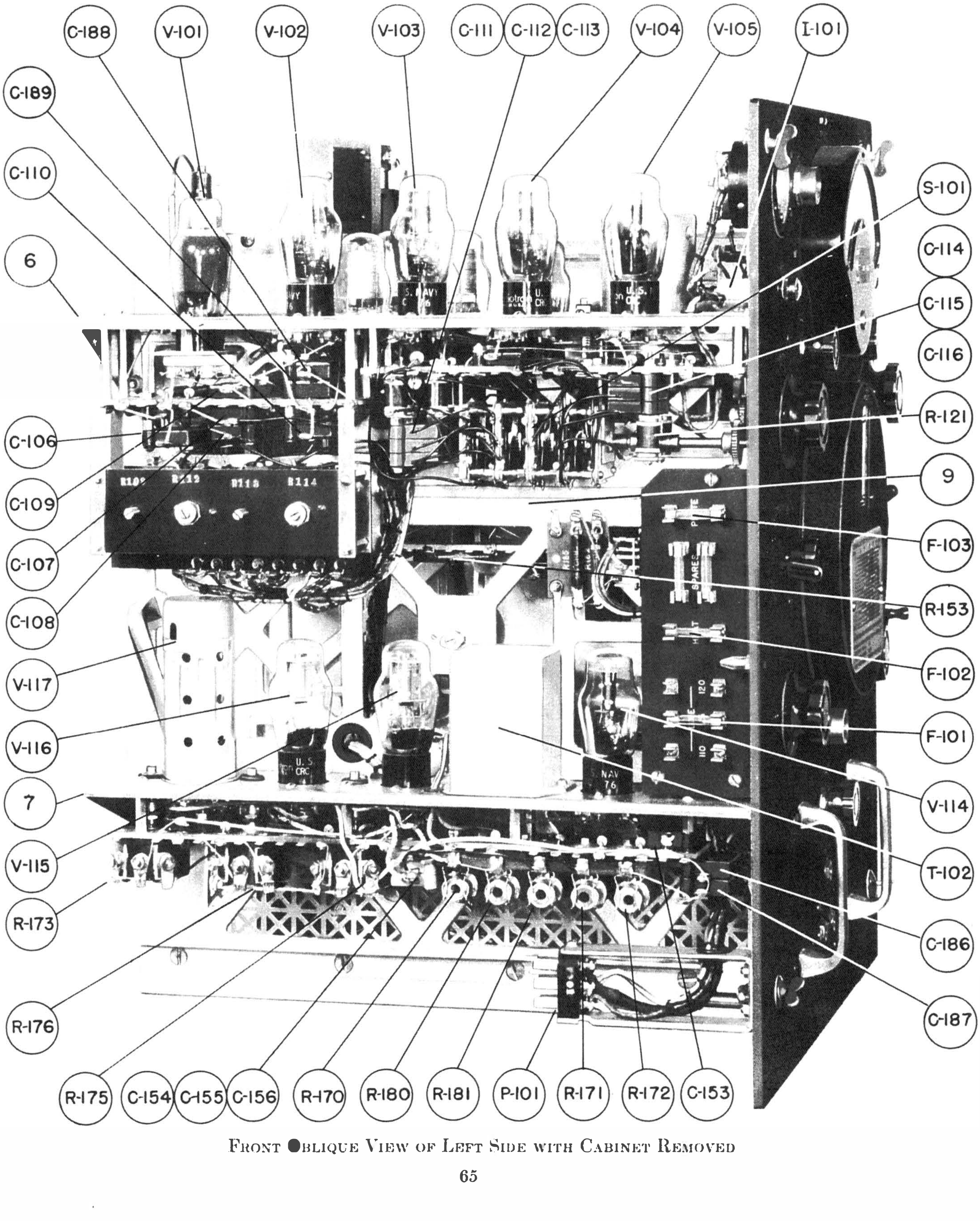
Panel View



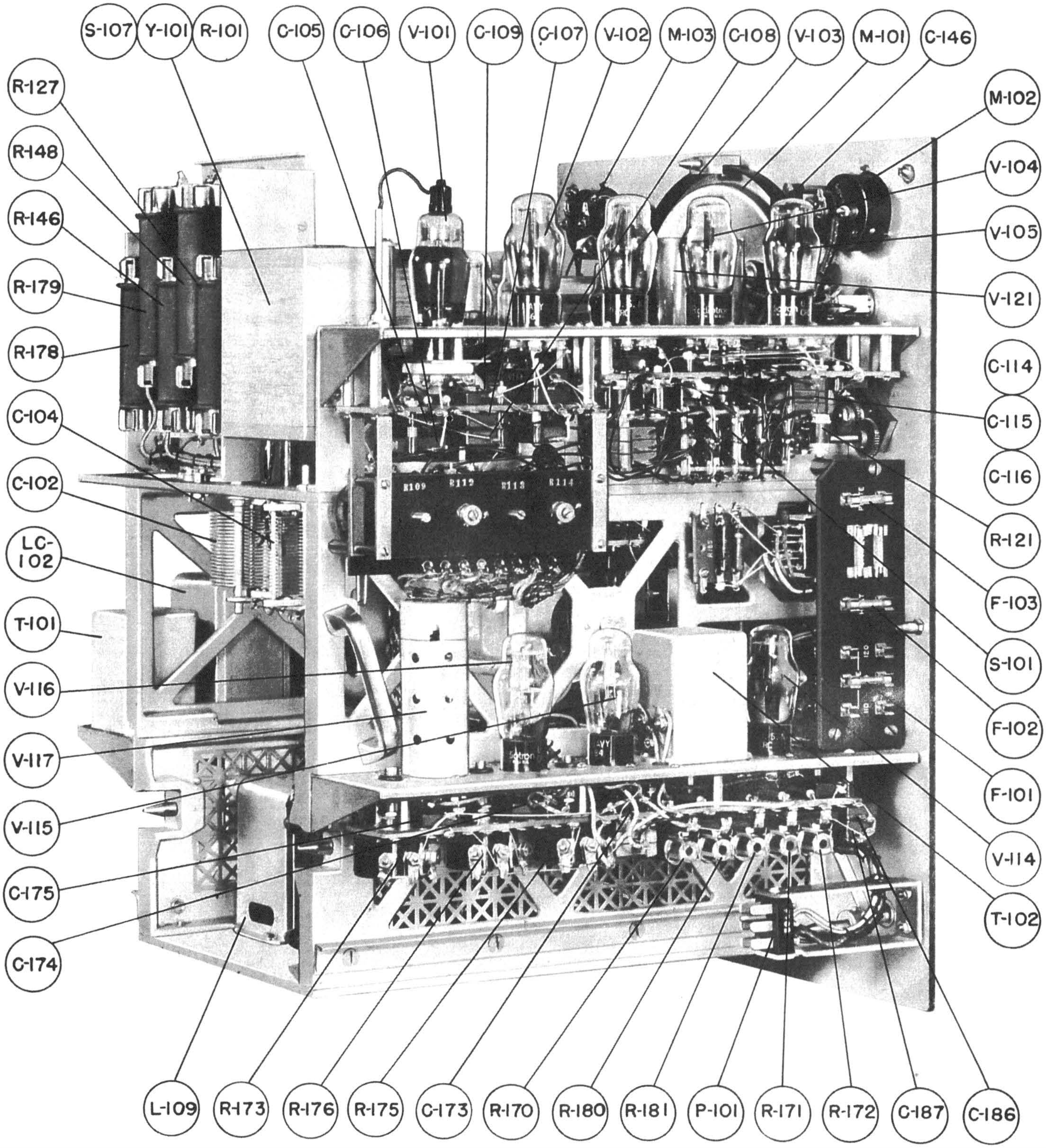
Side View Showing Unit Drawn Forward on Slides



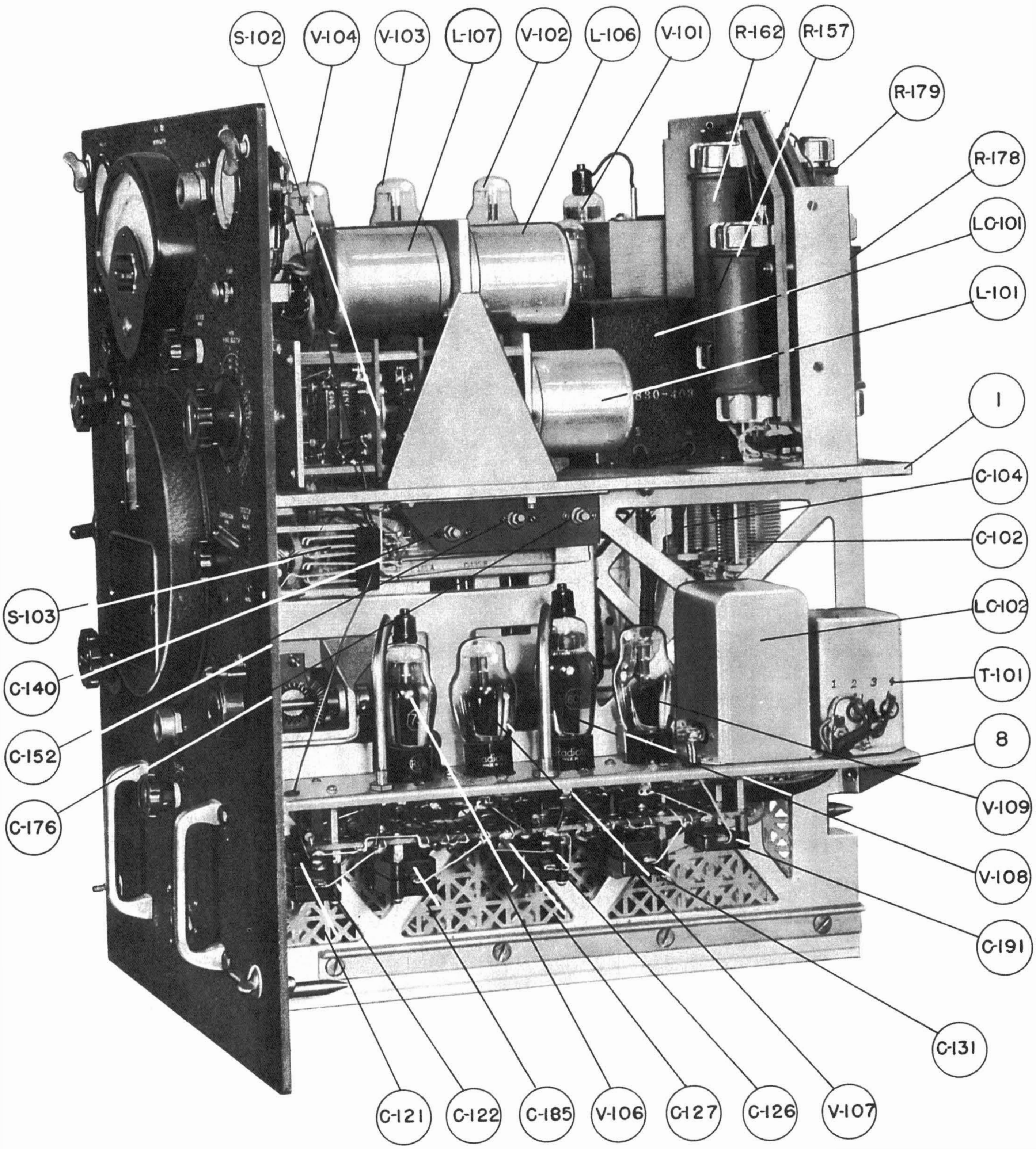
Rear View with Cabinet Removed



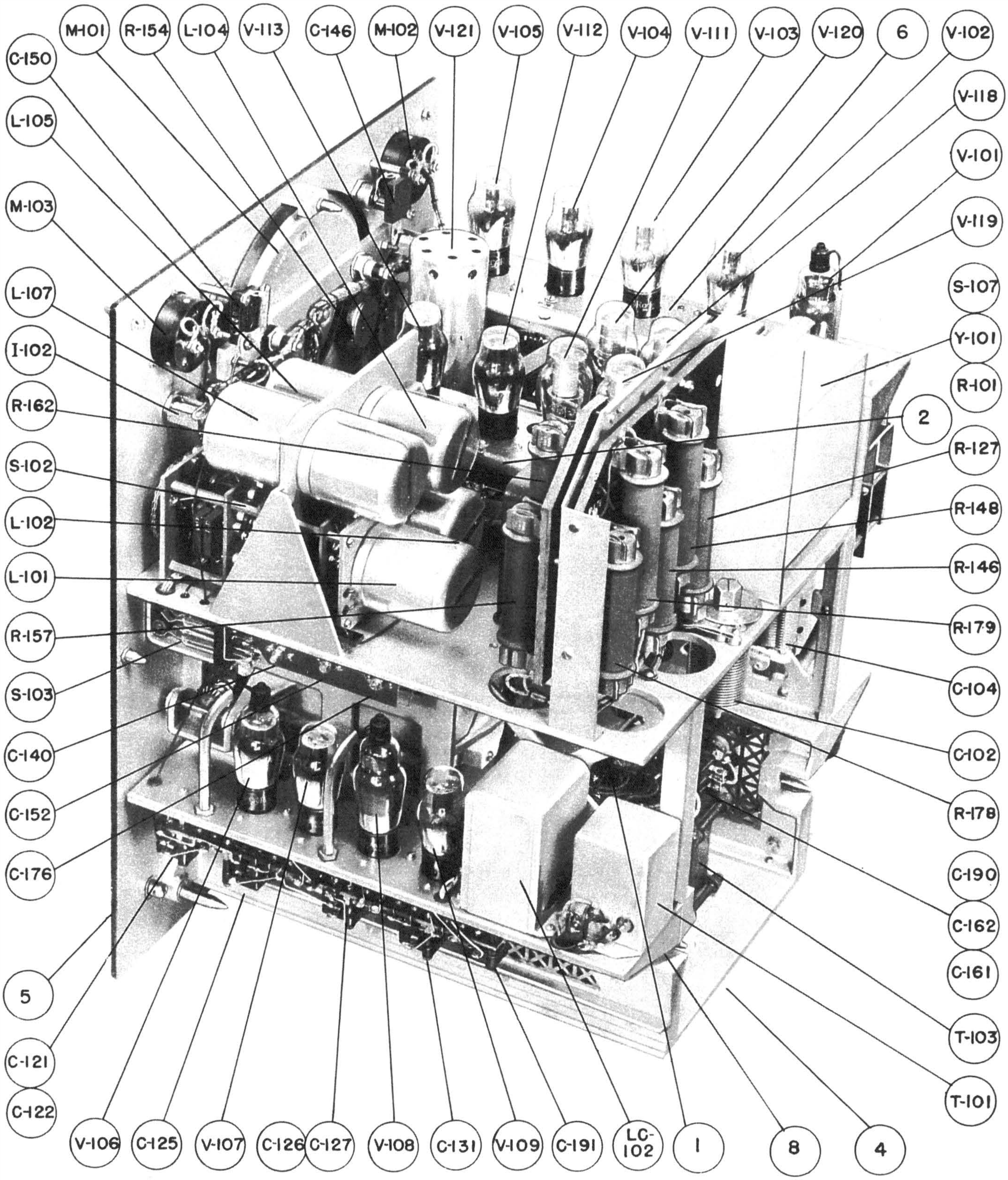
Front Oblique View of Left Side with Cabinet Removed



Rear Oblique View of Left Side with Cabinet Removed



FRONT OBLIQUE VIEW OF RIGHT SIDE WITH CABINET REMOVED



REAR OBLIQUE VIEW OF RIGHT SIDE WITH CABINET REMOVED

VACUUM-TUBE DATA AND PERTINENT INFORMATION

DATA ON VACUUM TUBES

NOTE: The data given here give the ratings of the tubes; for working voltages and currents see page 70.

Type 38075 (75)
Duplex-Diode High-Mu Triode

Used for: V-106
Base: Small 6-pin
Operating Conditions:

Heater Voltage	6.3 v
Heater Current	0.3 a
Plate Voltage	250 volts
Plate Current	0.9 ma
Plate Resistance	91,000 ohms
Grid Voltage	−2 v
Transconductance	1,100 μmhos

Diode plates connected together and used as half-wave rectifier for detector.

Type 38076 (76)
Super-Triode Amplifier, Detector

Used for: V-102, 103, 104, 105, 107, 109, 112, 113, 114.
Base: Small 5-pin.
Operating Conditions:

Heater Voltage	6.3 v
Heater Current	0.3 a
Plate Voltage	250 v max.
Plate Current	5 ma
Plate Resistance	9,500 ohms
Grid Voltage	−13.5 v
Transconductance	1,450 μmhos

Type 38183 (83)
Full-Wave Mercury-Vapor Rectifier

Used for: V-121
Base: Medium 4-pin.
Operating Conditions: (Choke-input filter)

Filament Voltage	5.0 v
Filament Current	3.0 a
RMS Voltage per plate	550 v max.
D-C Output Current	225 ma max.
Tube Drop	15 v approx.

Type 38184 (84)
Full-Wave High-Vacuum Rectifier

Used for: V-117
Base: Small 5-pin.
Operating Conditions:

Heater Voltage	6.3 v
Heater Current	0.5 amp.
Peak Inverse Voltage	1,250 v max.
Peak Current per plate	180 ma max.

Type 38205 (VR-105-30)
Voltage Regulator

Used for: V-111, 118, 119, 120
Base: Small shell octal 6-pin.
Operating Conditions:

Starting Supply Voltage	137 v min.
Operating Voltage	105 v
Operating Current	5 ma min. 30 ma max.

Type 38636 (6C6)
Triple-Grid Detector Amplifier

Used for: V-101, 108
Base: Small 6-pin.
Operating Conditions:

Heater Voltage	6.3 v
Heater Current	0.3 a
Plate Voltage	250 v
Plate Current	2 ma
Plate Resistance	over 1 meg.
Screen Voltage	100 v
Screen Current	0.5 ma
Grid Voltage	−3 v
Transconductance	1,225 μmhos

Suppressor connected to cathode at socket.

Type 38884 (884) Gas-Triode

Used for: V-115, 116
Base: Small shell octal 6-pin.
Operating Conditions:

Heater Voltage	6.3 v
Heater Current	0.6 a
Plate Voltage	300 v max.
Plate Current (Avg.)	75 ma max.

Type 6SK7 Triple-Grid
Super-Control Amplifier, Single Ended

Used for: V-110
Base: Small wafer octal 8-pin.
Operating Conditions:

Heater Voltage	6.3 v
Heater Current	0.3 a
Plate Voltage	250 v
Plate Current	9.2 ma
Plate Resistance	0.8 meg.
Screen Voltage	100 v
Screen Current	2.4 ma
Grid Voltage	−3 v
Transconductance	2,000 μmhos

Suppressor connected to cathode at socket.

SOCKET VOLTAGES AND CURRENTS

Socket	Tube Type	Service	Readings at or Between Terminals	MA D-C	Volts DC or AC	Model OE Analyzer Meter Scale	Remarks
V-101	38636 (6C6)	Crystal Oscillator	1–6		6.3 ac	8	Ground cap to shelf; Calibrator switch in 100-kc position.
			2–5		12 dc	25	
			3–5		93 dc	250	
			Cap	0		1	
			3	2.3		5	
			2	4.0		5	
V-102	38076 (76)	Crystal Oscillator Amplifier	1–5		6.3 ac	8	Ground cap of V-101 to shelf. Remove V-103. Calibrator switch in 100-kc position.
			2–4		180 dc	250	
			3–4		−5.5	50	
			4–Gnd		8.7	10	
			3	0		1	
			2	4.9		10	
V-103	38076 (76)	Multivibrator (1)	1–5		6.3 ac	8	Ground cap of V-101 to shelf. Remove V-104. Calibrator switch in 100-kc position.
			2–4		92 dc	250	
			3–4		−0.07 dc*	1	* Initial velocity; bias=0.
			3	0		1	
			2	9		10	
V-104	38076 (76)	Multivibrator (2)	1–5		6.3 ac	8	Ground cap of V-101 to shelf. Remove V-103. Calibrator switch in 100-kc position.
			2–4		95 dc	250	
			3–4		−0.07 dc*	1	* Initial velocity; bias=0.
			3	0		1	
			2	9		10	
V-105	38076 (76)	Multivibrator Output Amplifier	1–5		6.3 ac	8	Ground cap of V-101 to shelf. Remove V-104. Calibrator switch in 100-kc position.
			2–4		240 dc	250	
			3–4		−10 dc	25	
			4–Gnd		10 dc	25	
			3	0		1	
			2	9.5		10	
V-106	38075 (75)	Diode Detector and 1st Audio Amplifier	1–6		6.5 ac	8	Detector Input Switch in Center Position.
			3, 4–5		−0.3 dc	5	* Initial Velocity; bias=0.
			2-5		50 dc	250	
			Cap–5		−0.4 dc*	5	
			Cap	0		1	
			2	0.20		1	
V-107	38076 (76)	Impedance Transforming Tube	1–5		6.5 ac	8	Detector Input Switch in Center Position.
			2–4		52 dc	250	
			3–4		−0.55 dc	5	
			4–Gnd		−21.5 dc	25	
			3	0		1	
			2	0.95		1	
V-108	38636 (6C6)	2d Audio Amplifier	1–6		6.5 ac		Detector Input Switch in Center Position.
			Cap–5		−0.3 dc	5	
			2–5		95 dc	250	
			3–5		30 dc	250	
			5-Gnd		−0.55 dc	5	
			Cap	0		1	
			3	0.24		1	
			2	0.92		1	
V-109	38076 (76)	3d Audio Amplifier	1–5		6.5 ac	8	Detector Input Switch in Center Position.
			2–4		255 dc	500	
			3–4		−1.6 dc	5	
			4–Gnd		10.5 dc	5	
			3	0		1	
			2	9.2		10	

Except where indicating instruments are already incorporated in the equipment, operating personnel should not attempt to measure potentials in excess of 500 volts within the equipment due to hazards to life.

ALL TUBES SUPPLIED WITH THE EQUIPMENT OR AS SPARES ON THE EQUIPMENT CONTRACT SHALL BE USED IN THE EQUIPMENT PRIOR TO EMPLOYMENT OF TUBES FROM GENERAL STOCK.

SOCKET VOLTAGES AND CURRENTS — *Continued*

Socket	Tube Type	Service	Readings at or Between Terminals	MA D-C	Volts DC or AC	Model OE Analyzer Meter Scale	Remarks
V-110	6SK7	Het. Freq. Meter Oscillator	2–7		6.4 ac	8	Range Switch on Dead Point Between Ranges 1–2.
			8–5		7.0 dc	10	
			6–5		36 dc	50	
			4–5		−0.2 dc	5	
			4	0		1	
			6	1.5		2.5	
			8	2.6		5	
V-111	38205 (VR-105-30)	H.F.M. Regulator	5–2		108 dc	250	
			5	13		25	
V-112	38076 (76)	R.F. Input	1–5		6.5 ac	8	R.F. Input control at zero. Calibrator OFF.
			2–4		240 dc	250	
			3–4		−7.2 dc	50	
			4–Gnd		7.6 dc	10	
			3	0		1	
			2	15.2		25	
V-113	38076 (76)	H.F.M. Coupling Tube	1–5		6.5 ac	8	
			2–4		270 dc	500	
			3–4		−14 dc	50	
			4–Gnd		14.5 dc	25	
			3	0		1	
			2	7.5		10	
V-114	38076 (76)	Interp. Input Amplifier	1–5		6.4 ac	8	Detector Input Switch in Center Position.
			2–4		185 dc	250	
			3–4		−5 dc	50	
			4–Gnd		5.5 dc	10	
			3	0		1	
			2	11		25	
V-115	38884 (884)	Interp. Freq. Meter Tube	2–7		6.4 ac	8	Detector Input Switch in Center Position. Remove V-116.
			3–8		−14 dc	50	
			8–Gnd		94 dc	250	
			3	24		50	
V-116	38884 (884)	Interp. Freq. Meter Tube	2–7		6.4 ac	8	Detector Input Switch in Center Position. Remove V-115.
			3–8		−14.5 dc	50	
			8–Gnd		95 dc	250	
			3	23		50	
V-117	38184 (84)	Interp. Freq. Meter Switching Tube	1–5		6.5 ac	8	Detector Input Switch in Center Position.
			3–4		−5.5 dc	50	
			3–4		−5.5 dc	50	
			4–Gnd		5.6 dc	10	
V-118	38205 (VR-105-30)	Interp. Regulator 2d Stage	5–2		108 dc	250	
			5	11		25	
V-119	38205 (VR-105-30)	Interp. Regulator 1st Stage	5–2		108 dc	250	
			5	22.5		25	
V-120	38205 (VR-105-30)	Interp. Regulator 1st Stage	5–2		108 dc	250	
			5	22.5		25	
V-121	38183 (83)	Plate Voltage Rectifier	1–4		5.2 ac	8	
			3–Gnd		620 ac	800	
			2–Gnd		620 ac	800	

Except where indicating instruments are already incorporated in the equipment, operating personnel should not attempt to measur potentials in excess of 500 volts within the equipment due to hazards to life.

ALL TUBES SUPPLIED WITH THE EQUIPMENT OR AS SPARES ON THE EQUIPMENT CONTRACT SHALL BE USED IN THE EQUIPMENT PRIOR TO EMPLOYMENT OF TUBES FROM GENERAL STOCK.

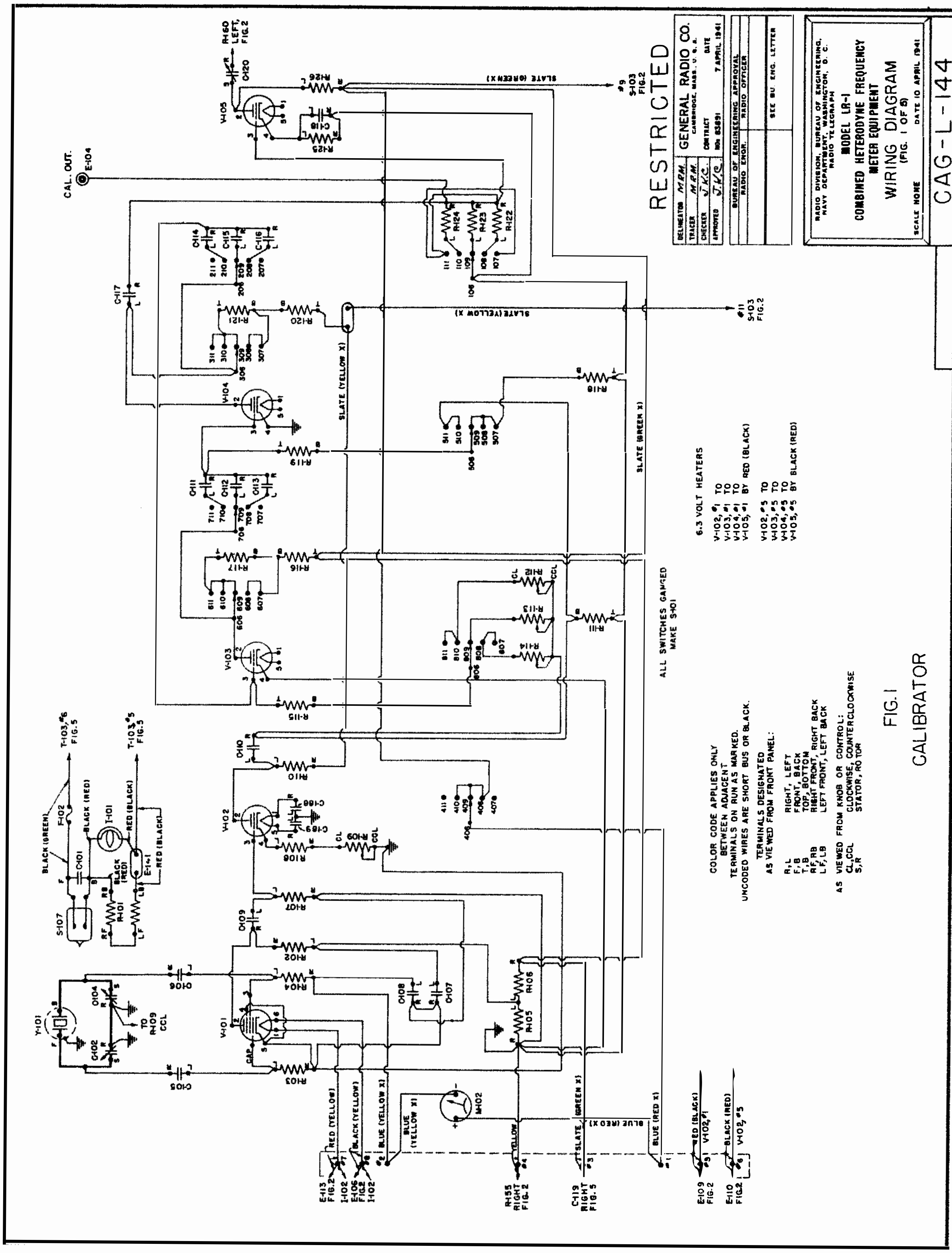


FIG. 1
CALIBRATOR

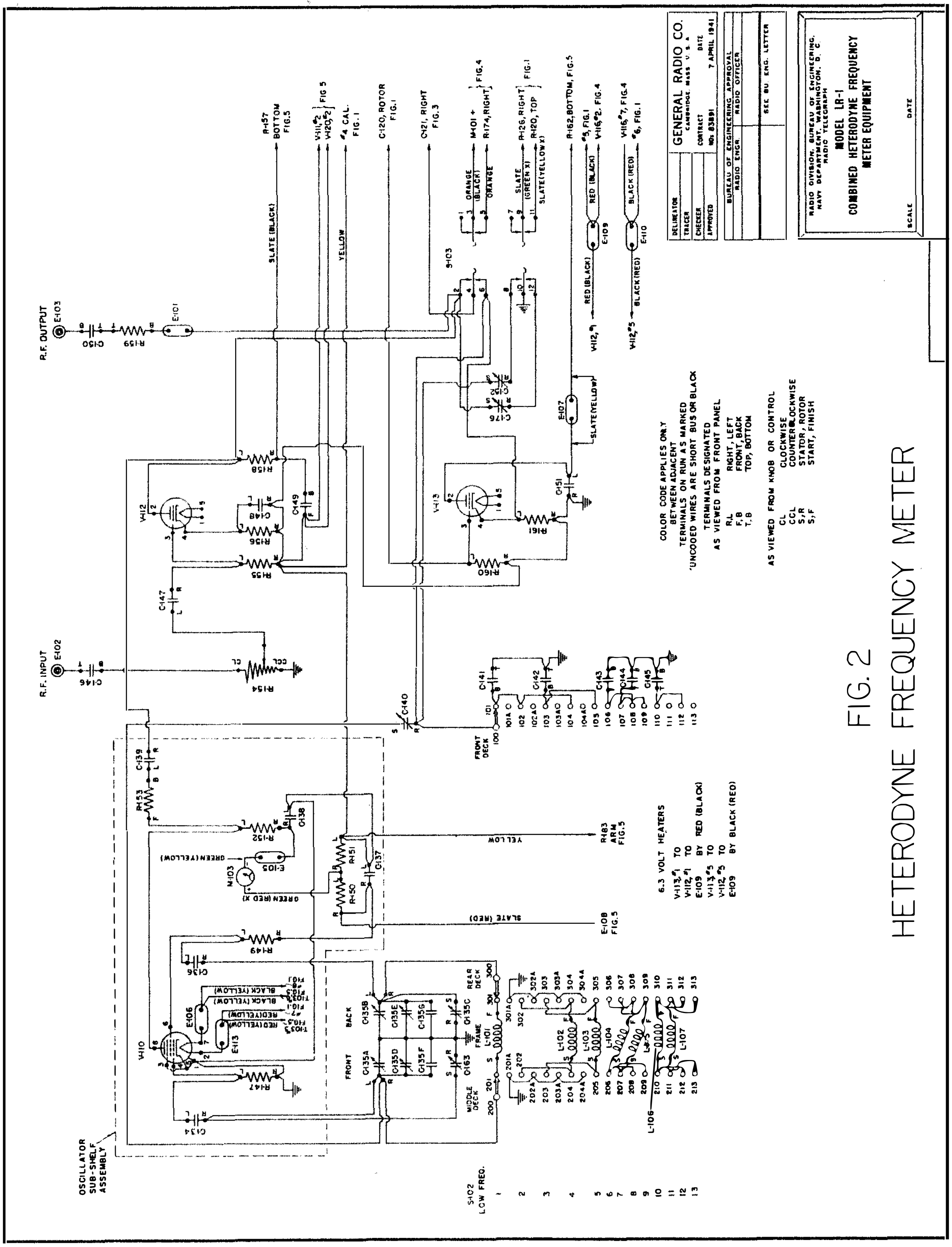
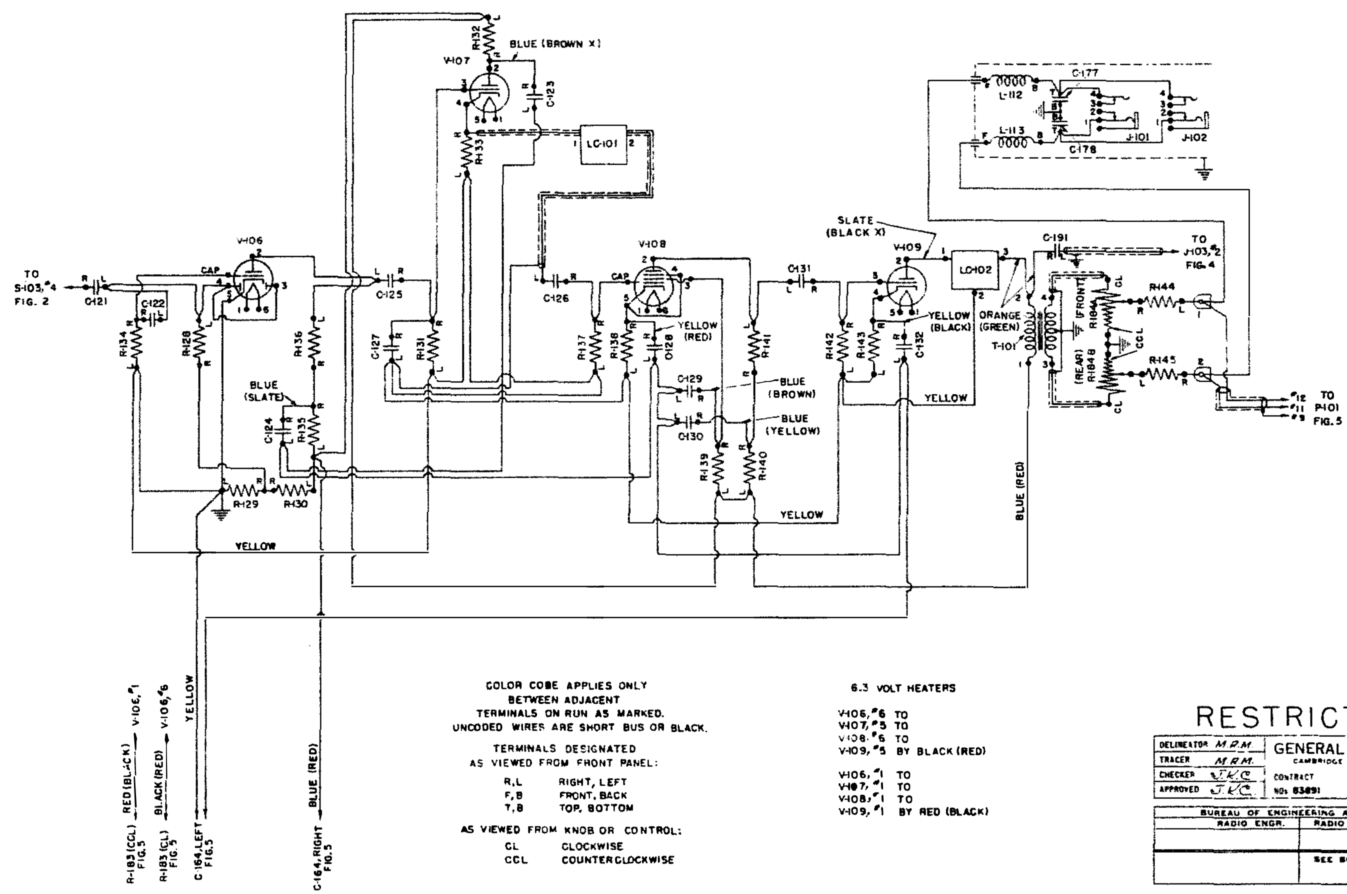


FIG. 2
HETERODYNE FREQUENCY METER



COLOR CODE APPLIES ONLY BETWEEN ADJACENT TERMINALS ON RUN AS MARKED.
UNCODED WIRES ARE SHORT BUS OR BLACK.

TERMINALS DESIGNATED AS VIEWED FROM FRONT PANEL:

R, L	RIGHT, LEFT
F, B	FRONT, BACK
T, B	TOP, BOTTOM

AS VIEWED FROM KNOB OR CONTROL:

CL	CLOCKWISE
CCL	COUNTERCLOCKWISE

6.3 VOLT HEATERS

V-106, #6 TO
V-107, #5 TO
V-108, #6 TO
V-109, #5 BY BLACK (RED)

V-106, #1 TO
V-107, #1 TO
V-108, #1 TO
V-109, #1 BY RED (BLACK)

FIG. 3
DETECTOR - A.F. AMPLIFIER

RESTRICTED

DELINEATOR	M.R.M.	GENERAL RADIO CO	
TRACER	M.R.M.	CAMBRIDGE MASS. U. S. A.	
CHECKER	J.K.C.	CONTRACT	DATE
APPROVED	J.K.C.	NOs 83691	7 APRIL 1941

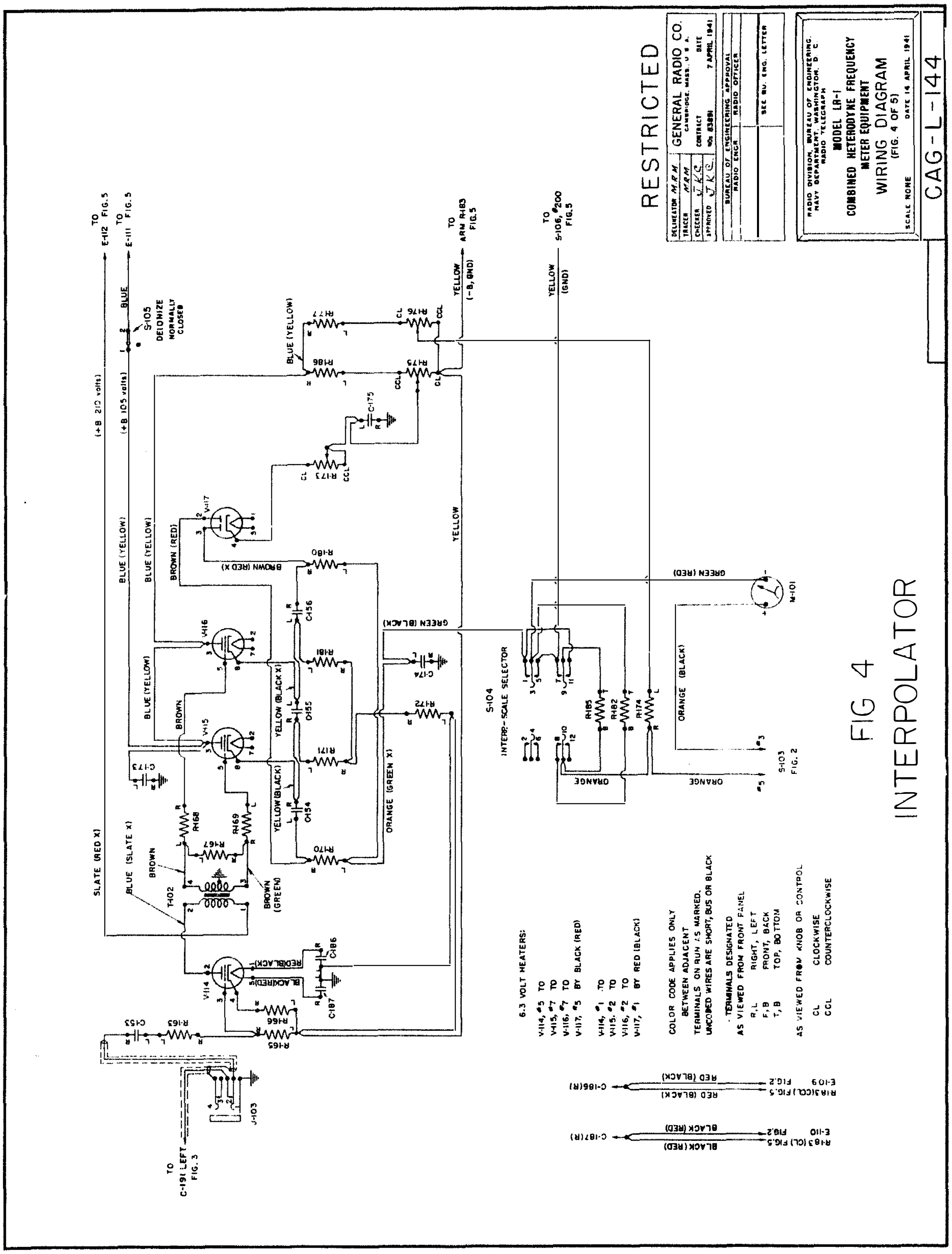
BUREAU OF ENGINEERING APPROVAL	
RADIO ENGR.	RADIO OFFICER
	SEE BU. ENG. LETTER

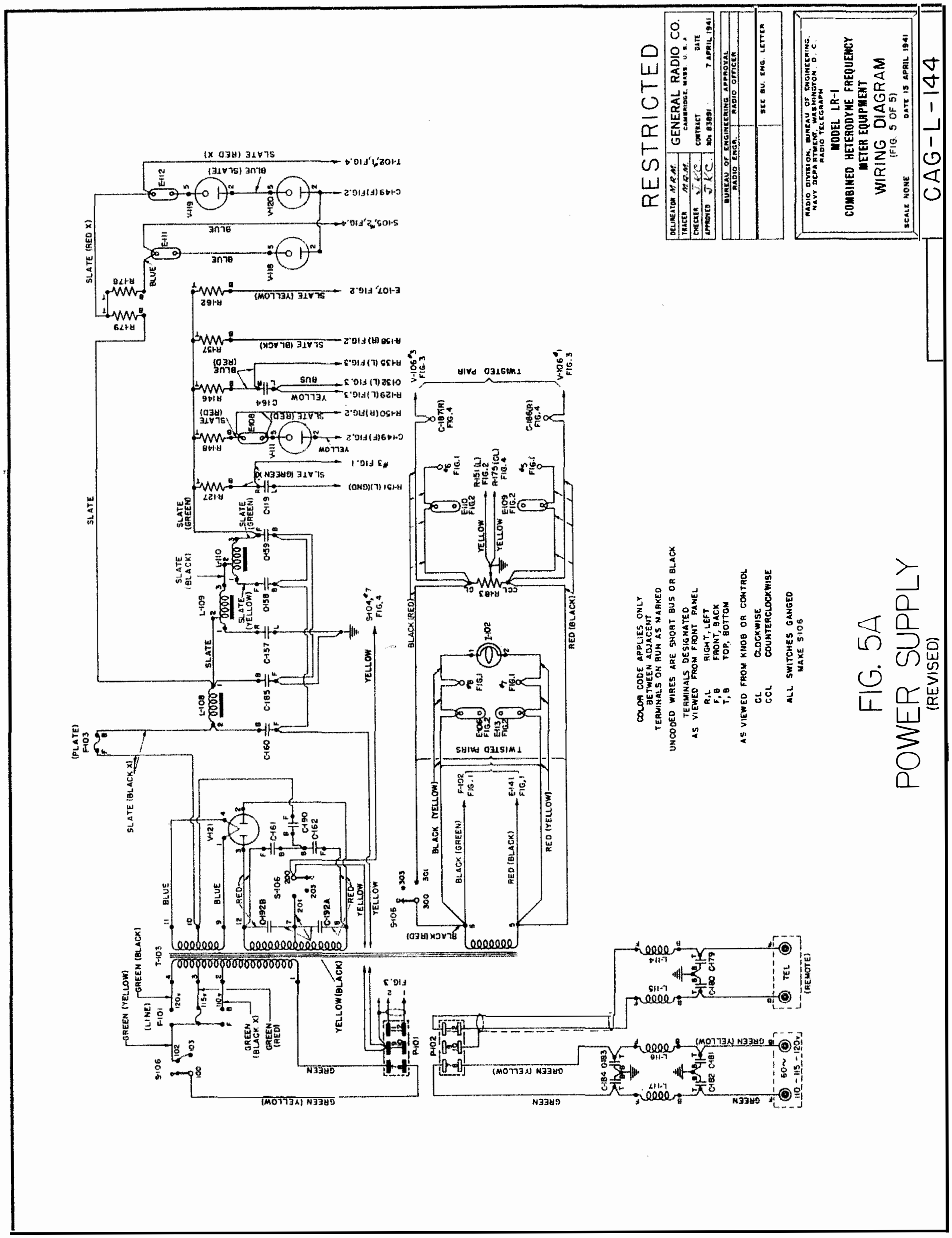
RADIO DIVISION, BUREAU OF ENGINEERING, NAVY DEPARTMENT, WASHINGTON, D. C.
RADIO TELEGRAPH

MODEL LR-1
COMBINED HETERODYNE FREQUENCY METER EQUIPMENT
WIRING DIAGRAM
(FIG. 3 OF 5)

SCALE NONE DATE 12 APRIL 1941

CAG-L-144


RESTRICTED
GENERAL RADIO CO.
CAMBRIDGE, MASS. U.S.A.
DATE 7 APRIL 1941
BUREAU OF ENGINEERING APPROVAL
RADIO DIVISION, BUREAU OF ENGINEERING, NAVY DEPARTMENT, WASHINGTON, D.C.
RADIO TELEGRAPH
MODEL LR-1
COMBINED HETERODYNE FREQUENCY METER EQUIPMENT
WIRING DIAGRAM
(FIG. 4 OF 5)
SCALE NONE
DATE 14 APRIL 1941
CAG-L-144
FIG 4
INTERPOLATOR
S-104 INTERP.-SCALE SELECTOR
S-105 DEIONIZE NORMALLY CLOSED
M-101
T-102
J-103
6.3 VOLT HEATERS:
V-114, #5 TO V-115, #7 TO V-116, #7 TO V-117, #5 BY BLACK (RED)
V-114, #1 TO V-115, #2 TO V-116, #2 TO V-117, #1 BY RED (BLACK)
COLOR CODE APPLIES ONLY BETWEEN ADJACENT TERMINALS ON RUN AS MARKED.
UNCODED WIRES ARE SHORT, BUS OR BLACK
TERMINALS DESIGNATED AS VIEWED FROM FRONT PANEL
R, L RIGHT, LEFT
F, B FRONT, BACK
T, B TOP, BOTTOM
AS VIEWED FROM KNOB OR CONTROL
CL CLOCKWISE
CCL COUNTERCLOCKWISE


RESTRICTED
GENERAL RADIO CO.
CAMBRIDGE, MASS. U.S.A.
CONTRACT NOs 83891
DATE 7 APRIL 1941
BUREAU OF ENGINEERING APPROVAL
RADIO ENGR.
RADIO OFFICER
SEE BU. ENG. LETTER
RADIO DIVISION, BUREAU OF ENGINEERING, NAVY DEPARTMENT, WASHINGTON, D.C.
RADIO TELEGRAPH
MODEL LR-1
COMBINED HETERODYNE FREQUENCY METER EQUIPMENT
WIRING DIAGRAM
(FIG. 5 OF 5)
SCALE NONE
DATE 15 APRIL 1941
CAG-L-144
COLOR CODE APPLIES ONLY BETWEEN ADJACENT TERMINALS OR RUN AS MARKED
UNCODED WIRES ARE SHORT BUS OR BLACK
TERMINALS DESIGNATED AS VIEWED FROM FRONT PANEL
R, L RIGHT, LEFT
F, B FRONT, BACK
T, B TOP, BOTTOM
AS VIEWED FROM KNOB OR CONTROL
CL CLOCKWISE
CCL COUNTERCLOCKWISE
ALL SWITCHES GANGED
MAKE S106
FIG. 5A
POWER SUPPLY
(REVISED)

WIRE COLOR CODE LIST

MAIN CABLE				
Wire		Starts at	Points of Call in Order	Ends at
Color	Tracer			
Red	(Black)	T-103 #5	——	E-141
Black	(Green)	T-103 #6	F-102 ——	C-101 (Front)
Red	(Black)	E-141	——	I-101
Black	(Red)	C-101 (Rear)	——	I-101
Red	(Black)	T-103 #5	R-183 (CCL) E-109	#5 Calibrator
Black	(Red)	T-103 #6	S-106 (#300 and #301), R-183 (CL), E-110	#6 Calibrator
Red	(Black)	R-183 (CCL)	C-186 Right	V-106 #1
Black	(Red)	R-183 (CL)	C-187 Right	V-106 #6
Red	(Yellow)	T-103 #5	E-113, #7 Calibrator	I-102
Black	(Yellow)	T-103 #6	E-106, #8 Calibrator	I-102
Green	——	T-103 #1	——	P-101 #7
Green	(Black X)	T-103 #2	——	F-101 110v
Green	(Red)	T-103 #3	——	F-101 115v
Green	(Black)	T-103 #4	——	F-101 120v
Green	(Yellow)	S-106 #100	——	P-101 #8
Yellow	(Black)	T-103 #7	——	S-106 #201
Slate	(Black X)	T-103 #10	F-103	L-108 #2
Slate	——	L-109 #2	L-108 #1	R-179 Bottom
Slate	(Black)	L-109 #3	——	L-110 #2
Slate	(Yellow)	L-110 #1	——	C-158 Front
Slate	(Green)	L-110 #3	C-159 Front	R-127 Top
Yellow	——	C-160 Front	P-101 #9, S-106 #200	S-104 #7
Slate	(Red X)	R-179 Top	E-112	T-102 #1
Blue	——	R-178 Bottom	E-111	S-105 #2
Slate	(Green X)	R-127 Bottom	C-119 Right	#3 Calibrator
Slate	(Red)	R-148 Bottom	E-108	R-150 Right
Yellow	——	R-151 Left	R-155 Right	#4 Calibrator
Blue	(Red)	R-146 Bottom	——	C-164 Right
Slate	(Black)	R-157 Bottom	——	R-158 Right
Slate	(Yellow)	R-162 Bottom	——	E-107
Green	(Red X)	R-151 Right	——	M-103+
Green	(Yellow)	E-105	——	M-103−
Blue	(Red X)	#1 Calibrator	——	M-102+
Blue	(Yellow X)	#2 Calibrator	——	M-102−
Orange	(Black)	S-103 #3	——	M-101+
Green	(Red)	S-104 #3	——	M-101−
Yellow	——	R-183 Arm	——	R-175 (CL)
Orange	——	S-104 #10	R-174 Right	S-103 #5
Green	(Black)	S-104 #1	——	C-174 Left
Blue	(Yellow)	S-105 #1	——	V-115 #3
Slate	(Green X)	S-103 #9	——	R-126 Right
Slate	(Yellow X)	S-103 #11	——	R-120 Top

WIRE COLOR CODE LIST

Wire Color	Wire Tracer	Starts at	Points of Call in Order	Ends at
MAIN CABLE — *Continued*				
Two Conductor Shielded		P-101 #11	——	#2 R-184 Assembly
		P-101 #12	——	#1 R-184 Assembly
Four Conductor Shielded				
Red		T-103 #8	——	V-121 #2
Red		T-103 #12	——	V-121 #3
Blue		T-103 #9	——	V-121 #1
Blue		T-103 #11	——	V-121 #4
				Shield GND at V-12[illegible]
DETECTOR-AMPLIFIER BY-PASS CONDENSER CABLE				
Yellow	——	R-129 Left	——	C-164 Left
Blue	(Brown X)	R-132 Right	——	C-123 Right
Blue	(Red)	R-135 Left	——	C-164 Right
Blue	(Slate)	R-135 Right	——	C-124 Right
Yellow	(Red)	R-138 Right	——	C-128 Right
Blue	(Brown)	R-139 Right	——	C-129 Right
Blue	(Yellow)	R-140 Right	——	C-130 Right
Yellow	(Black)	R-143 Right	——	C-132 Right
CALIBRATOR SHELF CABLE				
Blue	(Red X)	Terminal #1	——	S-101 #406
Blue	(Yellow X)	Terminal #2	——	R-104 Right
Slate	(Green X)	Terminal #3	——	R-106 Right
Yellow	——	Terminal #4	——	R-105 Right
Red	(Black)	Terminal #5	——	V-102 #1
Black	(Red)	Terminal #6	——	V-102 #5
Red	(Yellow)	Terminal #7	——	V-101 #1
Black	(Yellow)	Terminal #8	——	V-101 #6
CODED WIRES NOT IN CABLE				
Slate	(Yellow X)	R-110 Right	——	R-120 Top
Slate	(Green X)	R-106 Right	R-116 Top	R-126 Right
Slate	(Yellow)	C-151 Left	——	E-107
Yellow	——	R-183 Arm	——	R-151 Left
Yellow	——	R-131 Left	——	R-134 Left
Yellow	——	R-138 Left	R-142 Left	LC-102 #2
Blue	(Red)	R-140 Left	——	T-101 #1
Orange	(Green)	LC-102 #3	——	T-101 #2
Slate	(Black X)	V-109 #2	——	LC-102 #1
Yellow	——	R-165 Left	——	R-175 (CL)
Blue	(Slate X)	T-102 #2	——	V-114 #2
Brown	——	T-102 #4	——	R-168 Left
Brown	——	R-168 Right	——	V-116 #5
Brown	(Green)	T-102 #3	——	R-169 Right
Yellow	(Black)	C-154 Right	——	V-115 #8
Yellow	(Black X)	C-155 Left	——	V-116 #8
Orange	(Green X)	R-170 Left	——	C-174 Left
Blue	(Yellow)	V-115 #3	V-116 #3, R-186 Right	R-177, Right
Brown	(Red)	R-170 Right	——	V-117 #2

WIRE COLOR CODE LIST

CODED WIRES NOT IN CABLE — *Continued*				
Wire		Starts at	Points of Call in Order	Ends at
Color	Tracer			
Brown	(Red X)	R-180 Right	—	V-117 #3
Blue	(Slate)	V-119 #2	—	V-120 #5
Blue	—	E-111	—	V-118 #5
Slate	(Red)	E-108	—	V-111 #5
Green	—	L-117 Front	—	P-102 #7
Green	(Yellow)	L-116 Front	—	P-102 #8
Green	—	60~ Terminal Front	—	L-117 Rear
Green	(Yellow)	60~ Terminal Rear	—	L-116 Rear
Green	(Yellow)	S-106 #102	—	F-101 120v
Red	(Black)	R-101 Left Rear	—	E-141
Black	(Red)	R-101 Right Rear	—	C-101 Rear
Single Conductor Shielded		T-101 #2	—	J-103 #2
		Shield GND at T-101	—	J-103 #4
Single Conductor Shielded		C-153 Right	—	J-103 #1
		Shield GND Near C-153	—	J-103 #4
Two Conductor Shielded		L-114 Front	—	P-102 #11
		L-115 Front	—	P-102 #12
			—	Shield to P-102 #10
Two Conductor Shielded		T-101 #4	—	R-184A (CL)
		T-101 #3	—	R-184B (CL)
		GND at T-101	—	R-184A (CCL)