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 NO.: 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 applica-

**ARTIFICIAL RESPIRATION**

Proteus-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...
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. 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 trying to get water out of the stomach. Turn patient's face down and go to work immediately.
### WIRE COLOR CODE LIST

**MAIN CABLE — Continued**

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**INSTRUCTIONS FOR ASSEMBLY AND OPERATION OF**

**COMBINED HETERODYNE FREQUENCY METER AND CRYSTAL CONTROLLED CALIBRATOR EQUIPMENT**

**MODEL LR-1**

**SERIAL**

**FREQUENCY RANGE:** 160-30,000 KCS.

**SUPPLY:** 110-115-120 VOLTS — 60 CYCLES

**NAVY DEPARTMENT**

**BUREAU OF ENGINEERING**

**CONTRACTOR**

**GENERAL RADIO CO.**

**CAMBRIDGE, MASS.**

**CONTRACT NO. 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.
**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. Sa of October 3, 1934, or subsequent revisions thereof on the subject of "Radio-Safety Precautions to be Observed."

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CONTRACTUAL GUARANTEE

This equipment, including all parts and spares, 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 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 service 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 60 for instructions concerning Reports of Failures, etc.

Contract No.: No. 83991 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
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: 16 inches
Height: 8 ½ inches
Depth: 17 ½ 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 85 watts and for full operation
is 160 watts.

1.4 The equipment is intended for measuring the
frequency of radio transmitters, or for set-
ing 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 (elec-
tronic frequency meter).

SECTION 2. INSTALLATION

2.1 DRILLING FOR MOUNTING
2.11 Drill four holes in the deck 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 CARCAGE
2.21 Place the instrument on desk or on a
base desk, so that when the slide carriag-
ent 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 instru-
ment 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 per-
sons; 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
2.3 BOLTING DOWN SHOCK MOUNTINGS
2.31 Place the housing in position over the
holes drilled for mounting. Place a clock
winder 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, tighten-
ing 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 and note grounding connection, Section 2.4, following. Repeat for the front mount-
ings.

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
causing 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
### General Radio Company

**WARNING**

**Socket Voltages and Currents — Continued**

<table>
<thead>
<tr>
<th>Socket</th>
<th>Tube Type</th>
<th>Service</th>
<th>Readings at Up Between Terminals</th>
<th>MA DC or AC</th>
<th>Model GE Analyzer Meter Scale</th>
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</thead>
<tbody>
<tr>
<td>V-110</td>
<td>6SK7</td>
<td>H.F. Freq. Meter Oscillator</td>
<td>8-7</td>
<td>0.4 ac</td>
<td>8</td>
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<tr>
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<td></td>
<td></td>
<td>8-6</td>
<td>7.0 dc</td>
<td>10</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>4</td>
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<td>1</td>
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<td>1.3</td>
<td>2.5</td>
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<td>8</td>
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<tr>
<td></td>
<td>39010</td>
<td>H.F.M. Regulator</td>
<td>5-6</td>
<td>110 dc</td>
<td>820</td>
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<td>(VR-103-50)</td>
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<td>110</td>
<td>820</td>
</tr>
<tr>
<td>V-112</td>
<td>39070</td>
<td>H.F. Input</td>
<td>1-5</td>
<td>0.5 ac</td>
<td>8</td>
</tr>
<tr>
<td>(70)</td>
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<td></td>
<td>4-3</td>
<td>7.0 dc</td>
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<tr>
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<td>Interp. Input Amplifier</td>
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<td>820</td>
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<td>14.3 dc</td>
<td>25</td>
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<td>Interp. Freq. Meter Tube</td>
<td>2-7</td>
<td>6.4 ac</td>
<td>8</td>
</tr>
<tr>
<td>(94)</td>
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<td>3-8</td>
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<td>820</td>
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<tr>
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<td>3-7</td>
<td>-14 dc</td>
<td>20</td>
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<td>Interp. Regulator 1st Stage</td>
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<td>820</td>
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<td>820</td>
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<td>Plate Voltage</td>
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<td>5</td>
<td>110 dc</td>
<td>820</td>
</tr>
</tbody>
</table>

Except where indicated 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 contact shall be used in the equipment prior to employment of tubes from General stock.

---

**Diagram**

- **Restrictions:**
  - V-110
  - V-111
  - V-112
  - V-113
  - V-114
  - V-115
  - V-116
  - V-117
  - V-118
  - V-119
  - V-120
  - V-121

- **Socket Voltages and Currents:**
  - V-110
  - V-111
  - V-112
  - V-113
  - V-114
  - V-115
  - V-116
  - V-117
  - V-118
  - V-119
  - V-120
  - V-121

- **Notation:**
  - DC
  - AC
  - MA
  - Scale
  - Zero

---

**Notes:**

- Range Switch on Dead Point Between Ranges 1-2.
- R.F. Input control at zero. Calibrate OFF.
- Detector Input Switch in Center Position.
SHECKET VOLTAGES AND CURRENTS

<table>
<thead>
<tr>
<th>Socket</th>
<th>Tube Type</th>
<th>Service</th>
<th>Ratings at</th>
<th>MA</th>
<th>D.C.</th>
<th>Model OE</th>
<th>Voltage</th>
<th>Meter Scale</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>V-101</td>
<td>200504</td>
<td>(osc.)</td>
<td>1-6</td>
<td>0.5 cc</td>
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<td>2-6</td>
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<td>2-4</td>
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<td>V-109</td>
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<td>(out.)</td>
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<tr>
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<td>3-4</td>
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<td>1-2</td>
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3.1 PRINCIPLES OF OPERATION; ENGINEERING DISCUSSION

3.1.1 This section gives an engineering discussion covering the component circuits and the principles of operation. This section does not cover operating instructions; see Section 4 for operating instructions. THE ALL-TUBE SETS ARE SUITABLE FOR USE IN THE EQUIPMENT PRIOR TO EMPLOYMENT OF TUBES FROM GENERAL STOCK.

2.6 REPLACING INSTRUMENT IN CASE

2.6.1 First push the "half-speed" carriage back into the cabinet. Pick up instrument as described in Paragraph 2.4 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, try 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 back 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.
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 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 H.F. INPUT terminal by throwing DETECTOR INPUT switch, S-103, to the Interpolator, which automatically indicates the frequency thus set on the heterodyne frequency meter and the incoming frequency may then be compared with the calibrator harmonic (identified on the H.F.M. dial) and then adjust (by C-135 - C-136) the Heterodyne Frequency Meter to a selected frequency. The value of this beat frequency is given by the reading of the INTERPOLATOR meter M-101 on the proper scale. The beat frequency indicated by 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 Hanges 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 Extrinsic 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

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 38073 (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 mhos
Dode plates connected together and used as half-wave rectifier for detector.

TYPE 38076 (76)

SUPER-TRIODE AMPLIFIER, DETECTOR
Base: Small 5-pin.
Operating Conditions:
Heater Voltage .......... 6.3 v
Heater Current ........ 0.3 a
Plate Voltage .......... 250 v max.
Plate Current .......... 1 ma
Plate Resistance ....... 0.9 ohms
Grid Voltage .......... 3 v
Transconductance .... 1,250 mhos
Suppressor connected to cathode at socket.

TYPE 38084 (84) GAS-TUBE
Used for: V-111, 116
Base: Small shell 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 5-pin.
Operating Conditions:
Heater Voltage .......... 6.3 v
Heater Current ........ 0.3 a
Plate Voltage .......... 250 v
Plate Current .......... 5 ma
Plate Resistance ....... 0.8 meg.
Screen Voltage ....... 100 v
Screen Current .......... 2.4 ma
Grid Voltage ........ -3 v
Transconductance .... 8,000 mhos
Suppressor connected to cathode at socket.
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±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.

3.222 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-controlled 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 encloses the thermostat.
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 CHRYST. 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 \( \frac{1}{2}, \frac{1}{3}, \frac{1}{4}, \ldots \) 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 of the multivibrator is divided by the input of the output amplifier, the signal-to-noise ratio is increased by the factor of the division factor.

**FIGURE 3.23.** SCHEMATIC WIRING DIAGRAM OF HETERODYNE FREQUENCY METER. FOR COMPLETE WIRING DIAGRAM, SEE PAGE 73

**FIGURE 3.24.** FRONT ORIQUINE VIEW OF RIGHT SIDE WITH CABINET REMOVED
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-182, 183 or 184, 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

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.

<table>
<thead>
<tr>
<th>Range (on S-102)</th>
<th>Frequency Min.</th>
<th>Frequency Max.</th>
<th>Notes</th>
<th>Scale on Dial N-103</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>160 kc</td>
<td>830</td>
<td>BLACK</td>
<td>Fundamental</td>
</tr>
<tr>
<td>2</td>
<td>330</td>
<td>660</td>
<td>BLACK</td>
<td>Fundamental</td>
</tr>
<tr>
<td>3</td>
<td>470</td>
<td>940</td>
<td>BLACK</td>
<td>Fundamental</td>
</tr>
<tr>
<td>4</td>
<td>660</td>
<td>1330</td>
<td>BLACK</td>
<td>Second Harmonic of 2</td>
</tr>
<tr>
<td>5</td>
<td>940</td>
<td>1.87 Mc</td>
<td>RED</td>
<td>Second Harmonic of 3</td>
</tr>
<tr>
<td>6</td>
<td>1.33 Mc</td>
<td>1.87 Mc</td>
<td>RED</td>
<td>Second Harmonic of 6</td>
</tr>
<tr>
<td>7</td>
<td>1.87 Mc</td>
<td>2.65</td>
<td>RED</td>
<td>Second Harmonic of 7</td>
</tr>
<tr>
<td>8</td>
<td>2.65</td>
<td>3.75</td>
<td>RED</td>
<td>Second Harmonic of 10</td>
</tr>
<tr>
<td>9</td>
<td>3.75</td>
<td>5.3</td>
<td>RED</td>
<td>Second Harmonic of 11</td>
</tr>
<tr>
<td>10</td>
<td>5.3</td>
<td>7.5</td>
<td>RED</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>7.5</td>
<td>10.6</td>
<td>RED</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>10.6</td>
<td>15.0</td>
<td>RED</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>15.0</td>
<td></td>
<td>RED</td>
<td></td>
</tr>
</tbody>
</table>

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.

3.234 Compensator Aperture

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...
3.255 Interpolator Scale-Test Capatitor

The second auxiliary control is called the INTERPOLATOR SCALE-TEST control, C-165, 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-165, 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, Cary, 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 3.2535 and following paragraphs.

3.256 Output Circuits

3.261 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.101. 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 headphones. The frequency meter is then adjusted so as to obtain zero beats. When the detector input is switched to the MEASURE position, S.101, 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-165. See paragraphs 3.253 and 3.255.

3.270 Harmonic Range and Multiplier Chart

3.271 The harmonic range and multiplier chart, N.106, secured to the housing of the IFM FREQUENCY dial, X.100, 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 100 kc to 1.5 Me are to be set up or measured.

3.272 From the range table, paragraph 3.259, it is evident that ranges 10 and 11, covering 3.75-5.5 and 3.75-7.2 Me by the fundamental frequency, carry fundamental frequency calibrations on the IFM dial. Similarly, ranges 12 and 13, covering 7.5-10.6 and 10.6-15.0 Me 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.

3.273 If use is made of ranges 10 and 11 for frequencies 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 frequency 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 must only be multiplied by 2.

3.274 It will be seen from the above that if an odd numbered frequency 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.

3.275 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.

3.276 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 heavy solid range line. (Example: 44.0 Mc crosses the 150X2 range line roughly 1/2 from the left end).
FIGURE 3.237. HARMONIC RANGE AND MULTIPLIER CHART

(a) The range to be used is 13.

(b) The multiplier to be used is 2.

(c) Take 1/2 of the desired frequency. (Example: \(19.5/2 = 9.75\) Mc.)

(d) Set heterodyne frequency meter to 9.75 Mc on range 12 (which will lie at roughly \(3/4\) scale from low-frequency end, see (b) above).

(e) The harmonic used then falls at \(19.5 \times 2 = 39.0\) Mc, the desired frequency.

EXAMPLE B

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

(b) Enter chart with desired frequency, on frequency scale at top. (Example: 19.5 Mc.)

(c) Note where desired frequency crosses a heavy solid range line. (Example: 19.5 Mc crosses the \(18 \times 2\) range line roughly \(3/4\) from the left end.)

(d) The range to be used is 12.

(e) The multiplier to be used is 2.

(f) Set heterodyne frequency meter to 19.5 Mc on range 12 (which will lie at roughly \(3/4\) scale from low-frequency end, see (b) above).

(g) The harmonic used then falls at \(19.5 \times 2 = 39.0\) Mc, the desired frequency.

(h) To measure a frequency in the harmonic range.

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

(j) Note where the approximate frequency crosses a heavy solid range line. (Example: 19.5 Mc crosses the \(18 \times 2\) range line roughly \(3/4\) from the left end.)

(k) The range to be used is 12.

(l) The multiplier to be used is 2.

(m) Take 1/2 of approximate frequency. (Example: \(19.5/2 = 9.75\) Mc.)

(n) Set heterodyne frequency meter to 9.75 Mc on range 12 (which will lie at roughly \(3/4\) scale from low-frequency end, see (b) above).

(o) The harmonic used then falls at \(9.75 \times 2 = 19.5\) Mc, the desired frequency.
(g) Vary heterodyne frequency meter setting slightly either way until a beat against the frequency being measured is heard. Set for zero beat.

(b) Measure HFM frequency in regular way. (Example: 9.792 Me.)

(i) Multiply result obtained by 6 to get final result. (Example: 9.792 x 6 = 58.752 Me.)

3.2377 The chart shows, by the heavy solid range lines, the simplest choice of ranges and multipliers. These ranges are preferred for simplest calculations using multipliers and would therefore normally be used. These ranges leading to more complicated calculations would therefore normally be avoided. These heavy lines show that using ranges 18 and 13 with a multiplier of 2, a frequency range from 15 to 30 Mc is obtained (lines 10 x 3/4 and 13 x 2). Using a part of range 18 and all of range 15, with a multiplier of 3, a frequency range of 30 to 45 Mc is obtained (lines 10 x 3 and 13 x 3). Using a part of range 18 and a multiplier of 4, a frequency range of 45 to 60 Mc is obtained (line 13 x 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, 84.0 Mc could be set up or measured using range 10 and multiplier of 3 (line 10 x 3), or range 12 and multiplier of 3 (line 10 x 3), but neither of these is as convenient as the use of range 15 and multiplier of 3 (line 15 x 3), which is 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-e and the d-e 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-101:

1. Switch Position, S-101: 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-100.
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-101 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, 100 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 DIAGRAM OF DETECTOR AND AUDIO AMPLIFIER. FOR COMPLETE WIRING DIAGRAM, SEE PAGE 74.
3.242 The first filter, LC-101, is for the purpose of suppressing beat frequencies higher than, roughly, 0 to 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, Y-108 and Y-109, to obtain the required audio-frequency output power delivered to the telephones. The first stage consists of the screen-grid tube Y-108 and the second of the triode Y-109. The amplifier proper has an essentially flat frequency-gain characteristic, a second filter, LC-102, is employed, preceding the output transformer, T-101.

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.

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 telephone's 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 baily. It is troublesome, however, in operating the interpolator, since the input voltage to the telephone transformer, T-101, is used to drive the heterodyne transformer, T-101, is used to drive it, via J-10i and R-103. A small amount of resistance at R-114 and R-115 placed in series with the telephones limits this reduction in voltage to the telephone transformer, and this is the reason why the response from the transformers, TEL VOL-1.3, E-101, E-101: 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, along the horizontal HF.M frequency axis represent four harmonics of the calibrator, spaced 10 kc apart. If now the heterodyne frequency meter is set to point No. 1, a 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 HF.M frequency is moved toward the right, a beat tone is heard which increases in frequency as the HF.M frequency is raised. This beat tone is represented by the line 1-A. At the same time, a beat is obtained between the HF.M frequency and that of the next higher calibrator harmonic, No. 2. This beat frequency, indicated by line P-Q, 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 5-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-A. It will be seen that two beat frequencies are obtained, one where X-A crosses the line 1-A, representing the desired or "expected" beat frequency; the second is obtained where X-A crosses line P-Q, representing an undesired or "unexpected" beat frequency. If
the heterodyne-frequency-meter frequency is increased somewhat from that corresponding to \( f_1 \), the beat \( 1-1 \) increases and the beat \( 1-2 \) decreases, both becoming 5 ke at the point where these lines cross. In a region near this crossing point, the effect is that of a 5 ke 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 \( f_1 \), two beat frequencies are again obtained.

3.2453 Since it is necessary to measure the IFM frequency at any point between two calibrator harmonics, it is evident from the diagram that beat frequencies up to at least 5 ke must be available, but also that beat frequencies from 5 to 10 ke 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 ke 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-ke 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 ke. A simple change in calibrator frequency from 10 ke to 20 ke 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 1-1. Similarly for the lines \( B \) and \( C \). By this expedient, proper operation of the interpolator may be obtained throughout the range from one 10-ke calibrator harmonic to the next, if, when the beat frequency is very near 5 ke the calibrator be shifted from 10 ke to 80 ke. (This condition is marked by "BLUE" zones on the interpolator meter, S-101, with instructions to change calibrator from 10 ke to 80 ke.) Caution: Care should be taken to return CALIBRATOR switch, S-101, to 10 ke 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 \( A \), the zero beat points, for beats between the fundamentals (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 \( n \) kilocycles, as shown at the top of the figure.

3.2465 In line \( B \), 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 halfway 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 halfway between the harmonies \(2n\) 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 the zero 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-ke 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-ke interval \(f\) and so on. Similarly, if the calibrator frequency is 50 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 50-ke 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 halfway 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 10 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 180, 540, 900, or 1260 divisions apart, giving calibration points respectively 85, 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-165, 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.
3.252 Electronic Frequency Meter

3.2521 The electronic frequency meter consists of the gas-triodes V-115, V-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 current applied to the gas-triode grids, over a frequency range from 0 to 5 kc and independent of the amplitude of the voltage provided only that this voltage is appreciably greater than the threshold voltage required to ignite the gas-discharge.

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, V-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, alternately, by the normal 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, V-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 -180, momentarily raising the corresponding plate of V-117 to a positive voltage. A current pulse thus passes through V-117, V-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, when 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...
This condition is indicated by the reading of the momentary removal, by pressing the DEION-switching, both gas-triodes V-115 and V-116 the supply voltage is constant (which is the reason practice.

if the successive current pulses are constant and the voltage drops in 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).

3.2520 As stated above, for each transition 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.

3.2521 The average current through meter M-101 is thus seen to be inherently proportional to frequency; a standard d-e 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, -180). 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 3.0 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 As is pointed out in more detail in Section 3.845 the beat frequencies to be indicated by the interpolator vary from 0 to 5 kc, or from 5 kc to 0 kc, 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 kc. This scale is provided by reversing the meter M-101 with the ENTROPOLATOR 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.

3.253 Referring to Section 3.845 on the formation of beat notes, and Figure 3.845, 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 3.845 (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 1-A, Figure 3.845 (B). The regions enclosed in the dotted circles of Figure 3.845 (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 5 kc.

3.2533 In Figure 3.825 (A) the essentials of Figure 3.845 (B) are repeated, showing the beat between the HPM 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 3.845 (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 3.825 (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
3.2539 CAUTION: Do not advance the INTERPOLATOR SCALE-TEST control, C-103, 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-103, 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 The power supply is from a 110-115-120 volt 60-cycle supply.

3.2611 The power supply consists of the power transformer T-103, rectifier V-101, and a smoothing filter (L-108, -109, -110 and C-100, -107, -158, -159). In the filter, one output is obtained at the junction of L-108, -109 for operation of the interpolarator 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 0.6-volt winding on the power transformer T-101.

3.262 Power Switch

3.2621 The power switch S-101 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-101 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-101, 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 0.6-volt winding. At the same time the plate

FIGURE 3.94 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.

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 Using Equipment in Operation

4.21 STAND BY OPERATION

4.22 Full operation

4.3 Checking the Heterodyne Frequency Meter Against Calibrator

4.31 Pulling 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

3.263 Such voltage regulators may be cascaded, which is done here, with the tubes V-119, -180 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-100, to MATCH and turning the R. F. INPUT control, R-134, back to zero.
4.22 FULL OPERATION

4.221 To place equipment in full operation, turn POWER switch, S-100, to ON position. Wait 5 minutes for tubes to reach full operating temperature.

4.222 When the POWER switch, S-100, is turned to the ON position, the HFM plate current meter, M-101, should read 10. If the RANGE SELECTOR switch, S-100, is set on a ‘dead’ point, turn POWER switch, S-100, to OFF position.

4.3 TEST OF INTERPOLATOR SCALE ALIGNMENT: CHECK OF HETERO-DYNE 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) Throw CALIBRATOR switch, S-102, to working point.
(2) Turn CALIBRATOR switch, S-102, to ‘dead’ point.
(3) Turn INTERPOLATOR switch, S-103, to ‘dead’ point.
(4) Turn INTERPOLATOR switch, S-103, to working point.

4.32 SHORT CHECKING PROCEDURE

(1) Throw DETECTOR INPUT switch, S-100, to measure position.
(2) Select range desired on HFM RANGE SELECTOR switch, S-100.
(3) Turn HFM FREQUENCY control, C-135-A, to nearest calibrator harmonic to the required frequency (100 kc, 0.1 Mc, multiples on BLACK or RED scales), setting HFM FREQUENCY dial, N-101, to index line at this frequency.

NOTE: On the BLACK scales of the direct-reading frequency dial, N-101, the calibrator harmonics of 10, 100, and 1000 kc fall at multiples of 10, 100, and 1000 kc. On the RED scales, the calibrator harmonics of 10, 100, and 1000 kc fall at multiples of 0.02, 0.2, and 0.002 Mc (all of which can be checked from the calibrator, but which are not principal beat points which are utilized in estimating frequencies lying between calibrator harmonics).

4.4 BLOCKING PROVISIONS

(1) If a beat tone is heard in the telephones, plugged in at the TEL jacks, J-101 or J-102, throw INTERPOLATOR meter, C-135-C, making the HFM frequency dial reading agree with the calibrator.

4.5 FOR EXTRA-SENSITIVE ARRANGEMENTS

(1) Thrown INTERPOLATOR switch, S-102, to 10 kc position.
(2) Thrown INTERPOLATOR switch, S-102, to 10 kc position.
(3) Thrown INTERPOLATOR switch, S-102, to 10 kc position.
(4) Thrown INTERPOLATOR switch, S-102, to 10 kc position.
(5) Thrown INTERPOLATOR switch, S-102, to 10 kc position.
(6) Thrown INTERPOLATOR switch, S-102, to 10 kc position.

4.6 GENERAL RADIO COMPANY
(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-100, reduce this beat to zero by carefully setting COMPENSATOR, C-185-C, making the HFM FREQUENCY dial N-109 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 Me

(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-109, has been checked very recently near the desired frequency, step (2) may be omitted. If there is any question, however, ALWAYS CHECK THE CALIBRATION.

(2) Select range 12 or 13 on HFM RANGE SELECTOR switch, S-100, as required for (1). See line 13X4, heavy section, on MULTIPLIER chart, N-106.

(3) Proceed as given in paragraph 4.411 above, setting one-fourth the desired frequency in 4.411(8).

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

4.421 Frequency between 160 kc and 15 Me

(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-109, has been checked very recently near the frequency to be measured, step (2) may be omitted. If there is any question, however, ALWAYS CHECK THE CALIBRATION.

(2) Set HFM FREQUENCY dial, N-109, to estimated value of frequency to be measured.

(3) Proceed as given in paragraph 4.411 above, at a setting near the frequency to be measured.

4.422 Frequency between 15 and 30 Me

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

(2) Select range 13 or 15 on HFM RANGE SELECTOR switch, S-100, as required for (1). See line 13X4, heavy section, on MULTIPLIER chart, N-106.

(3) Proceed as given in paragraph 4.411 above, setting one-half the desired frequency in 4.411(9).

4.43 Frequency between 30 and 60 Me

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

(2) Select range 15 or 18 on HFM RANGE SELECTOR switch, S-100, as required for (1). See line 18X3 and 15X3, heavy sections, on MULTIPLIER chart, N-106.

(3) Proceed as given in paragraph 4.411 above, setting one-third the desired frequency in 4.411(9).

4.44 Frequency between 60 and 90 Me

(1) Take one-quarter of the estimated value of the frequency to be measured.
4.5 TO SET UP OR MEASURE A FREQUENCY—ACCURATE METHOD

4.51 TO SET UP A DESIRED FREQUENCY BY THE ACCURATE METHOD

4.51H FREQUENCY from 100 kc to 15 Me

(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 HF FREQUENCY dial, N-103, has been checked very recently near the desired frequency, Step (2) may be omitted. If there is any question, however, ALWAYS CHECK THE CALIBRATION.

(2) Set HF 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 HF FREQUENCY dial, N-103, this FREQUENCY DIFFERENCE will be from 0 to 10 kc; for RED scales on the HF FREQUENCY dial, N-103, this FREQUENCY DIFFERENCE will be from 0 to 35 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.

<table>
<thead>
<tr>
<th>STEP (2)</th>
<th>REQUIRED FREQUENCY DIFFERENCE ON INTERPOLATOR SCALE SELECTOR S-104</th>
<th>STEP (4)</th>
<th>READ REQUIRED FREQUENCY DIFFERENCE ON INTERPOLATOR Meter (M-101)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLACK</td>
<td>0-5</td>
<td>LOWER</td>
<td>BLACK-LOWER</td>
</tr>
<tr>
<td>BLACK</td>
<td>5-10</td>
<td>UPPER</td>
<td>BLACK-UPPER</td>
</tr>
<tr>
<td>RED</td>
<td>0-10</td>
<td>LOWER</td>
<td>RED-LOWER</td>
</tr>
<tr>
<td>RED</td>
<td>10-20</td>
<td>UPPER</td>
<td>RED-UPPER</td>
</tr>
</tbody>
</table>

4.51L To make the adjustment of (4) 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 the 20-kc position. Complete the readjustment called for in (4).

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

(6) Beats between this desired frequency and the frequency of an external source (connected to the R.F. INPUT terminal E-103) are obtained by throwing the DETECTOR INPUT switch.
S-109, to the MATCH position. The level of the voltage introduced at the R. F. INPUT terminal, E-109, can be adjusted by the R. F. INPUT control, R-104.

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 if the final frequency because this error is only a small part of the 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-109, as required for (1). See lines 1X2 and 1X3 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-109, as required for (1). See lines 1X2, 1X3, and 1X4, 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-109, as required for (1). See line 1X3, 1X4, 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 100 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.

(2) Set HF FREQUENCY dial, N-101, to the estimated value of frequency to be measured.

(3) Throw DETECTOR INPUT switch, S-109, to MATCH position.

(4) Vary HF FREQUENCY control, C-125, A, B, to obtain zero beat against frequency to be measured (introduced at R. F. INPUT terminal, E-109, 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 convenient with measuring this frequency by the ACCURATE method.

(6) Throw DETECTOR INPUT switch, S-109, to MEASURE position.

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

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

(9) If reading of INTERPOLATOR meter, M-101, falls in BLUE zone, follow instructions on note on the meter scale and change the calibrator frequency to 60 kc.

(10) 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, depress button, S-105, should be pressed and then released. See paragraph 4.511 (9).

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

(12) The value of the frequency being measured is given for the SCM of the calibrator frequency next below the setting of the HF FREQUENCY dial, N-103, and the reading on the INTERPOLATOR meter, M-101, taken on the correct scale, as tabulated on page 44. (The HF FREQUENCY dial, N-103, indicates the approximate value of the frequency being measured.)

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

NOTE that having determined the correct position of the INTERPOLATOR SCALE SELECTOR switch, S-104 (Step 9), the position of the switch indicates the 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-109, as required for (1).
4.6 CRYSTAL AND STANDARD FREQUENCY COMPARISONS

4.61 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 3.211) should rarely be encountered.

4.62 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 5 cycles.

4.63 The frequency of the crystal control oscillator may be checked in terms of standard frequency transmissions, through the use of an external receiver. (Refer to \textit{Bell} 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. \textbf{Note:} Keep snap cover on circuits by coupling from the CAL. OUT concentric jack, C-104, to obtain the estimated value of the frequency for zero beat in 4.261, (2) through (10).

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

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

<table>
<thead>
<tr>
<th>STEP (5)</th>
<th>STEP (9)</th>
<th>STEP (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale of HFM FREQUENCY DIAL (N-100) in use:</td>
<td>INTERPOLATOR SCALE SELECTOR</td>
<td>READ following INTERPOLATOR SCALE on Meter, M-101:</td>
</tr>
<tr>
<td>BLACK</td>
<td>BLACK</td>
<td>LOWER</td>
</tr>
<tr>
<td>BLACK</td>
<td>BLACK</td>
<td>LOWER</td>
</tr>
<tr>
<td>RED</td>
<td>RED</td>
<td>LOWER</td>
</tr>
<tr>
<td>RED</td>
<td>RED</td>
<td>UPPER</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>STEP (5)</th>
<th>STEP (9)</th>
<th>STEP (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale of HFM FREQUENCY DIAL (N-100) in use:</td>
<td>INTERPOLATOR SCALE SELECTOR</td>
<td>READ following INTERPOLATOR SCALE on Meter, M-101:</td>
</tr>
<tr>
<td>BLACK</td>
<td>BLACK</td>
<td>LOWER</td>
</tr>
<tr>
<td>BLACK</td>
<td>BLACK</td>
<td>LOWER</td>
</tr>
<tr>
<td>RED</td>
<td>RED</td>
<td>LOWER</td>
</tr>
<tr>
<td>RED</td>
<td>RED</td>
<td>UPPER</td>
</tr>
</tbody>
</table>

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 3.211) 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 5 cycles.

4.62 The frequency of the crystal control oscillator may be checked in terms of standard frequency transmissions, through the use of an external receiver. (Refer to \textit{Bell} 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. \textbf{Note:} Keep snap cover on circuits by coupling from the CAL. OUT concentric jack, C-104, to obtain the estimated value of the frequency for zero beat in 4.261, (2) through (10).

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

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

<table>
<thead>
<tr>
<th>STEP (5)</th>
<th>STEP (9)</th>
<th>STEP (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale of HFM FREQUENCY DIAL (N-100) in use:</td>
<td>INTERPOLATOR SCALE SELECTOR</td>
<td>READ following INTERPOLATOR SCALE on Meter, M-101:</td>
</tr>
<tr>
<td>BLACK</td>
<td>BLACK</td>
<td>LOWER</td>
</tr>
<tr>
<td>BLACK</td>
<td>BLACK</td>
<td>LOWER</td>
</tr>
<tr>
<td>RED</td>
<td>RED</td>
<td>LOWER</td>
</tr>
<tr>
<td>RED</td>
<td>RED</td>
<td>UPPER</td>
</tr>
</tbody>
</table>
**GENERAL RADIO COMPANY**

**TABLE III**

<table>
<thead>
<tr>
<th>MISCELLANEOUS PARTS (CLASS 10)</th>
<th>QUANTITY</th>
<th>NAVY TYPE No.</th>
<th>ALL SYMBOL DESIGNATIONS INVOLVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>E-101, 141</td>
<td>1</td>
<td>H-104</td>
</tr>
<tr>
<td>9</td>
<td>E-105, 106, 107, 108, 109, 110, 111, 112, 113</td>
<td>1</td>
<td>H-105</td>
</tr>
<tr>
<td>1</td>
<td>E-114</td>
<td>1</td>
<td>H-108</td>
</tr>
<tr>
<td>1</td>
<td>E-115</td>
<td>1</td>
<td>N-101</td>
</tr>
<tr>
<td>1</td>
<td>E-116, 117</td>
<td>1</td>
<td>N-102</td>
</tr>
<tr>
<td>1</td>
<td>E-118</td>
<td>1</td>
<td>N-105</td>
</tr>
<tr>
<td>1</td>
<td>E-119</td>
<td>1</td>
<td>N-106</td>
</tr>
<tr>
<td>1</td>
<td>E-120, 102</td>
<td>1</td>
<td>N-108</td>
</tr>
</tbody>
</table>

**ELECTRICAL INDICATING INSTRUMENTS (CLASS 26)**

<table>
<thead>
<tr>
<th>QUANTITY</th>
<th>NAVY TYPE No.</th>
<th>ALL SYMBOL DESIGNATIONS INVOLVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>E-127, 129</td>
<td>M-101</td>
</tr>
<tr>
<td>1</td>
<td>E-131</td>
<td>M-103</td>
</tr>
<tr>
<td>1</td>
<td>E-132</td>
<td>M-104</td>
</tr>
<tr>
<td>1</td>
<td>E-133</td>
<td>M-106</td>
</tr>
<tr>
<td>1</td>
<td>E-134</td>
<td>M-107</td>
</tr>
<tr>
<td>1</td>
<td>E-135</td>
<td>M-108</td>
</tr>
<tr>
<td>1</td>
<td>E-136</td>
<td>S-101</td>
</tr>
<tr>
<td>1</td>
<td>E-137, 100</td>
<td>S-102</td>
</tr>
<tr>
<td>1</td>
<td>E-138, 150</td>
<td>S-103</td>
</tr>
<tr>
<td>1</td>
<td>E-139</td>
<td>S-104</td>
</tr>
<tr>
<td>1</td>
<td>E-140, 141</td>
<td>S-105</td>
</tr>
<tr>
<td>1</td>
<td>E-142</td>
<td>S-106</td>
</tr>
</tbody>
</table>

**SWITCHES (CLASS 64)**

<table>
<thead>
<tr>
<th>QUANTITY</th>
<th>NAVY TYPE No.</th>
<th>ALL SYMBOL DESIGNATIONS INVOLVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S-101</td>
<td>S-102</td>
</tr>
<tr>
<td>1</td>
<td>S-103</td>
<td>S-104</td>
</tr>
</tbody>
</table>

**FUSES (CLASS 80)**

<table>
<thead>
<tr>
<th>QUANTITY</th>
<th>NAVY TYPE No.</th>
<th>ALL SYMBOL DESIGNATIONS INVOLVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F-101, 102</td>
<td>F-103</td>
</tr>
<tr>
<td>1</td>
<td>F-105</td>
<td>F-106</td>
</tr>
</tbody>
</table>
to the "low" (ground) side of the source. On inserting the plug in the jack, J-101, 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 megohms 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 heat 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 90 kc position.
(2) Turn HFM RANGE SELECTOR switch, S-102, to range 1, 100-200 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 increase the heat 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.

4.82 The audio-frequency output is obtained at either of the TEL jacks, J-101 or J-102, and at the NOTE telephone jack. 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 0.9 volts into a 600-ohm load. The output voltage may be adjusted by means of the TELEPHONE 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 results 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, 4.44) 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, 0-9.9 kc and 11-15 kc for the respective scales. Interpolation by the use of the scale of equal parts (N-101, 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, 4.44) can be obtained. Somewhat over 50% coverage can be obtained by EXACT METHOD (5.5 kc on either side of every 10 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-101, 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-101, 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 obtained may still be obtained by the QUICK METHOD (see Sections 4.41, 4.44) 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 4.932.) 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 near the reference calibrator point; if the HFM frequency is decreased, ADD the INTERPOLATOR reading on UPPER scale to the frequency of the calibrator point near 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 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 $f_2$ or the frequency to be measured. $f_1$ and $f_2$ represent the corresponding scale setting read on the equal parts scale, and $f_1$, $f_2$ represent the frequency of the calibrator point next above $f_1$ and $f_2$, and $N_1$, $N_2$ represent the corresponding scale setting. If $f_1$ and $f_2$ represent 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 $N_1$. Set to zero beat against $f_2$ and note the scale reading, in divisions, corresponding; this is $N_2$. Find the "divisions per kilocycle" factor $D$ from

$$D = \frac{N_1 - N_2}{f_1 - f_2}$$

where $(N_1 - N_2)$ is the number of scale divisions between the settings for $f_1$ and $f_2$. $(f_2 - f_1)$ is 10, 80 or 100 kc, depending upon the CALIBRATOR
5.1 GENERAL STATEMENT

5.1.1 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 is to locate the portion of the circuit in question by simple methodical tests. Having established the portion of the circuit affected, the next step is to determine the cause of the difficulty.

5.1.2 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 will always quickly disclose any serious circuit fault. 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.

5.1.3 The use of a test circuit as described in the circuit and the multi-vibrator will not control on any position of the CALIBRATOR switch. 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 switch settings, 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 \((f_2 - f_1)\), that is, the number of kilocycles \(f_2\) is above \(f_1\). Then this frequency difference \((f_2 - f_1)\) multiplied by the "kilocycles per kilocycle" factor \(D\) gives the scale difference \((S_2 - S_1)\) or the number of divisions \(S_1\) lies above \(S_2\).

\[ (f_2 - f_1)D = (S_2 - S_1) \]

4.965 To measure a frequency, find the scale difference \((S_2 - S_1)\), that is, the number of divisions \(S_1\) lies above \(S_2\). Then this scale difference \((S_2 - S_1)\) multiplied by the "kilocycles per kilocycle" factor \(D\) gives the frequency differences \((f_2 - f_1)\) or the number of kilocycles that \(f_2\) lies above \(f_1\).

\[ (S_2 - S_1)D = (f_2 - f_1) \]
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-101, lighted by the HEAT signal lamp, L-101, not lighting at all or staying lit. If the HEAT signal lamp fails to light, first check reading of thermometer, M-101, mounted on the top of the temperature control box, rear left of top shelf in equipment (by drawing equipment forward on slides). If the thermometer shows an abnormally low reading, or no reading, the fault is in the heater circuits. Check HEAT fuse, F-101; 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.

5.222 If the thermometer reads 50°C±0.5°C, the control is functioning properly. The trouble is then a burned-out HEAT signal lamp, L-101, or poor connections in the lamp socket.

5.223 If the thermometer shows an abnormally high reading, or no reading, the fault is in the heater circuits. Check HEAT fuse, F-101; 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 reads an abnormally high, reading, either to a faulty thermostat, S-107, which fails to open 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 as 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 one or two positions of the CALIBRATOR switch, S-101, to the 1.33 to 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 100-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 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 check 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 check until the correct count is obtained. The correct count has been obtained, set the heterodyne frequency meter to one of the 100-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 notes suddenly changes, noting the position of R-113. Make final setting of R-113 in middle of this range.

5.232 To check the 10-kc position, proceed as in 5.231 except set two successive 100-kc harmonics on heterodyne frequency meter dial. Throw CALIBRATOR switch, S-101, to the 10-kc position. Make count of zero beat points, as described in 5.231, which should give 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. If the count is less than 10, correct by adjusting R-113, as described for 5.231 in 5.234, and make final setting in same manner.

5.233 To check for faults or to check the alignment of the multivibrator V-103, -104, replace these tubes and remove amplifier V-109. 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 900 kc. This frequency should be 800 kc±1 kc. If it is not, adjust R-114 to bring the frequency close to 800 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-109 and let it reach operating temperature. Using the heterodyne frequency meter, set it for a beat of, say, 0.5 kc near 800 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 80-kc position, throw the CALIBRATOR switch, S-101, to the 100-kc position. Throw the heterodyne frequency meter RANGE SELECTOR switch, S-106, to the 1.33 to 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 80-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 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 check 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 check until the correct count is obtained. The correct count has been obtained, set the heterodyne frequency meter to one of the 100-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 notes suddenly changes, noting the position of R-113. Make final setting of R-113 in middle of this range.

5.235 To check the harmonic frequency meter, proceed as in 5.232, except set two successive 100-kc harmonics on heterodyne frequency meter dial. Throw CALIBRATOR switch, S-101, to the 10-kc position. Make count of zero beat points, as described in 5.232, which should give 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. If the count is less than 10, correct by adjusting R-113, as described for 5.232 in 5.234, and make final setting in same manner.

5.236 If the beat output at the telephones is heard for both between the CALIBRATOR and the heterodyne-frequency meter is below normal, the difficulty may be due, among other
5.422 If the above tests fail to disclose a failure 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 first 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 grid 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 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 switch. Turn Calibrator Switch, S-101, the INTERPOLATOR SCALE SELECT Switch. Verify the operation of V-119, -118, and V-119 by inspection to see that they glow, to be certain that proper plate supply voltage is obtained. Check input amplifier as in Section 5.11 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 Quick Test for INTERPOLATOR SCALE Adjustment

5.525 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 DECTROR INPUT Switch, S-100, to MEASURE INPUT position. Throw INTERPOLATOR SCALE SELECT Switch, S-104, to LOWER position. Turn HFM Scale to FREQUENCY control, C-135-A, -B, rapidly. The Interpolator Meter, M-101, should read 8.5 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 8.5 kc on LOWER BLACK scale, while the frequency control is being turned rapidly.

5.526 Accurate Alignment of INTERPOLATOR

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

(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 calibrator. Remove V-114. Keep INTERPOLATOR SCALE SELECT Switch, S-104, in LOWER position. Turn R-175 back to zero (clockwise end), by screw driver adjust- ment on top of lower left-hand shelf. Meter M-101 will then read about one-tenth full scale. With a high resistance voltmeter, connected be- tween the clockwise end of R-175 (located at cen- ter 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 direc- tion 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 3½ inch along winding.)
(c) Replace V-114 removed above.
(d) Set IFM RANGE SELECTOR switch, S-102, to lowest frequency range. Set CALI- BRATOR switch, S-101, to 10 kc position. Throw DETECTOR INPUT switch, S-103, to MEAS- URE position. Adjust the IFM FREQUENCY control, C-135-A, B, carefully, half-way between two 10 kc calibration harmonics. This setting can be made accurately by bringing the flatter heater on the 5-kc note to a very slow waxing and wan- ning. Throw calibrator switch, S-101, to 80 kc position. The audio output 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 fol- lows, after sliding instrument out of cabinet on slides, attaching serving table and operating in R.U.X. condition for ten minutes or more.
(a) FIRST ALIGN the LOWER scales as given in Section 5.2861 above.
(b) Remove V-114. Throw the INTERPO- LATOR SCALE SELECTOR switch, S-104, to UPPEm position. Meter M-101 will then read near full scale.
(c) Adjust R-176 (screw driver adjustment on top, rear, of lower left-hand shelf) until Inter- polator 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-119, -120, 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 L-102, and F-102 (to open the heaters of the temperature-controlled system). If the rectifier tube filament lights, and the remaining tube heaters and temperature con- trol operate normally, but there is no plate supply voltage, check F-101. If the fuse F-101 is normal, then the trouble is likely an open circuit in L-108, -109 or -110.

5.62 The plate supply voltage which is regu- lated by V-119, -130 and V-118 is taken from the junction of L-108, -109. If the total supply voltage is normal and the rectifier 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 L-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 sur- face or any in which the discharge goes out if the line voltage drops momentarily.

TABLE II (Continued)

<table>
<thead>
<tr>
<th>RESISTORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>symbol</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>R-100</td>
</tr>
<tr>
<td>R-101</td>
</tr>
<tr>
<td>R-102</td>
</tr>
<tr>
<td>R-103</td>
</tr>
<tr>
<td>R-104</td>
</tr>
<tr>
<td>R-105</td>
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<tr>
<td>R-106</td>
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<tr>
<td>R-107</td>
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<tr>
<td>R-108</td>
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<tr>
<td>R-109</td>
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<tr>
<td>R-110</td>
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<tr>
<td>R-111</td>
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<tr>
<td>R-112</td>
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<tr>
<td>R-113</td>
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<tr>
<td>R-114</td>
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<tr>
<td>R-115</td>
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<tr>
<td>R-116</td>
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<tr>
<td>R-117</td>
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<tr>
<td>R-118</td>
</tr>
<tr>
<td>R-119</td>
</tr>
<tr>
<td>R-120</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-1</td>
<td>Automatic Power Control Unit</td>
</tr>
<tr>
<td>P-100</td>
<td>Automatic Power Control Unit</td>
</tr>
<tr>
<td>P-101</td>
<td>Automatic Power Control Unit</td>
</tr>
<tr>
<td>P-102</td>
<td>Automatic Power Control Unit</td>
</tr>
<tr>
<td>P-103</td>
<td>Automatic Power Control Unit</td>
</tr>
<tr>
<td>P-104</td>
<td>Automatic Power Control Unit</td>
</tr>
<tr>
<td>P-105</td>
<td>Automatic Power Control Unit</td>
</tr>
<tr>
<td>P-106</td>
<td>Automatic Power Control Unit</td>
</tr>
<tr>
<td>P-107</td>
<td>Automatic Power Control Unit</td>
</tr>
<tr>
<td>P-108</td>
<td>Automatic Power Control Unit</td>
</tr>
<tr>
<td>P-109</td>
<td>Automatic Power Control Unit</td>
</tr>
<tr>
<td>P-110</td>
<td>Automatic Power Control Unit</td>
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<tr>
<td>P-111</td>
<td>Automatic Power Control Unit</td>
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<tr>
<td>P-112</td>
<td>Automatic Power Control Unit</td>
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<tr>
<td>P-113</td>
<td>Automatic Power Control Unit</td>
</tr>
<tr>
<td>P-114</td>
<td>Automatic Power Control Unit</td>
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<tr>
<td>P-115</td>
<td>Automatic Power Control Unit</td>
</tr>
<tr>
<td>P-116</td>
<td>Automatic Power Control Unit</td>
</tr>
<tr>
<td>P-117</td>
<td>Automatic Power Control Unit</td>
</tr>
<tr>
<td>P-118</td>
<td>Automatic Power Control Unit</td>
</tr>
<tr>
<td>P-119</td>
<td>Automatic Power Control Unit</td>
</tr>
<tr>
<td>P-120</td>
<td>Automatic Power Control Unit</td>
</tr>
</tbody>
</table>

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#### 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 occasion-ally be necessary in service operation.

<table>
<thead>
<tr>
<th>SYMPTOM</th>
<th>CAUSE</th>
<th>REASON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessively high hum in telephone, when checking against calibrator.</td>
<td>Open grid circuit.</td>
<td></td>
</tr>
<tr>
<td>Steady audio note in phones, regular beats against calibrator heard in background.</td>
<td>Improper by-passing in audio amplifier.</td>
<td></td>
</tr>
<tr>
<td>No normal beat tones when checking against calibrator; steady very low frequency “popping.”</td>
<td>Shorted dials detector.</td>
<td>Bus leads, at front of set of V-106, shunted together.</td>
</tr>
<tr>
<td>No audio output.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No audio output.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High hum in audio output. Abnormal heating of hum-centred R-106.</td>
<td>Abnormal voltage on part R-106.</td>
<td>Grounded on one side of heater circuit.</td>
</tr>
<tr>
<td>Low audio output.</td>
<td>Poor detachment.</td>
<td></td>
</tr>
<tr>
<td>Noisy audio output when making zero-set adjustments.</td>
<td>External noise pick-up or faulty detector.</td>
<td></td>
</tr>
<tr>
<td>Buzz in audio output. Sounds like R.F. buzz from mercury rectifier.</td>
<td>Sparking in buffer condensers.</td>
<td>If a fault in C-101, 102 or 103 is open, sparking may take place across gap. Condensers do not break down on voltage test.</td>
</tr>
<tr>
<td>Noise in audio output.</td>
<td>Poor contact in connections of power filter and audio by-pass-condensers (bottom shelf).</td>
<td>Loosened soldering to condenser connections. Resolder.</td>
</tr>
<tr>
<td>Het. Freq. Meter calibration does not agree with calibrator.</td>
<td>Multivibrator out of control.</td>
<td>All calibrator adjustments have been turned to end of range. Reset according to instructions.</td>
</tr>
<tr>
<td>Unsteady beat tones; wobbly reading of interpolation meter.</td>
<td>Multivibrator out of control.</td>
<td>Beat not according to instructions.</td>
</tr>
<tr>
<td>Erratic operation of interpolator. Rends S A K IF IF DENONZLZ switch is pressed and released after switching instrument to ON.</td>
<td>Improper plate supply voltage to interpolator shelf.</td>
<td>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 definite switch is pressed and released.</td>
</tr>
<tr>
<td>Erratic interpolator operation.</td>
<td>Improper bias.</td>
<td>Leads from power plus P-301 to lower left corner of panel, and bring against R-178, on front lower side of interpolator shelf, grounding R-178.</td>
</tr>
</tbody>
</table>
### TABLE II (Continued)

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

<table>
<thead>
<tr>
<th>Symbol Code</th>
<th>Function</th>
<th>Description</th>
<th>Navy Type Number</th>
<th>Navy Dwg or Spec Number and Style</th>
<th>MFR's Dwg or Part Number</th>
<th>Special Tolerance</th>
<th>General Radio</th>
<th>Approximate</th>
<th>Location (See P. 55)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HARDWARE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-101</td>
<td>Handle</td>
<td>Pearl handle</td>
<td>1</td>
<td>1-134-140A</td>
<td>P-400-304</td>
<td>+C closer</td>
<td>S-1R upper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-102</td>
<td>Fuse pans, Small</td>
<td>Pearl fuse pan, upper corners</td>
<td>7</td>
<td>7-1W-60</td>
<td>P-400-305</td>
<td>+E closer</td>
<td>S-2R upper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-103</td>
<td>Fuse pans, Large</td>
<td>Pearl fuse pan, lower corners</td>
<td>7</td>
<td>7-1W-80</td>
<td>P-400-308</td>
<td>+E closer</td>
<td>S-2R upper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-104</td>
<td>Stop Switch</td>
<td>Inside, main frame, Lt rev</td>
<td>1</td>
<td>1-135-140A</td>
<td>P-400-304</td>
<td>+C closer</td>
<td>S-1R upper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-105</td>
<td>Handle</td>
<td>Inside, main frame, Lt rev</td>
<td>1</td>
<td>1-135-140A</td>
<td>P-400-304</td>
<td>+C closer</td>
<td>S-1R upper</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>INDICATING DEVICES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-101</td>
<td>Cryo. Temp. Control Pilot Light</td>
<td>Bumper base, 0.8v</td>
<td>Same as L-101</td>
<td>1-153-252</td>
<td>2-L upper</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-102</td>
<td>Power Supply Pilot Light</td>
<td>Same as L-101</td>
<td>1</td>
<td>1-153-252</td>
<td>2-L upper</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J-102</td>
<td>Connection for Telephone Receivers</td>
<td>Connection to Interpolator Input</td>
<td>Same as L-101</td>
<td>-4000A</td>
<td>RE-58A-40 E</td>
<td>14</td>
<td>Inserted from Ground</td>
<td>L-101</td>
<td>S-C lower</td>
</tr>
<tr>
<td>J-103</td>
<td>Connection for Telephone Receivers</td>
<td>Connection to Interpolator Input</td>
<td>Same as L-101</td>
<td>-4000A</td>
<td>RE-58A-40 E</td>
<td>14</td>
<td>Inserted from Ground</td>
<td>L-101</td>
<td>S-C lower</td>
</tr>
<tr>
<td></td>
<td>JACKS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-101</td>
<td>H.F.M. Oscillator Coil</td>
<td>Special Radio Frequency Coil, low-base ceramic form, adj., was incorporated.</td>
<td>1</td>
<td>1</td>
<td>P-400-L-101</td>
<td>+F closer</td>
<td>S-C lower</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-102</td>
<td>H.F.M. Oscillator Coil</td>
<td>Special Radio Frequency Coil, low-base ceramic form, adj., was incorporated.</td>
<td>1</td>
<td>1</td>
<td>P-400-L-101</td>
<td>+F closer</td>
<td>S-C lower</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-103</td>
<td>H.F.M. Oscillator Coil</td>
<td>Special Radio Frequency Coil, low-base ceramic form, adj., was incorporated.</td>
<td>1</td>
<td>1</td>
<td>P-400-L-101</td>
<td>+F closer</td>
<td>S-C lower</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-104</td>
<td>H.F.M. Oscillator Coil</td>
<td>Special Radio Frequency Coil, low-base ceramic form, adj., was incorporated.</td>
<td>1</td>
<td>1</td>
<td>P-400-L-101</td>
<td>+F closer</td>
<td>S-C lower</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-105</td>
<td>H.F.M. Oscillator Coil</td>
<td>Special Radio Frequency Coil, low-base ceramic form, adj., was incorporated.</td>
<td>1</td>
<td>1</td>
<td>P-400-L-101</td>
<td>+F closer</td>
<td>S-C lower</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-106</td>
<td>H.F.M. Oscillator Coil</td>
<td>Special Radio Frequency Coil, low-base ceramic form, adj., was incorporated.</td>
<td>1</td>
<td>1</td>
<td>P-400-L-101</td>
<td>+F closer</td>
<td>S-C lower</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-107</td>
<td>H.F.M. Oscillator Coil</td>
<td>Special Radio Frequency Coil, low-base ceramic form, adj., was incorporated.</td>
<td>1</td>
<td>1</td>
<td>P-400-L-101</td>
<td>+F closer</td>
<td>S-C lower</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-108</td>
<td>Power Supply Filter Seating Cover</td>
<td>Case; General Radio 802-805, Metalina, intermetal, with 0.010 inch gap, secured by an 800 turn No. 30 enamelled wire. Welding: 800 turn No. 30 enamelled wire.</td>
<td>1</td>
<td>1</td>
<td>465-49</td>
<td>+F closer</td>
<td>S-C lower</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Spares furnished, for quantities refer to Table IV.*
6.1 GENERAL STATEMENT

6.1.1 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 sides. 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 sides, 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 6.3) 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 CAPACITOR OF AUDIO-FREQUENCY AMPLIFIER

6.2.1 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.

6.2.2 To remove 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 AND THERMOSTAT

6.3.1 To obtain access to the crystal or the heaters of the temperature-control system, remove first the cover 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" on the bottom, mounted on the shelf). This exposes the aluminum-temperature control unit. The aluminum box is removed 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.

6.3.2 To remove the thermostat, S-107, first remove balsa box as in 6.3.1 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.

6.3.3 To remove crystal mounting, V-101, first remove the balsa and aluminum boxes, as in 6.3.1 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; HETERO-DYNE FREQUENCY METER OSCILLATOR CIRCUITS

6.4.1 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 also possible through left side frame.

6.4.2 For greater access, place instrument as directed in Paragraph 6.41 and remove power supply shelf. Remove eight screws, four along each side casting, which secure the middle of the equipment. 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.

6.4.3 If the heterodyne oscillator sub-assembly must be removed, proceed as in 6.44. 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-136 (on panel) to sub-assembly at C-183 (left). Disconnect coupling wire going through top shelf to C-139, left. Disconnect wire from C-183 arm.

6.4.4 Remove four mounting screws on under side of top shelf, two near V-110 and two below shield of V-347. 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

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

6.5.2 Remove the direct-reading dial, N-103, in accordance with the instructions in Section 6.6. Remove control knob, E-183.

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**SECTION 6. ACCESS**

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6.65 After removal of the dial plate, with both tubes, panel mounting screws of the 
slotted plate and collar of sprocket gear, loosen the setscrews and remove the collar of the sprocket gear from the shaft sleeve. 

6.66 Move the dial mechanism in reverse.

6.7 TO REMOVE RANGE SELECTOR HORN.

6.71 Remove five mounting screws that hold the horn assembly to the right side of the instrument face. 

6.72 Remove the horn assembly from the instrument face.

6.8 ACCESS TO POWER SWITCH, S-008.

6.81 Remove screws that secure the three-section shield control on the main top shelf. 

6.82 Remove screws that secure the shield on the power switch, S-008, to the top shelf. 

6.9 ACCESSIBLE TO SUB-ASSEMBLY.

6.91 Raise left-hand edge of tube shelf, to access to sub-assembly.

6.92 Remove tubes from tube-shelf sockets.

6.10 TO REMOVE DIAL, S-003.

6.101 Remove cover of dial mechanism.

6.102 Loosen two nuts on the dial shaft, at point under Y-113, to obtain further access to sub-assembly.

6.11 ELECTRICAL CONNECTIONS.

6.111 Connect the leads from the various components to the panel, as indicated on alignment diagram 6.34.

6.112 Connect the leads from the various components to the panel, as indicated on alignment diagram 6.34.

6.113 Connect the leads from the various components to the panel, as indicated on alignment diagram 6.34.

6.114 Connect the leads from the various components to the panel, as indicated on alignment diagram 6.34.

6.115 Connect the leads from the various components to the panel, as indicated on alignment diagram 6.34.

6.116 Connect the leads from the various components to the panel, as indicated on alignment diagram 6.34.

6.117 Connect the leads from the various components to the panel, as indicated on alignment diagram 6.34.

TABLE II (Continued)

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

Symbol Designation | Function | Navy Type No. | Navy Drg. or Spec. | MFRS Design 1 | Special Reference, Dating or Modification | General Radio/CEG or Part Number | Approximate Location (See P. 55)

CAPACITORS (Continued)

C-81 Supply Line U.H.F. Fiber Cap. | Output | 4084x10 | 10-LB
C-82 Supply Line U.H.F. Fiber Cap. | Output | 4084x10 | 10-LB
C-83 Supply Line U.H.F. Fiber Cap. | Input | 4084x10 | 10-LB
C-84 Supply Line U.H.F. Fiber Cap. | Input | 4084x10 | 10-LB
C-85 Power Supply Buffer Capacitor | Input | 4084x10 | 10-LB
C-86 Interpolator Filament R.F. by pass | Battery | 4084x10 | 10-LB
C-87 Interpolator Filament R.F. by pass | Battery | 4084x10 | 10-LB
C-88 Calibrator Filament R.F. by pass | Battery | 4084x10 | 10-LB
C-89 Calibrator Filament R.F. by pass | Battery | 4084x10 | 10-LB
C-90 Power Supply Buffer Capacitor | Battery | 4084x10 | 10-LB
C-91 A.F. Output Buffer Capacitor | Battery | 4084x10 | 10-LB
C-92 BER Surge Buffer Capacitor | with de-wetting. Oil filled; 0 sections | 4084x10 | 10-LB

MISCELLANEOUS ELECTRICAL PARTS

E-101 Anchor Terminal | Anchor Terminal | 4910 | 1740-00 | 10 No. 5 | Replace Eyelet and Washers
E-102 A.F. Input Connection | Connector lead | 4910 | 1740-00 | 10 No. 5 | Replace Eyelet and Washers
E-103 B | Connector Plug | 4910 | 1740-00 | 10 No. 5 | Replace Eyelet and Washers
E-104 C | Binding Post Adapter | 4910 | 1740-00 | 10 No. 5 | Replace Eyelet and Washers
E-105 A | A.F. Output Connection | Same as E-100-A | P-400-401 | 10 No. 5 | Replace Eyelet and Washers
E-106 B | Same as E-100-B | P-400-401 | 10 No. 5 | Replace Eyelet and Washers
E-107 C | Same as E-100-C | P-400-401 | 10 No. 5 | Replace Eyelet and Washers
E-108 A Calibrator Output Connection | Same as E-100-A | P-400-401 | 10 No. 5 | Replace Eyelet and Washers
E-109 B | Same as E-100-B | P-400-401 | 10 No. 5 | Replace Eyelet and Washers
E-110 C | Same as E-100-C | P-400-401 | 10 No. 5 | Replace Eyelet and Washers
E-111 A Calibrator Terminal | Cable Tensioning Strip | 10 No. 5 | Replace Eyelet and Washers
E-112 A Anchor Terminal | Same as E-18 | 3-B
E-113 B Anchor Terminal | Same as E-18 | 3-B
E-114 A Anchor Terminal | Same as E-18 | 3-B
E-115 B Anchor Terminal | Same as E-18 | 3-B
E-116 A Anchor Terminal | Same as E-18 | 3-B
E-117 B Anchor Terminal | Same as E-18 | 3-B
E-118 A Anchor Terminal | Same as E-18 | 3-B
E-119 B Anchor Terminal | Same as E-18 | 3-B
E-120 A Anchor Terminal | Insulating Washers, Skirted | 3-B
E-121 B Anchor Terminal | Insulating Washers, Skirted | 3-B
E-122 A Anchor Terminal | Insulating Washers, Skirted | 3-B
E-123 B Anchor Terminal | Insulating Washers, Skirted | 3-B
E-124 A Anchor Terminal | Insulating Washers, Skirted | 3-B
E-125 B Anchor Terminal | Insulating Washers, Skirted | 3-B

*Spaces furnished for quantities refer to Table IV.

§P.B. = Spare Parts Box No.
### TABLE II (Continued)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Design'n</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-150</td>
<td>R.F. Output Blocking Capacitor</td>
<td></td>
</tr>
<tr>
<td>C-151</td>
<td>H.F.M. Coupling Tube Plate By-pass</td>
<td></td>
</tr>
<tr>
<td>C-152</td>
<td>H.F.M. Switching Compensator</td>
<td></td>
</tr>
<tr>
<td>C-153</td>
<td>Interpolator Amplifier Grid Capacitor</td>
<td></td>
</tr>
<tr>
<td>C-154</td>
<td>Interpolator Metering Capacitor</td>
<td></td>
</tr>
<tr>
<td>C-155</td>
<td>Interpolator Switching Capacitor</td>
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<tr>
<td>C-156</td>
<td>Interpolator Metering Capacitor</td>
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<tr>
<td>C-157</td>
<td>Power Supply Filter Capacitor</td>
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<tr>
<td>C-158</td>
<td>Power Supply Filter Capacitor</td>
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<tr>
<td>C-159</td>
<td>Power Supply Filter Capacitor</td>
<td></td>
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<tr>
<td>C-160</td>
<td>Power Supply H. F. Transient Suppr.</td>
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</tr>
<tr>
<td>C-161</td>
<td>Power Supply Buffer Capacitor</td>
<td></td>
</tr>
<tr>
<td>C-162</td>
<td>Power Supply Buffer Capacitor</td>
<td></td>
</tr>
<tr>
<td>C-163</td>
<td>Interpolator Scale-Test Capacitor</td>
<td></td>
</tr>
<tr>
<td>C-164</td>
<td>Detector, A.F. Amplifier Plate By-pass</td>
<td></td>
</tr>
<tr>
<td>C-165</td>
<td>Not used</td>
<td></td>
</tr>
<tr>
<td>C-166</td>
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<tr>
<td>C-171</td>
<td>Not used</td>
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</tr>
<tr>
<td>C-172</td>
<td>Interpolator Suppressor, Plate</td>
<td></td>
</tr>
<tr>
<td>C-173</td>
<td>Interpolator Suppressor, Bias</td>
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</tr>
<tr>
<td>C-174</td>
<td>Interpolator Suppressor, Cathode</td>
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</tr>
<tr>
<td>C-175</td>
<td>H.F.M. Switching Compensator</td>
<td></td>
</tr>
<tr>
<td>C-176</td>
<td>Local Tel. U.H.F. Filter Capacitor</td>
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<tr>
<td>C-177</td>
<td>Local Tel. U.H.F. Filter Capacitor</td>
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<tr>
<td>C-178</td>
<td>Remote Tel. U.H.F. Filter Capacitor</td>
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<tr>
<td>C-179</td>
<td>Remote Tel. U.H.F. Filter Capacitor</td>
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<tr>
<td>C-180</td>
<td>Remote Tel. U.H.F. Filter Capacitor</td>
<td></td>
</tr>
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</table>

*Spares furnished, for quantities refer to Table IV.*

#### TABLE I

<table>
<thead>
<tr>
<th>Name</th>
<th>Symbol Group Designation</th>
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</thead>
<tbody>
<tr>
<td>Combined Crystal Controlled Calibrator and Heterodyne Frequency Meter</td>
<td>101-109</td>
</tr>
</tbody>
</table>

#### TABLE II

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

**LOCATION CODE**

- 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 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
### Table II

**Parts List by Symbol Designation for Model LR-1**

**Combined Crystal Controlled Calibrator and Heterodyne Frequency Meter Equipment**

<table>
<thead>
<tr>
<th>Symbol Design</th>
<th>Function</th>
<th>Description</th>
<th>Navy Type Number</th>
<th>Navy DWG or SPEC. Number and Style</th>
<th>MFRS Design</th>
<th>Special Tolerance, Rating or Modification</th>
<th>General Radio DWG. or Part Number</th>
<th>Approximate Location (See P. 30)</th>
</tr>
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<tbody>
<tr>
<td><strong>CAPACITORS</strong></td>
<td><strong>(Continued)</strong></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>C-127</td>
<td>First A.F. Stage High Freq. Suppressor</td>
<td>Mica; 0.000010 to 0.000015, 5000 to 15000 DC dkG</td>
<td>-84810-10</td>
<td>RE-80-401A</td>
<td>C</td>
<td>1-13083</td>
<td>Complete Assembly General Radio</td>
<td>1CA-2</td>
</tr>
<tr>
<td>C-128</td>
<td>Second A.F. Stage Cathode By-pass</td>
<td>Same as C-128</td>
<td>-84815</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4-6FR</td>
</tr>
<tr>
<td>C-129</td>
<td>Second A.F. Stage Screen By-pass</td>
<td>Same as C-129</td>
<td>-84816-10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4-6FR</td>
</tr>
<tr>
<td>C-130</td>
<td>Second A.F. Stage Plate By-pass</td>
<td>Same as C-129</td>
<td>-84817-10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4-6FR</td>
</tr>
<tr>
<td>C-131</td>
<td>Second A.F. Stage Plate Coupling</td>
<td>Same as C-129</td>
<td>-84818-10</td>
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<td>4-6FR</td>
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<tr>
<td>C-132</td>
<td>Third A.F. Stage By-pass</td>
<td>Same as C-129</td>
<td>-84819-10</td>
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<td></td>
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<td></td>
<td>4-6FR</td>
</tr>
<tr>
<td>C-133</td>
<td>Not used</td>
<td>H.F.M. Grid Capacitor</td>
<td>Mica; 0.000010 to 0.000015, 5000 to 15000 DC dkG</td>
<td>-84815-10</td>
<td>RE-80-401A</td>
<td>C</td>
<td>1-13083</td>
<td>Complete Assembly General Radio</td>
</tr>
<tr>
<td>C-134</td>
<td>Automatic Detector Coupling</td>
<td>Mica; 0.000010 to 0.000015, 5000 to 15000 DC dkG</td>
<td>-84815-10</td>
<td>RE-80-401A</td>
<td>C</td>
<td>1-13083</td>
<td>Complete Assembly General Radio</td>
<td>1CA-2</td>
</tr>
<tr>
<td>C-135</td>
<td>Automatic Detector Coupling</td>
<td>Mica; 0.000010 to 0.000015, 5000 to 15000 DC dkG</td>
<td>-84816-10</td>
<td>RE-80-401A</td>
<td>C</td>
<td>1-13083</td>
<td>Complete Assembly General Radio</td>
<td>1CA-2</td>
</tr>
<tr>
<td>C-136</td>
<td>Automatic Detector Coupling</td>
<td>Mica; 0.000010 to 0.000015, 5000 to 15000 DC dkG</td>
<td>-84817-10</td>
<td>RE-80-401A</td>
<td>C</td>
<td>1-13083</td>
<td>Complete Assembly General Radio</td>
<td>1CA-2</td>
</tr>
<tr>
<td>C-137</td>
<td>Automatic Detector Coupling</td>
<td>Mica; 0.000010 to 0.000015, 5000 to 15000 DC dkG</td>
<td>-84818-10</td>
<td>RE-80-401A</td>
<td>C</td>
<td>1-13083</td>
<td>Complete Assembly General Radio</td>
<td>1CA-2</td>
</tr>
<tr>
<td>C-138</td>
<td>Automatic Detector Coupling</td>
<td>Mica; 0.000010 to 0.000015, 5000 to 15000 DC dkG</td>
<td>-84819-10</td>
<td>RE-80-401A</td>
<td>C</td>
<td>1-13083</td>
<td>Complete Assembly General Radio</td>
<td>1CA-2</td>
</tr>
<tr>
<td>C-139</td>
<td>Automatic Detector Coupling</td>
<td>Mica; 0.000010 to 0.000015, 5000 to 15000 DC dkG</td>
<td>-84815-10</td>
<td>RE-80-401A</td>
<td>C</td>
<td>1-13083</td>
<td>Complete Assembly General Radio</td>
<td>1CA-2</td>
</tr>
<tr>
<td>C-140</td>
<td>Automatic Detector Coupling</td>
<td>Mica; 0.000010 to 0.000015, 5000 to 15000 DC dkG</td>
<td>-84816-10</td>
<td>RE-80-401A</td>
<td>C</td>
<td>1-13083</td>
<td>Complete Assembly General Radio</td>
<td>1CA-2</td>
</tr>
<tr>
<td>C-141</td>
<td>Automatic Detector Coupling</td>
<td>Mica; 0.000010 to 0.000015, 5000 to 15000 DC dkG</td>
<td>-84817-10</td>
<td>RE-80-401A</td>
<td>C</td>
<td>1-13083</td>
<td>Complete Assembly General Radio</td>
<td>1CA-2</td>
</tr>
<tr>
<td>C-142</td>
<td>Automatic Detector Coupling</td>
<td>Mica; 0.000010 to 0.000015, 5000 to 15000 DC dkG</td>
<td>-84818-10</td>
<td>RE-80-401A</td>
<td>C</td>
<td>1-13083</td>
<td>Complete Assembly General Radio</td>
<td>1CA-2</td>
</tr>
<tr>
<td>C-143</td>
<td>Automatic Detector Coupling</td>
<td>Mica; 0.000010 to 0.000015, 5000 to 15000 DC dkG</td>
<td>-84819-10</td>
<td>RE-80-401A</td>
<td>C</td>
<td>1-13083</td>
<td>Complete Assembly General Radio</td>
<td>1CA-2</td>
</tr>
<tr>
<td>C-144</td>
<td>Automatic Detector Coupling</td>
<td>Mica; 0.000010 to 0.000015, 5000 to 15000 DC dkG</td>
<td>-84815-10</td>
<td>RE-80-401A</td>
<td>C</td>
<td>1-13083</td>
<td>Complete Assembly General Radio</td>
<td>1CA-2</td>
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<tr>
<td>C-145</td>
<td>Automatic Detector Coupling</td>
<td>Mica; 0.000010 to 0.000015, 5000 to 15000 DC dkG</td>
<td>-84816-10</td>
<td>RE-80-401A</td>
<td>C</td>
<td>1-13083</td>
<td>Complete Assembly General Radio</td>
<td>1CA-2</td>
</tr>
<tr>
<td>C-146</td>
<td>Automatic Detector Coupling</td>
<td>Mica; 0.000010 to 0.000015, 5000 to 15000 DC dkG</td>
<td>-84817-10</td>
<td>RE-80-401A</td>
<td>C</td>
<td>1-13083</td>
<td>Complete Assembly General Radio</td>
<td>1CA-2</td>
</tr>
<tr>
<td>C-147</td>
<td>Automatic Detector Coupling</td>
<td>Mica; 0.000010 to 0.000015, 5000 to 15000 DC dkG</td>
<td>-84818-10</td>
<td>RE-80-401A</td>
<td>C</td>
<td>1-13083</td>
<td>Complete Assembly General Radio</td>
<td>1CA-2</td>
</tr>
<tr>
<td>C-148</td>
<td>Automatic Detector Coupling</td>
<td>Mica; 0.000010 to 0.000015, 5000 to 15000 DC dkG</td>
<td>-84819-10</td>
<td>RE-80-401A</td>
<td>C</td>
<td>1-13083</td>
<td>Complete Assembly General Radio</td>
<td>1CA-2</td>
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<tr>
<td>C-149</td>
<td>Automatic Detector Coupling</td>
<td>Mica; 0.000010 to 0.000015, 5000 to 15000 DC dkG</td>
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<td>RE-80-401A</td>
<td>C</td>
<td>1-13083</td>
<td>Complete Assembly General Radio</td>
<td>1CA-2</td>
</tr>
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</table>

*Spaces furnished, for quantities refer to Table IV.*
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Desig'n</th>
<th>Function</th>
<th>MFR's</th>
<th>Approximate Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-101</td>
<td>Thermoshrk Spur Filter</td>
<td>MFR: 0.0024 μf ±10%, 500 V DC wkg.</td>
<td>4</td>
<td>4-13005</td>
</tr>
<tr>
<td>C-102</td>
<td>Crystal Osc. Frequency Adjust</td>
<td>Air: Var. 39 to 40.5 μf, 300 V DC wkg.</td>
<td>1</td>
<td>4-13035</td>
</tr>
<tr>
<td>C-103</td>
<td>Not used</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>C-104</td>
<td>Crystal Osc. Feed Tnunig</td>
<td>Air: Var. 300 μf ±10%, 500 V DC wkg.</td>
<td>1</td>
<td>4-13035</td>
</tr>
<tr>
<td>C-105</td>
<td>Crystal Osc. Grid Capacitor</td>
<td>MFR: 0.005 μf ±10%, 500 V DC wkg.</td>
<td>1</td>
<td>4-13035</td>
</tr>
<tr>
<td>C-106</td>
<td>Crystal Osc. Plate Blocking Capacitor</td>
<td>Same as C-111</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-107</td>
<td>Crystal Osc. Plate R.F. By-pass Cap.</td>
<td>Same as C-112</td>
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</tr>
<tr>
<td>C-108</td>
<td>Crystal Osc. Screen R.F. By-pass Cap.</td>
<td>Same as C-112</td>
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<td></td>
</tr>
<tr>
<td>C-109</td>
<td>Crystal Osc. Grid Amplifier Grid Capacitor</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-110</td>
<td>Crystal Osc. Plate By-pass</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-111</td>
<td>Multivibrator Freq. Setting Capacitor</td>
<td>MFR: 0.0005 μf ±10%, 500 V DC wkg.</td>
<td>1</td>
<td>4-14905</td>
</tr>
<tr>
<td>C-112</td>
<td>Multivibrator Freq. Setting Capacitor</td>
<td>MFR: 0.0005 μf ±10%, 500 V DC wkg.</td>
<td>1</td>
<td>4-14905</td>
</tr>
<tr>
<td>C-113</td>
<td>Multivibrator Freq. Setting Capacitor</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-114</td>
<td>Multivibrator Freq. Setting Capacitor</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-115</td>
<td>Multivibrator Freq. Setting Capacitor</td>
<td>Same as C-112</td>
<td></td>
<td></td>
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<tr>
<td>C-116</td>
<td>M.V. Homoc. Ampl. Grid Capacitor</td>
<td>MFR: 0.0005 μf ±10%, 500 V DC wkg.</td>
<td>1</td>
<td>4-14905</td>
</tr>
<tr>
<td>C-117</td>
<td>M.V. Homoc. Ampl. Plate By-pass</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-118</td>
<td>M.V. High Ampl. Cathode By-pass</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-119</td>
<td>Calibrator Plate Supply By-pass</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-120</td>
<td>Calibrator R.F. Output Coupling Cap.</td>
<td>Paper: 1 μf 4-10,000 V DC wkg.</td>
<td>3</td>
<td>EBC-6209</td>
</tr>
<tr>
<td>C-121</td>
<td>Detector R.F. Grid Coupling Cap.</td>
<td>Paper: 1 μf 4-10,000 V DC wkg.</td>
<td>3</td>
<td>EBC-6209</td>
</tr>
<tr>
<td>C-122</td>
<td>Detector A.F. Coupling Grid</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-123</td>
<td>Impedance Transformer Plate By-pass</td>
<td>Paper: 1 μf 4-10,000 V DC wkg.</td>
<td>3</td>
<td>EBC-6209</td>
</tr>
<tr>
<td>C-124</td>
<td>First A.F. Stage Plate By-pass Cap.</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-125</td>
<td>Imped. Transformer Grid Capacitor</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-126</td>
<td>Second A.F. Stage Grid Coupling</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Spares furnished, for quantities refer to Table IV.*

### TABLE II (Continued)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Desig'n</th>
<th>Function</th>
<th>MFR's</th>
<th>Approximate Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-127</td>
<td>First A.F. Stage High Freq. Suppressor</td>
<td>MFR: 0.0006 μf ±10%, 500 V DC wkg.</td>
<td>4</td>
<td>4-13035</td>
</tr>
<tr>
<td>C-128</td>
<td>Second A.F. Stage Cathode By-pass</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-129</td>
<td>Second A.F. Stage Screen By-pass</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-130</td>
<td>Second A.F. Stage Plate By-pass Cap.</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-131</td>
<td>Second Third A.F. Stages Coupling Cap.</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-132</td>
<td>Third A.F. Stage Cathode By-pass</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-133</td>
<td>Not used</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-134</td>
<td>H.F.M. Osc. Grid Capacitor</td>
<td>MFR: 0.0005 μf ±10%, 500 V DC wkg.</td>
<td>1</td>
<td>4-14905</td>
</tr>
<tr>
<td>C-135</td>
<td>H.F.M. Osc. Tuning Cap. Front Section</td>
<td>Air: Var. 187 to 200 μf wkg.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-136</td>
<td>H.F.M. Tuning Cap. Rear Section</td>
<td>Air: Var. 193 to 201 μf wkg.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-137</td>
<td>H.F.M. Tuning Cap. Compensator</td>
<td>Air: Var. 3 to 30 μf wkg.</td>
<td>3</td>
<td>1-APC-2C</td>
</tr>
<tr>
<td>C-138</td>
<td>H.F.M. Tuning Cap. Compensator</td>
<td>Compens. 30 μf wkg.</td>
<td>3</td>
<td>1-APC-2C</td>
</tr>
<tr>
<td>C-139</td>
<td>H.F.M. Tuning Cap. Temp. Comp. Rear</td>
<td>Compens. 30 μf wkg.</td>
<td>3</td>
<td>1-APC-2C</td>
</tr>
<tr>
<td>C-140</td>
<td>H.F.M. Fundamental Output Coupling</td>
<td>Air: Var. 3 to 8 μf wkg.</td>
<td>3</td>
<td>1-APC-2C</td>
</tr>
<tr>
<td>C-141</td>
<td>Automatic Detector Coupling</td>
<td>MFR: 0.0002 μf ±10%, 500 V DC wkg.</td>
<td>1</td>
<td>4-13035</td>
</tr>
<tr>
<td>C-142</td>
<td>Automatic Detector Coupling</td>
<td>MFR: 0.0002 μf ±10%, 500 V DC wkg.</td>
<td>1</td>
<td>4-13035</td>
</tr>
<tr>
<td>C-143</td>
<td>Automatic Detector Coupling</td>
<td>MFR: 0.0002 μf ±10%, 500 V DC wkg.</td>
<td>1</td>
<td>4-13035</td>
</tr>
<tr>
<td>C-144</td>
<td>Automatic Detector Coupling</td>
<td>MFR: 0.0002 μf ±10%, 500 V DC wkg.</td>
<td>1</td>
<td>4-13035</td>
</tr>
<tr>
<td>C-145</td>
<td>Automatic Detector Coupling</td>
<td>MFR: 0.0002 μf ±10%, 500 V DC wkg.</td>
<td>1</td>
<td>4-13035</td>
</tr>
<tr>
<td>C-146</td>
<td>R.F. Input Blocking Capacitor</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-147</td>
<td>R.F. Input Amplitude Grid Capacitor</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-148</td>
<td>R.F. Input Amplifier Plate By-pass</td>
<td>Same as C-112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-149</td>
<td>R.F. Input Amplifier Plate By-pass</td>
<td>Same as C-112</td>
<td></td>
<td></td>
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</tbody>
</table>

*Spares furnished, for quantities refer to Table IV.*
<table>
<thead>
<tr>
<th>Symbol Design</th>
<th>Function</th>
<th>Description</th>
<th>Navy Type Number</th>
<th>Navy DWG. or Spec. Number and Style</th>
<th>MPD's Design</th>
<th>Special Tolerance, Rating or Modification</th>
<th>General Radio DWG. or Part Number</th>
<th>Location (See P. 50)</th>
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<tbody>
<tr>
<td>*C-150</td>
<td>R.F. Output Blocking Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1410</td>
<td>5-R upper</td>
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<tr>
<td>*C-151</td>
<td>H.F.M. Coupling Tube By-pass</td>
<td>Same as C-149</td>
<td>-48104</td>
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<td></td>
<td></td>
<td>4-B</td>
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<td>*C-152</td>
<td>H.F.M. Switching Compensator</td>
<td>Same as C-180</td>
<td>-4879HA</td>
<td></td>
<td></td>
<td></td>
<td>5-F</td>
<td></td>
</tr>
<tr>
<td>*C-153</td>
<td>Interpolator Amplifier Grid Capacitor</td>
<td>Mica; 0.00146 uF = 10% 400 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
<td></td>
</tr>
<tr>
<td>*C-154</td>
<td>Interpolator Metering Capacitor</td>
<td>Mica; 0.0001 uF = 10% 600 v DC wkg.</td>
<td>-4803FA</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1410 LT-2</td>
<td></td>
</tr>
<tr>
<td>*C-155</td>
<td>Interpolator Switching Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
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</tr>
<tr>
<td>*C-156</td>
<td>Interpolator Metering Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
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</tr>
<tr>
<td>*C-157</td>
<td>Interpolator Switching Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
<td></td>
</tr>
<tr>
<td>*C-158</td>
<td>Interpolator Metering Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
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</tr>
<tr>
<td>*C-159</td>
<td>Interpolator Switching Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
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</tr>
<tr>
<td>*C-160</td>
<td>Interpolator Metering Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
<td></td>
</tr>
<tr>
<td>*C-161</td>
<td>Interpolator Switching Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
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</tr>
<tr>
<td>*C-162</td>
<td>Interpolator Metering Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
<td></td>
</tr>
<tr>
<td>*C-163</td>
<td>Interpolator Switching Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
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</tr>
<tr>
<td>*C-164</td>
<td>Interpolator Metering Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
<td></td>
</tr>
<tr>
<td>*C-165</td>
<td>Interpolator Switching Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
<td></td>
</tr>
<tr>
<td>*C-166</td>
<td>Interpolator Metering Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
<td></td>
</tr>
<tr>
<td>*C-167</td>
<td>Interpolator Switching Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
<td></td>
</tr>
<tr>
<td>*C-168</td>
<td>Interpolator Metering Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
<td></td>
</tr>
<tr>
<td>*C-169</td>
<td>Interpolator Switching Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
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</tr>
<tr>
<td>*C-170</td>
<td>Interpolator Metering Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
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</tr>
<tr>
<td>*C-171</td>
<td>Interpolator Switching Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
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</tr>
<tr>
<td>*C-172</td>
<td>Interpolator Metering Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
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</tr>
<tr>
<td>*C-173</td>
<td>Interpolator Switching Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
<td></td>
</tr>
<tr>
<td>*C-174</td>
<td>Interpolator Suppressor, Plate</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
<td></td>
</tr>
<tr>
<td>*C-175</td>
<td>Interpolator Suppressor, Cathode</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
<td></td>
</tr>
<tr>
<td>*C-176</td>
<td>Power Supply Filter Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
<td></td>
</tr>
<tr>
<td>*C-177</td>
<td>Power Supply Filter Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
<td></td>
</tr>
<tr>
<td>*C-178</td>
<td>Power Supply Filter Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
<td></td>
</tr>
<tr>
<td>*C-179</td>
<td>Power Supply Filter Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
<td></td>
</tr>
<tr>
<td>*C-180</td>
<td>Power Supply Filter Capacitor</td>
<td>Mica; 0.00001 uF = 10% 600 v DC wkg.</td>
<td>-4811F.10</td>
<td>RE-48A-291A C</td>
<td>2</td>
<td>or 19</td>
<td>1445 LT-2</td>
<td></td>
</tr>
</tbody>
</table>

* Spares furnished; for quantities refer to Table IV.
GENERAL RADIO COMPANY

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 Heterolyme 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-109

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-138, 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-100, 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-104, AND COIL ASSEMBLY

6.71 Disconnect the 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, S-102, to take the tension off the spider. Mask can then be drawn forward out of the coil. If necessary, move spider.

6.73 Remove knob, E-112, of RANGE SELECTOR switch, S-104.

6.74 Loosen two set-screws in collar of sprocket on shaft of S-104.

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-108, and switch, S-104.

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-113.

6.93 Remove five mounting screws in the tube shelf.

6.94 Remove tube 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 E-161, at point under V-113, to obtain further access to sub-assembly.

---

**Table II (Continued)**

**PARTS LIST BY SYMBOL DESIGNATION FOR MODEL 1154 COMBINED CRYSTAL-CONTROLLED CALIBRATOR AND HETEROLOGIC FREQUENCY DETECTOR**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Part No.</th>
<th>Remarks</th>
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</thead>
<tbody>
<tr>
<td>C-33 A</td>
<td>Capacitor</td>
<td>6.5 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-34 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-36 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-44 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-49 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-50 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-51 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-52 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-53 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-54 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-55 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
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<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
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<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
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<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-59 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-60 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
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<tr>
<td>C-61 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-62 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-63 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-64 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-65 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-66 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-67 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-68 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-69 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-70 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-71 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-72 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-73 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-74 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-75 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-76 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-77 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-78 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-79 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-80 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-81 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-82 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-83 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-84 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-85 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-86 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-87 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-88 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-89 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-90 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-91 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-92 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-93 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-94 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-95 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-96 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-97 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-98 A</td>
<td>Capacitor</td>
<td>10 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
<tr>
<td>C-99 A</td>
<td>Capacitor</td>
<td>6.8 MFD</td>
<td>1-30 200 V dip.</td>
</tr>
</tbody>
</table>

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*Fig. 1-Tube Shield Enclosure, 1154, as supersedes Fig. 4, 1153. The parts enclosed by dotted line are optional. The parts enclosed by heavy dotted line are for use in 1154 only.*
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 slides 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 backheads 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 6.5) 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 CIRCUIT 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 remove 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 THERMOSTAT

6.31 To obtain access to the crystal or the heaters of the temperature-control system, remove the top cover of the temperature box exposing the thermometer, M-104. Slide a piece of free 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 released 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 mounting, 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 balsa 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-133: HETEROODYNE 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 also possible through left side frame.

6.42 For greater access, place instrument as directed in Paragraph 6.41 and remove power supply shelf. Remove eight screws, four along each side casting, which secure the middle shelf in position. Slide the middle shelf out of instrument position; then fasten the shelf securely with the eight screws provided.

6.5 ACCESS TO CRYSTAL MOUNTING: HEATERS OF TEMPERATURE CONTROL, REMOVAL OF CRYSTAL THERMOSTAT

6.51 The heterodyne oscillator sub-assembly must be removed, proceed as in 6.41. 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-135 (on panel) to sub-assembly at C-163 (left). Disconnect coupling wire going through top shelf at C-139, left. Disconnect wire from R-138 arm.

6.52 Remove four mounting screws on under side of top shelf, two near V-110 and two below back shelf of V-114. 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-133

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-163.
Table II (Continued)  Scale in MHz  Symbol  Indicating Defects  Number and Size  Indicating Defects

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Discussion</th>
<th>INDICATING DEFECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-100</td>
<td>Shorted between plate and grid</td>
<td>R-147 defective; resistance increased from normal of 0.1 meg. to nearly one megohm.</td>
<td></td>
</tr>
</tbody>
</table>

Table III  Connection for Thévenin Resistor Connection to Interpolating Input

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Discussion</th>
<th>INDICATING DEFECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-100</td>
<td>High-fid. Power Supply for High-fid. Power Supply for High-fid. Power Supply for</td>
<td>R-147 defective; resistance increased from normal of 0.1 meg. to nearly one megohm.</td>
<td></td>
</tr>
</tbody>
</table>

Table IV  Connection for Thévenin Resistor Connection to Interpolating Input

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Discussion</th>
<th>INDICATING DEFECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-100</td>
<td>Shorted between plate and grid</td>
<td>R-147 defective; resistance increased from normal of 0.1 meg. to nearly one megohm.</td>
<td></td>
</tr>
</tbody>
</table>

End of Document
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Navy Type</th>
<th>MFR's Desig'n</th>
<th>Navy DWG. or SPEC.</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>L-108</em></td>
<td>Power Supply Filter Choke</td>
<td>Same as L-109</td>
<td>485-425</td>
</tr>
<tr>
<td><em>L-111</em></td>
<td>Power Supply Filter Choke</td>
<td>Same as L-112</td>
<td>P-400-M101</td>
</tr>
<tr>
<td><em>L-112</em></td>
<td>Local Tel. F.H.F. Filter Choke</td>
<td>Same as L-112</td>
<td>P-400-M101</td>
</tr>
<tr>
<td><em>L-113</em></td>
<td>Local Tel. F.H.F. Filter Choke</td>
<td>Same as L-112</td>
<td>P-400-M101</td>
</tr>
<tr>
<td><em>L-114</em></td>
<td>Remote T.V. U.H.F. Filter Choke</td>
<td>Same as L-112</td>
<td>P-400-M102</td>
</tr>
<tr>
<td><em>L-115</em></td>
<td>Remote T.V. U.H.F. Filter Choke</td>
<td>Same as L-112</td>
<td>P-400-M102</td>
</tr>
<tr>
<td><em>L-116</em></td>
<td>Supply Line U.H.F. Filter Choke</td>
<td>Same as L-112</td>
<td>P-400-M103</td>
</tr>
<tr>
<td><em>L-117</em></td>
<td>Supply Line D.H.F. Filter Choke</td>
<td>Same as L-112</td>
<td>P-400-M103</td>
</tr>
</tbody>
</table>

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 operations.

<table>
<thead>
<tr>
<th>SYMPTOM</th>
<th>CAUSE</th>
<th>REASON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraordinarily high hum in telephones, when checking against calibrator.</td>
<td>Open grid circuit.</td>
<td>Opencircuit in V-108 (output tube of calibrator).</td>
</tr>
<tr>
<td>Steady audio note in phones, regular beats against calibrator heard in background.</td>
<td>Improper by-passing in audio amplifier.</td>
<td>Improper by-passing in audio amplifier.</td>
</tr>
<tr>
<td>No normal beat tones when checking against calibrator; steady very low frequency &quot;popping.&quot;</td>
<td>Shorted diode detector.</td>
<td>Bus leads, at front of switch of V-108, shorted together.</td>
</tr>
<tr>
<td>No audio output.</td>
<td>Volume control set at minimum.</td>
<td>Incorrect operation.</td>
</tr>
<tr>
<td>No audio output.</td>
<td>No audio output.</td>
<td>No audio output.</td>
</tr>
<tr>
<td>Low audio output.</td>
<td>Poor detection.</td>
<td>Faulty detector, V-106.</td>
</tr>
<tr>
<td>Noisy audio output when making zero beat settings.</td>
<td>External noise pick-up or faulty detector.</td>
<td>By replacing V-108, if noise continues with coupling leads disconnected.</td>
</tr>
<tr>
<td>Buzz in audio output. (Sounds like R. F. buzz from mercury rectifier.)</td>
<td>Sparking in buffer condensers.</td>
<td>If a fall in U-101, 102 or 108 is open, sparking may take place across gap. Condensers do not break down on voltage test.</td>
</tr>
<tr>
<td>Noise in audio output.</td>
<td>Poor contact in connections of power filter and audio bypass condensers (bottom shelf).</td>
<td>Loose soldering to condenser connections, Resistor.</td>
</tr>
<tr>
<td>Het, Freq. Meter calibration does not agree with calibrator.</td>
<td>Multivibrator out of control.</td>
<td>All calibrator adjustments have been turned to end of range. Reset according to instructions.</td>
</tr>
<tr>
<td>Unsteady beat tones; wobbly reading of interpolation meter.</td>
<td>Multivibrator out of control.</td>
<td>Beat adjusting instructions are incorrect.</td>
</tr>
</tbody>
</table>

**Erreur operateur of interpolator.** Reads OK if INTERCONNECT switch is pressed and released after switching instrument to ON.

**Erreur interpolator operation.**

Improper plate supply voltage to interpolator shelf.

Defective V-119; replace. Tube glow on first switching instrument ON, then goes out as tubes warm up (Normal) but fails to light up again unless diode switch is pressed and released.

Leads from power plus P-303 (lower left corner of panel) blend against R-178, on front lower side of interpolator shelf, grounding R-178.
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 calibrator. Remove V-114. Keep INTERPOLATOR SCALE SELECTor, S-104, in LOWER position. Turn R-175 back to zero (clockwise end), by screw driver adjust- ment on top of lower left-hand shelf. Meter M-101 will then read about one-tenth full scale. With a high resistance voltmeter, connected be- tween the clockwise end of R-175 (located at cen- ter of lower left-hand shelf) and the arm, adjust R-175 to obtain a reading of 3.0 volts. (If a volt- meter 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 ohm- meter measure the resistance included between the arm of R-175 and the clockwise end (ground). Then advance R-175 in the counterclockwise direc-
tion 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 ½ inch along winding.)

(c) Replace V-114 removed above.

(d) Set IFM RANGE SELECTor switch, S-102, to lowest frequency range. Set CALIBR-

ator switch, S-101, to 10-kc position. Throw DETECTOR INPUT switch, S-103, to MEAS-

URE position. Adjust the IFM FREQUENCY control, C-133-A, -B, carefully, half-way between two 10-kc calibrator harmonics. This setting can be made accurately by bringing the flatter head on the 3-kc note to a very slow waxing and waxing.

(c) Throw calibrator switch, S-101, to 80-kc.

(t) The audio output be heard and then be a single tone of 3 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 fol-

ows, after sliding instrument out of cabinet on

slips, attaching servicing cable and operating in RU X condition for ten minutes or more.

(a) FIRST ALIGN the LOWER scales as given in Section 3.2801 above.

(b) Remove V-114. Throw the INTERP-

LATOR SCALE SELECTor, S-104, to UP-

PER 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 Inter-
polator 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-101, 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 P-103, and the output sides of L-108 and L-110, for short-circuits or broken down capacitors. Also check C-106A, B for defects. If the trouble appears as a blow-out of F-101, and the fault is in the plate supply circuits, check for a short-
circuit in the tube heater circuits, removing all tubes, the POWER pilot light I-101, and F-102 (to open the heaters of the temperature-controlled 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-101. If the fuse F-105 is normal, then the trouble is likely an open circuit in L-108, 109 or 110.

5.62 The plate supply voltage which is regu-

lated by V-110, -110 and V-118 is taken from the junction of L-108, -109. If the total supply voltage is normal, and the rectifier tubes V-115, -116, -118 and 119 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-106, 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-115, -116 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 sur-
face or any in which the discharge goes out if the line voltage drops momentarily.
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 may 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-109, note that on applying the voltage between cathode and grid 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 switch S-104, the INTERPOLATOR SCALE SELECT Switch. Verify the operation of V-119, V-110, 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 Quick Test for INTERPOLATOR SCALE Adjustment

5.525 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. Turn HFM FREQUENCY control, C-105-A, B, rapidly. The Interpolator Meter, M-101, should read 8.5 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 8.5 kc on LOWER BLACK scale, while the frequency control is being turned rapidly.

5.526 Accurate Alignment of INTERPOLATOR SCALE

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

(a) Turn INTERPOLATOR SCALE SELECT Switch, S-104, to center (OFF) position. Check mechanical zero of Interpolator Meter, M-101. Reset, if
5.3 HETEROODYNE FREQUENCY METER

5.3.1 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 8.6 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-103, the difficulty is either in the switch, S-103, or in the coil associated with the defective range or ranges.

5.3.2 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.

5.3.3 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.

5.3.4 Check adjustments by setting RANGE SELECTOR switch, S-102, on Range 13; setting C-110 to 0 or 9200 divisions on scale of equal parts; see that dial and cover indexes are in alignment.

5.3.5 Check reading of the meter for a beat of, say, 13 and making certain that the right and left edges of mask opening are in alignment with the edges of the window opening in the dial cover. If the edges are not aligned, loosen the set screws in the sprocket until the edges are aligned. Set index with index line of direct-reading scale. Secure cover firmly by tightening clamps.

5.3.6 Check the alignment of the knob indicator on the RANG SELECTOR switch, S-102, with the engraving on the panel. If not in alignment, loosen set screws in knob, turn knob into alignment and tighten set screws.

5.4 DETECTOR AND A.F. AMPLIFIER

5.4.1 Detector

5.4.1.1 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.

5.4.2 Audio Amplifier

5.4.2.1 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 may, l ke 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.
5.22 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, L-101, not lighting at all or staying lit. 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 the thermometer reads 50°C ± 5°C, the control is functioning properly. The trouble is then a burned out HEAT signal lamp, L-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-108; check heater circuit for resistance or for continuity. A thermostat which fails to close the circuit when cold, or an open-circuit in the thermost at heater connections, is indicated.

5.224 If the thermometer, M-104, shows an abnormally high, reading, either a a faulty thermostat, S-107, which fails to open when hot, or a short-circuit across the thermostat connections is indicated, at S-109 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 in the CALIBRATOR itself — those circuits associated with V-103 and V-104, but such difficulty may possibly be contingent on subnormal value from the calibrator V-109.

5.232 If the crystal oscillator is normal (see 5.41) the input and output of the amplifier may be easily checked if a vacuum-tube voltmeter is available. Remove multivibrator tubes V-105, V-104. Throw CALIBRATOR switch, S-101, to 100-kc position. Set 0.5 kc. Normally, the multivibrator remains in contact with the control is functioning properly.

5.233 To check a 10-kc position, proceed as in 5.234 to the counterclockwise direction, to a new control range is obtained and check the 10-kc position, proceed as in 5.234, noting the position of R-111. Make full setting of R-111 in middle of this range.

5.235 To check the 10-kc position, proceed as in 5.234 to the counterclockwise 10-kc harmonics on heterodyne frequency meter dial. Throw CALIBRATOR switch, S-101, to 100-kc position. Make count of zero beats, as described in 5.235, which should give 1, 2, 3, 4. 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 check the 10-kc position, following 5.234, noting the position of R-111. Make full setting of R-111 in middle of this range.

5.236 If the output at the telephones for beats between the CALIBRATOR and the heterodyne-frequency meter is below normal, the difficulty may be due, among other
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 will always quickly disclose open-circuits, particularly those in series with capacitors or within capacitors. If the difficulty may be traceable to old or defective tubes, systematically replace the tube 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 38000 (VR-101) and 38004 (SS-101), 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 CRYSTAL OSC. meter, M-102, and from the control of the multivibrator. If the crystal oscillator fails to oscillate, M-102 will read 3.4 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
TABLE II (Continued)

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

<table>
<thead>
<tr>
<th>Symbol Design'</th>
<th>Function</th>
<th>Description</th>
<th>Navy Type Number</th>
<th>Navy DWG. or SPEC. Number and Style</th>
<th>MFR's Design'</th>
<th>Special Tolerances, Rating or Modification</th>
<th>General Radio DWG. or Part Number</th>
<th>Approximate Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-106</td>
<td>Power or Supply Transformer</td>
<td>Converter. General Radio 360-90 luminating, intercal. Primary: 312 turns. No. 34 stranded, tapped at 0, 90, 180, 312 turns. Secondary: No. 1, 18 turns 0.007 5009 rectangular wire. Secondary: No. 8, 14 turns, 4 number 16 stranded wire parallel. Control tap at 72 turns. Secondary: No. 8, 181 turns. No. 34 stranded wire; center tap 1405 turns. Discontinuities 0.001 inch copper coil be behind Primary and Secondary No. 1. Vacuum impregnated in glyptol.</td>
<td>1</td>
<td></td>
<td>502-429</td>
<td>4-LB</td>
<td></td>
<td></td>
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<tr>
<td>V-101</td>
<td>Crystal Oscillator</td>
<td>Triple Grid Detector, Amplifier.</td>
<td>(-458) RE-13A-0000</td>
<td>608</td>
<td>6-230</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V-102</td>
<td>Crystal Oscillator Amplifier</td>
<td>Same as V-101</td>
<td>(-387) RE-13A-0000</td>
<td>70</td>
<td>6-265</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V-104</td>
<td>Multivibrator (O)</td>
<td>Same as V-104</td>
<td>(-387) RE-13A-0000</td>
<td>70</td>
<td>6-265</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>V-105</td>
<td>Multivibrator (O)</td>
<td>Same as V-104</td>
<td>(-387) RE-13A-0000</td>
<td>70</td>
<td>6-265</td>
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<tr>
<td>V-106</td>
<td>Diode Detector and 1st Stage Audio Amplifier</td>
<td>Same as V-104</td>
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<td>V-108</td>
<td>1st Stage A.F. Amplifier</td>
<td>Same as V-104</td>
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<td>V-109</td>
<td>2nd Stage A.F. Amplifier</td>
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<td>70</td>
<td>6-265</td>
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<td></td>
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</tr>
<tr>
<td>V-111</td>
<td>H.F.M. Rat. Voltage Regulator</td>
<td>Voltage Regulator</td>
<td>(-387) RE-13A-0000</td>
<td>6587</td>
<td>1-14C</td>
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<tr>
<td>V-112</td>
<td>R.F. Input and filter</td>
<td>Same as V-104</td>
<td>(-387) RE-13A-0000</td>
<td>70</td>
<td>6-265</td>
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</tr>
<tr>
<td>V-113</td>
<td>Interplane Input Filter.</td>
<td>Same as V-104</td>
<td>(-387) RE-13A-0000</td>
<td>70</td>
<td>6-265</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>V-114</td>
<td>Interplane Reg. Meter.</td>
<td>Same as V-115</td>
<td>(-387) RE-13A-0000</td>
<td>884</td>
<td>7-6C</td>
<td></td>
<td></td>
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<tr>
<td>V-115</td>
<td>Interplane Reg. Meter.</td>
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<td>(-387) RE-13A-0000</td>
<td>884</td>
<td>7-6C</td>
<td></td>
<td></td>
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<tr>
<td>V-116</td>
<td>Interplane Plate Voltage Reg.</td>
<td>Same as V-111</td>
<td>(-387) RE-13A-0000</td>
<td>884</td>
<td>7-6C</td>
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<td></td>
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<tr>
<td>V-117</td>
<td>Interplane Plate Voltage Reg.</td>
<td>Same as V-111</td>
<td>(-387) RE-13A-0000</td>
<td>884</td>
<td>7-6C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V-118</td>
<td>Plate Supply Rectifier.</td>
<td>Full-Wave Mercury Vapor Rectifier</td>
<td>(-387) RE-13A-0000</td>
<td>884</td>
<td>7-6C</td>
<td></td>
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</tbody>
</table>

*Figures furnished; for quantities refer to Table IV.
to the "low" (ground) side of the source. On inserting the plug in the jack, J-100, 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 90kc position.
2. Turn HFM RANGE SELECTOR switch, S-102, to range 1, 100-222 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 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.

5. The audio-frequency output is obtained at either of the TEL jacks, J-101 or J-102, and at the NOTE telephone. 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 0.9 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 demonstrated 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, 4.44) can be obtained. Only partial operation by EXACT METHOD can be obtained. INTERPOLATOR readings are restricted to ranges outside of BLUE zones giving ranges of 0-4.5 kc, 5.5-10 kc, 0-9.9 kc and 11-15 kc for the respective scales. Interpolation by the use of the scale of equal parts (N-101, 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, 4.44) can be obtained. Somewhat over 50% coverage can be obtained by EXACT METHOD, 5.5 to 10 kc on either side of every 10 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-101, 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-101, N-104) may be used. (See Section 4.96.)

4.924 If the calibrator is faulty in all three positions, 10, 20 and 100 kc, no accurate operation is possible. Results may still be obtained by the QUICK METHOD (see Sections 4.41, 4.44) but only by relying upon the accuracy with which the heterodyne frequency meter keeps its calibration.
### TABLE III

PARTS LIST BY NAVY TYPE NUMBERS

<table>
<thead>
<tr>
<th>QUANTITY</th>
<th>SYMBOL</th>
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<tr>
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<td>M-102, 103</td>
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### General Radio Company

#### ELECTRICAL INDICATING INSTRUMENTS

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<th>QUANTITY</th>
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#### SWITCHES (CLASS 44)

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#### FUSES (CLASS 28)

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<tr>
<td>1</td>
<td>F-100</td>
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</tr>
</tbody>
</table>

#### General Radio Company

#### ADJUSTING CALIBRATOR

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 USING CALIBRATOR 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, 40 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.

#### General Radio Company

#### 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. Turn 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-105-A, -B, until no interference remains, or turn the RANGE SELECTOR switch, S-102, to another range.

#### 4.643 USING CALIBRATOR 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, 40 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.

#### General Radio Company

#### 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. Turn 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-105-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 to an equipment ground.
4.61 Crystal and Standard Frequency Comparisons

4.611 In this equipment the stability and accuracy of the crystal oscillators can be checked in terms of standard frequency transmissions, through the use of an external receiver. (Refer to Fig. 117, October 1, 1940.) Pick up the standard frequency transmission in the receiver, which is preferably of the oscillating type. Insert 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 concentratic jack, M-101, when not in use to provide shielding of circuits from noise and radio frequencies. The crystal frequency harmonics or for making adjustments to the crystal frequency to be measured, 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. It is preferably of the oscillating type. Introduce standards, 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 thus: Proceed as given in paragraph 4.2.5 above.

4.622 While the procedure of paragraph 4.621 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.

4.63 Checking and Adjusting Calibrator Against Standard Frequency Transmissions. Using Calibrator Output in External Circuits

4.631 The CALIBRATOR 100-ke output is obtained at the CAL OUT terminal, as follows:

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

---

TABLE III (Continued)

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Navy Type No.</th>
<th>All Symbol Designations Involved</th>
<th>Quantity</th>
<th>Navy Type No.</th>
<th>All Symbol Designations Involved</th>
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VACUUM TUBES (CLASS 80)

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<th>Quantity</th>
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<td>4</td>
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<td>5</td>
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<td>6</td>
<td>V-115, 116</td>
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THERMOMETERS, THERMOSTATS, CRYSTALS (CLASS 40)

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R-F INDUCTORS (CLASS 47)

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<td>L-118, 119</td>
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R F INDUCTORS (CLASS 47)

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<td>L-115, 116, 114, 113</td>
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TABLE III (Continued)

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<td>T-105</td>
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</tbody>
</table>

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NOTE:

GENERAL RADIO COMPANY

See lines 13x2 and 13x3, heavy sections, on MUL 112, chart, N-106.

(3) Proceed as given in paragraph 4.2.51 above, setting at one-third the estimated value of the frequency for zero beat in 4.521, (4) through (10).

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

4.523 Frequencies Between 45 and 60 Mc

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

(2) Select range 19 or 18 on HF RPM RANGE SELECTOR switch, N-106, as required for (1). See lines 1X3,4, heavy section, on MUL 112, chart, N-106.

(3) Proceed as given in paragraph 4.2.51 above, setting at one-third the estimated value of the frequency for zero beat in 4.521, (4) through (10).

(4) Multiply final readings by 2 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 19 or 18 on HF RPM RANGE SELECTOR switch, N-106, as required for (1). See line 1X3,4, heavy section, on MUL 112, chart, N-106.

(3) Proceed as given in paragraph 4.2.51 above, setting at one-quarter the estimated value of the frequency for zero beat in 4.521, (4) 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

STEP (5) Scale of HF RPM FREQUENCY DIAL (N-103) in use:

BLACK BLACK LOWER LOWER BLACK-LOWER

BLACK BLACK UPPER UPPE'L BLACK-UPPER

RED RED LOWER LOWER RED-LOWER

RED RED UPPER UPPE'l RED-UPPER

STEP (9) INTERPOLATOR SCALE SELECTOR Switch S-104 thrown to:

STEP (10) READ FOLLOWING INTERPOLATOR SCALE on Meter, M-101:
### TABLE III (Continued)

#### PARTS LIST BY NAVY TYPE NUMBERS

<p>| MODEL LR-1 COMBINED CRYSTAL CONTROLLED CALIBRATOR AND HETERODYNE FREQUENCY METER |
|------------------------------------------|-------------------|-------------------------------|</p>
<table>
<thead>
<tr>
<th>NAVY TYPE NO.</th>
<th>ALL SYMBOL DESIGNATIONS</th>
<th>NAVY TYPE NO.</th>
<th>ALL SYMBOL DESIGNATIONS</th>
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<tbody>
<tr>
<td>JACKS, PLUGS, AND RECEPTACLES (CLASS 49)</td>
<td>J-101, 102, 105</td>
<td>R-104</td>
<td>B-104, 105, 106</td>
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<td>69861A</td>
<td>J-101, 102, 105</td>
<td>R-104</td>
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<td>E-104A, 105A, 106A</td>
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<td>69863</td>
<td>E-104B, 105B, 106B</td>
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<td>X-106, 114, 115</td>
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<td>FILTERS (CLASS 45)</td>
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<td>INSULATORS (CLASS 61)</td>
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<td>W-101</td>
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<td>RESISTORS (CLASS 63)</td>
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<tr>
<td>69887-1E</td>
<td>R-187</td>
<td>3</td>
<td>69888</td>
</tr>
</tbody>
</table>

### 4.512 Frequencies from 15 to 30 Mc

#### (1) Take one-half the desired frequency.

#### (2) Select range 12 or 13 on HFM RANGE SELECTOR switch, S-104, as required for (1).

#### (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 60 Mc

#### (1) Take one-third the desired frequency.

#### (2) Select range 12 or 13 on HFM RANGE SELECTOR switch, S-104, as required for (1).

#### (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 60 to 90 Mc

#### (1) Take one-quarter the desired frequency.

#### (2) Select range 12 or 13 on HFM RANGE SELECTOR switch, S-104, as required for (1).

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

### 4.52 Measuring a Frequency by the Accurate Method

#### (1) Check heterodyne frequency meter against calibrator, as given in Section 4.5, at a setting near the estimated value of the frequency being measured.

#### (2) Take INTERPOLATOR SCALE SELECTOR switch, S-104, to LOWER position.

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

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

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

#### (6) Throw DETECTOR INPUT switch, S-105, to MEASURING position.

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

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

#### (9) If reading of INTERPOLATOR meter, M-101, falls in BLUE zone, follow instructions on the meter scale and change the calibrator frequency to 60 kc.

#### (10) 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 DEER-IZE button, S-105, should be pressed and then released. See paragraph 4.514(1).

#### (11) Advance the INTERPOLATOR SCALE-TEST control, C-161, in direction of arrow, until a change in reading of the interpolator meter M-101 takes place.

#### (12) 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.

#### (13) The value of the frequency being measured is given for the SCM 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.)

#### (14) Note the correspondence of colors, that is, 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; 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.

#### (15) 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.

#### (16) The accuracy of the result is limited by the same factors as those given under paragraph 4.511.
FREQUENCY DIFFERENCE found is above the frequency of the calibrator
SELECTOR switch, S-104, to LOWER or
frequency, S-103,
ACCPHATELY to this desired frequency.

Proceed as given in paragraph

Check heterodyne frequency meter circuit;

by 4

DESIRED FREQUENCY
by

(1). 0-1

Meter

(2). 0-1

FREQUENCY
(3)

R.

(4)

FREQUENCY

(5)

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MULTIPLIER chart, N-106.
See lines 12X2 and 18X2, heavy sections, on the HFM RANGE dial, N-103, to desired frequency. The desired frequency is then available at the R.F. OUTPUT terminal on panel.

2. Select range 13 on HFM RANGE SELECTOR switch, S-100, as required for (1). See line 13X4, heavy section, on MULTIPLIER chart, N-106.

Proceed as given in paragraph 4.41 above, setting one-half the desired frequency in 4.41(2).

4.412 Frequency between 15 and 50 Mc
(2) Take one-half of the estimated value of the frequency to be measured.

(3) Proceed as given in paragraph 4.41 above, setting one-third the desired frequency in 4.41(2).

4.413 Frequency between 30 and 60 Mc
(2) Take one-third of the estimated value of the frequency to be measured.

(3) Proceed as given in paragraph 4.41 above, setting one-third the desired frequency in 4.41(2).

4.414 Frequency between 50 and 80 Mc
(1) Take one-quarter of the estimated value of frequency to be measured.
4.22 Full Operation (Continued)

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-101, should read 0 ma. 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 0.6 ma. If the RANGE SELECTOR switch, S-102, is on a working point and the HFM Oscillator is oscillating, the meter, M-101, 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 crystal does not oscillate, the meter should read approximately 0.4 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 the required frequency range.

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

(3) Throw DETECTOR INPUT switch, S-105, to MEASURE position.

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

(5) Turn HFM FREQUENCY control, C-135-A, -B, to nearest 10 or 100 kc, and 0.1 or 0.01 Mc, multiples on BLACK or 20 or 200 kc, or 0.04 or 0.004 Mc, multiples on RED scale, calibrator, to the required frequency, setting the 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, 100, 1000 kc fall at multiples of 10, 100, and 1000 kc. On the RED scale, the calibrator harmonics of 10 and 100 kc fall at multiples of 20, 40, and 80 kc, and 0.04 and 0.08 Mc (all of which can be checked from the calibrator), but which are not principal beat points which are of assistance in estimating frequencies lying between calibrator harmonics.

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

(7) If a beat tone is then heard in the telephone, plugged in at the TEL jacks, J-101 or J-102, reduce this beat to zero by carefully setting COMPENSATOR, C-133-B, making the HFM FREQUENCY dial reading agree with the calibrator.

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

(9) Turn HFM FREQUENCY control, C-135-A, -B, to nearest 100 or 1000 kc, 0.04 or 0.004 Mc, multiples on BLACK or 20 or 200 kc, or 0.04 or 0.004 Mc, multiples on RED scale, calibrator, to the required frequency, setting the HFM FREQUENCY dial, N-103, carefully to index line at this frequency.

(10) If a beat tone is then heard in the telephone, 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-133-B, 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 100 kc away, but it is desirable to make this test at any desired frequency, and taking all precautions to avoid any possible error or ambiguity.

Where the instrument is known to be in good order, the full procedure is not necessary, and the following short checking procedure will serve.

4.32 Short Checking Procedure

(1) Throw DETECTOR INPUT switch, S-105, 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, on BLACK, or 400 kc, or 0.4 Mc, on RED scale), setting the HFM FREQUENCY dial, N-103, carefully to index line at this frequency.

(4) Repeat (3) with INTERPOLATOR SCALE SELECT switch, S-104, to MEASURE position.

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

(6) If a beat tone is then heard in the telephone, plugged in at the TEL jacks, J-101 or J-102, reduce this beat to zero by carefully setting COMPENSATOR, C-133-B, making the HFM FREQUENCY dial reading agree with the calibrator.

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

(8) If a beat tone is then heard in the telephone, 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-133-B, 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 100 kc away, but it is desirable to make this test at any desired frequency, and taking all precautions to avoid any possible error or ambiguity.

Where the instrument is known to be in good order, the full procedure is not necessary, and the following short checking procedure will serve.
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 inter­
potator, 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.

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:

4.3 Making Equipment in Operation

4.31 STAND BY OPERATION

4.32 Full operation

4.33 Checking the Interpolator and Dendrite Frequency Meter

4.34 Setting Up or Measuring a Frequency, QUICK METHOD

4.35 Setting Up or Measuring a Frequency, EXACT METHOD

4.36 Checking and Adjusting Calibrator Against Standard-Frequency Transmissions; Use of Calibrator Output in External Circuits

4.37 Crystal and Standard-Frequency Comparisons

4.38 Adjusting Calibrator

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-118 and V-119 the second stage.

3.264 The adjustable center-tap resistor, R-161, is provided as a “hum­control” 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-163, 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-100, to MATCH and turning the R. F. INPUT control, R-154, back to zero.

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 in 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

4.10 To Place Equipment in OPERAT­ING CONDITION

4.21 STAND BY OPERATION

4.211 Turn POWER switch, S-100, to STAND BY position at least 30 minutes before exacting use is to be made of the equipment. The POWER and CRYSTAL HEAT pilot lights, 1-101, -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 33 seconds and off 60 seconds, after the STAND BY period of 30 minutes.
GENERAL RADIO COMPANY

3.259 (C) for the UPPER scale (selected by the INTERPOLATOR SCALE SELECTOR switch, S-104). The connection between the blue zone and the double heat section in Figure 3.258 (4) is indicated by the dotted lines.

3.256 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 Tester. C-103, 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-103 A-E. See paragraph 3.253.

3.257 With the INTERPOLATOR SCALE SELECTOR switch, S-101, 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 downward to a lower reading. This signifies that the LOWER scale should be used.

3.258 With the INTERPOLATOR SCALE SELECTOR switch, S-101, 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 upward to a higher reading. This signifies that the UPPER scale should be used, so that the INTERPOLATOR SCALE SELECTOR switch, S-101, should be thrown to the UPPER position and the reading taken on the upper scale.

3.259 CAUTION: Do not advance the INTERPOLATOR SCALE TEST control, C-103, too rapidly, and be sure to use the initial indication of pointer on INTERPOLATOR meter, M-101. A too rapid movement, or too great an angular displacement of the INTERPOLATOR SCALE TEST control, C-103, 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 The power supply is from a 110-115-120 Volt 60-Cycle Supply.

3.2611 The power supply consists of the power transformer T-101, rectifier R-101 and a smoothing filter (L-108, 109, -110 and C-109, -115, -118, -119). 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-109 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-101.

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-101 and power is delivered to the heterodyne oscillator tube V-101 filament, the crystal oscillator tube V-101 filament, and crystal temperature control R-101. The rectifier filament, V-101, 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...
3.2520 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-175 the output current is regulated to fit the scale of the meter M-101, the scale of which is consequently marked directly in frequency.

3.2521 All 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, -190). 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 DEION 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.

3.2523 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 to 10 kc, 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 second 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.

3.2522 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.

3.2523 In Figure 3.245 (B) the essentials of Figure 3.245 (A) are repeated, showing the beat between the HPM 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).
3.252 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-discharge.

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.

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 of the tube is charged to the cathode voltage to ground. In so doing, a current pulse passes through the metering resistance, R-170 or -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
For example, suppose the calibrator frequency is 100 kc and the dial divisions difference between two calibrator harmonics is 10 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 180/4 = 45 divisions apart, giving calibration points respectively 85, 50 and 75 kc above the lower calibrator harmonic frequency.

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.

For a calibrator frequency, \( f \), of 10 kc, the intervals will be one-tenth those given above for the frequency of 100 kc.

Setting is found, where the second harmonic of the heterodyne frequency meter beats zero with the \( (2n+1) \) harmonic of the calibrator, lying halfway between the harmonies \( 2n \) and \( 0(2n+1) \). This point is shown at \( f/2 \).

The third harmonic will give zero beat points at \( f/2 \) or \( 100/2 = 50 \) kc above the lower calibrator harmonic marking the 100-ke 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-ke interval \( f \) and so on. Similarly, if the calibrator frequency \( f \) is 40 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 90-ke 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.

Since relatively high signal voltages are applied to the input, a series resistance, \( R \), 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.
the heterodyne-frequency-meter frequency is increased somewhat from that corresponding to X-A, the beat 1-4 increases and the beat 1-3 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-J, two beat frequencies are again obtained.

3.2453 Since it is necessary to measure the IFM 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-ke interval, from one calibrator harmonic to the next, to a small region midway between 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 1-1. Similarly for the lines B-8 and C-C. By this expedient, proper operation of the interpolator may be obtained throughout the range from one 10-ke 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 two circles 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 zero point, 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 halfway between the two original zero beat settings, another zero beat...
3.242 The output transformer, T-101, steps up from the impedance of the output tube, V-109, roughly 10,000 ohms, to the impedance of the telephones, roughly 600 ohms at 1 kHz.

3.243 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-103. A small amount of resistance in R-114 and R-115 placed in series with the telephones limits this reduction in voltage to the interpolator without noticeably affecting the response from the telephones. The Tel-Vol-Meter control, R-104 A, B, provides for adjustment of the level of the telephone response.

3.244 Formation of Beat Frequencies

3.245 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 HF 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 HF frequency is moved toward the right, a beat tone is heard which increases in frequency as the HF frequency is raised. This beat tone is represented by the line 1-1. At the same time, a beat is obtained between the HF frequency and that of the next higher calibrator harmonic, No. 2. This beat frequency, indicated by line P-Q, 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 P-Q, Q-R, R-S, S-T, etc.

3.245 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-Y crosses the line 1-1, representing the desired or "expected" beat frequency, the second is obtained where X-Z crosses line P-Q, representing an undesired or "unexpected" beat frequency. If
(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: 9,702 X 2 = 19,404 Me.)

(i) Multiply result obtained by 2 to get final result. (Example: 9,702 X 2 = 19,404 Me.)

3.2377 The chart shows, by the heavy solid range lines, the simplest choice 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 X 2 and 13 X 2). Using a part of range 13 and all of range 12, with a multiplier of 3, a frequency range of 30 to 45 Mc is obtained (lines 12 X 3 and 13 X 3). Using a part of range 13 and a multiplier of 4, a frequency range of 45 to 60 Mc is obtained (line 13 X 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, 84.0 Mc could be set up or measured using range 10 and multiplier of 3 (line 10 X 3) or range 12 and multiplier of 3 (line 12 X 3), but neither of these is as convenient as the use of range 13 and multiplier of 2 (line 13 X 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-e 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

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 HF coupler, 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.
MULTIPLIERS FOR RANGES 10, 11, 12 & 13; FREQS. > 15 Mc

**FIGURE 3.2B.** HARMONIC RANGE AND MULTIPLIER CHART

(c) The range to be used is 13.
(e) Take \( \frac{1}{2} \) of the desired frequency. (Example: \( 24.0 \times \frac{1}{2} = 12.0 \) Mc.)
(g) The harmonic used then falls at 12.0X2 = 24.0 Mc, the desired frequency.

(e) 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 13X2 range line roughly \( \frac{3}{4} \) from the left end.)
(c) The range to be used is 13.
(d) The multiplier to be used is 2.
(e) Take \( \frac{1}{2} \) of approximate frequency. (Example: \( \frac{24.1}{2} = 12.05 \) Mc.)
(f) Set heterodyne frequency meter to 12.05 Mc on range 12 (which will lie at roughly \( \frac{3}{4} \) scale from low-frequency end, see (b) above).
(g) The harmonic used then falls at 12.05X2 = 24.1 Mc, the desired frequency.

(h) 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 12X2 range line roughly \( \frac{3}{4} \) from the left end.)
(c) The range to be used is 12.
(d) The multiplier to be used is 2.
(e) Take \( \frac{1}{2} \) of approximate frequency. (Example: \( \frac{19.5}{2} = 9.75 \) Mc.)
(f) Set heterodyne frequency meter to 9.75 Mc on range 12 (which will lie at roughly \( \frac{3}{4} \) scale from low-frequency end, see (b) above).

**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: 18.4 Mc.)
(b) Note where desired frequency crosses a heavy solid range line. (Example: 18.4 Mc crosses the 12X2 range line roughly \( \frac{3}{4} \) from the left end.)
(c) The range to be used is 12.
(d) The multiplier to be used is 2.
(e) Take \( \frac{1}{2} \) of the desired frequency. (Example: \( \frac{18.4}{2} = 9.2 \) Mc.)
(f) Set heterodyne frequency meter to 9.2 Mc on range 12 (which will lie at roughly \( \frac{3}{4} \) scale from low-frequency end, see (b) above).
(g) The harmonic used then falls at 9.2X2 = 18.4 Mc, the desired frequency.
Jreq111cy c

·unknown frequenc-y is heard irr the telephorws.

·under, :

The unknown frequency is heard immediately from the direct-reading dial. Since the calibrator harmonics are used, the frequency meter is adjusted so as to obtain zero beat. When the detector input is switched to the MEASURE position, at S-101, without changing the setting of the heterodyne frequency meter, the beat between the heterodyne frequency meter and the known 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-101, 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 harmonics are identified immediately from the direct-reading dial, the frequency is the amount that the unknown frequency is above or below the known standard frequency. The frequency number is indicated automatically by the interpolator meter M-100. The sum is determined by use of the HETERODYNE SCALE-TEST resator, C-106. See paragraphs 3.235 and 3.236.

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-108, is for and in quickly determining which range of the heterodyne frequency meter and what multiplier should be used when frequencies above the direct-reading range of 10 k to 15 M are to be set up or measured.

3.2372 From the range table, paragraph 3.242, it is evident that ranges 10 and 11, covering 3.237-3.3 and 3.7-3.75 Mc by the fundamental frequency, carry fundamental frequency calibrations on the HF M dial. Similarly, ranges 12 and 13, covering 7.5-10.5 and 10.5-12.5 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, the fourth harmonic, the fundamental scale must be multiplied by 4, but the second harmonic scale need 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 1. 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: 24.0Mc.)

(b) Note where desired frequency crosses a heavy solid range line. (Example: 2.9 Mc crosses the 3.237 range line roughly 1/2 from the left end).

(c) Move across to the proper range, and down to the proper multiplier.

(d) Enter the range number and multiplier on the fundamental frequency scale, or enter multipliers above applicable range and note the difference between the range and multiplier used.

(e) Interpolate between adjacent multipliers to determine the multiplier at the desired frequency.

(f) To check result, multiply the fundamental frequency by the determined multiplier, and check result against the desired frequency.
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-141, 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 3.94.

3.232 HETERODYNE FREQUENCY METER

3.2321 The heterodyne frequency meter oscillator, 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-104 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 ranges 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.

3.2322 Ranges of Frequency Meter

<table>
<thead>
<tr>
<th>Range (on S-102)</th>
<th>Frequency</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>160 ke</td>
<td>Fundamental</td>
</tr>
<tr>
<td>2</td>
<td>220 ke</td>
<td>Fundamental</td>
</tr>
<tr>
<td>3</td>
<td>280 ke</td>
<td>Fundamental</td>
</tr>
<tr>
<td>4</td>
<td>340 ke</td>
<td>Second Harmonic of 2</td>
</tr>
<tr>
<td>5</td>
<td>400 ke</td>
<td>Second Harmonic of 3</td>
</tr>
<tr>
<td>6</td>
<td>440 ke</td>
<td>Fundamental</td>
</tr>
<tr>
<td>7</td>
<td>500 ke</td>
<td>Fundamental</td>
</tr>
<tr>
<td>8</td>
<td>600 ke</td>
<td>Fundamental</td>
</tr>
<tr>
<td>9</td>
<td>700 ke</td>
<td>Second Harmonic of 6</td>
</tr>
<tr>
<td>10</td>
<td>1000 ke</td>
<td>Second Harmonic of 7</td>
</tr>
<tr>
<td>11</td>
<td>1300 ke</td>
<td>Fundamental</td>
</tr>
<tr>
<td>12</td>
<td>1500 ke</td>
<td>Second Harmonic of 10</td>
</tr>
<tr>
<td>13</td>
<td>1800 ke</td>
<td>Second Harmonic of 11</td>
</tr>
</tbody>
</table>

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 identifyed on both fundamental and second harmonic ranges of the heterodyne frequency meter covering a total range from 160 ke to 15 Me. 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
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 CRYST. 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 \(\frac{1}{10}\), \(\frac{1}{100}\), \(\frac{1}{1000}\) ... 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, 10, and 1 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 10 kc up to the 750th. If the output

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**FIGURE 3.23. SCHEMATIC WIRING DIAGRAM OF HETEROODYNE FREQUENCY METER.** For complete wiring diagram, see page 73.

**FIGURE 3.24. FRONT OBLIQUE VIEW OF RIGHT SIDE WITH CABINET REMOVED.**
3.22 Crystal Controlled Calibrator

3.221 Crystal Oscillator

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±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-101. 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 encloses the thermostat.

FIGURE 3.23
Schematic Circuit Diagram of Crystal-Controlled Calibrator.
For Complete Wiring Diagram, See Page 78
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 H.F. 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-10:3, is thrown to the MATCH 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 dial) and then adjust (by C-135 - 0-135-C) the frequency set up on the heterodyne frequency meter and the incoming frequency may then be set the Heterodyne Frequency Meter to a selected value. The frequency thus set is throwable to 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 H.F. INPUT terminal by throwing DETECTOR INPUT switch, S-10:3, 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 dial) and then adjust (by C-135 - 0-135-C) the reading of the INTERPOLATOR meter M-101 on the proper scale. The calibrator harmonic frequency is given by the H.F. FREQUENCY dial, and the beat frequency is given by the reading of the INTERPOLATOR meter M-101 on the proper scale.

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 HETEROODYNE FREQUENCY METER

3.231 Oscillator

3.232 Range 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 Excessive 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

FIGURE 3.12 Block Diagram Illustrating General Principle of Operation

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 38073 (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............... 9.9 ma
Plate Resistance........... 91,000 ohms
Grid Voltage.............. -2 v
Transconductance....... 1,100 umhos

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

TYPE 38076 (76) SUPER-TriODE AMPLIFIER, DETECTOR

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........... 9,000 ohms
Grid Voltage.............. -13.5 v
Transconductance....... 1,450 umhos

SUPPER-TRIODE AMPLIFIER, DETECTOR

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........... 9,000 ohms
Grid Voltage.............. -13.5 v
Transconductance....... 1,450 umhos

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............... 5 ma
Plate Resistance........... 9,000 ohms
Grid Voltage.............. -3 v
Transconductance....... 8,000 umhos
Suppressor connected to cathode at socket.
2.5 CONNECTING POWER AND REMOTE TRANSMITTER 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. Screw the wires to the terminals. Then clamp on cable so that no strain will come at the terminal connections.

2.53 The cable clamps mentioned in Paragraph 2.51 and 2.52 are suitable for clamping the ends of Type TTHF-1 and 1ISC-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.

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 61.

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

3.131 In measuring a frequency, $f_0$, introduced at the R. F. INPUT terminal, the DETECTOR INPUT switch S-105 is thrown to the MATCH position. Beats between the fundamental, or a harmonic, of the heterodyne frequency meter, HF, and the frequency, $f_0$, under measurement, are such 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-105-A. B, to obtain an audible beat, matching the usual output frequency to the heterodyne frequency meter. This process is advantageous, particularly if the frequency, $f_0$, being measured is intermittently applied, as by keying of the transmitter.

3.132 Having matched the heterodyne frequency meter to the frequency, $f_0$, to be measured, the readings of the frequency meter are left strictly as-is. The DETECTOR INPUT switch, S-105, 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, HF, and a harmonic of the CALIBRATOR. This beat frequency is amplified in the audio-frequency amplifier and may be heard in the telephone. This beat frequency is always less than about 5 kc. (See paragraphs 3.45 following for discussion of the formation and frequency ranges of these beat frequencies.) While an output voltage is applied to the telephone, so that the beat is strong enough to be heard, the heterodyne frequency meter is then adjusted to match the beat frequency $f_0$.
### SOCKET VOLTAGES AND CURRENTS — Continued

<table>
<thead>
<tr>
<th>Socket</th>
<th>Tube Type</th>
<th>Service</th>
<th>Readings at Output Between Terminals</th>
<th>MA DC or AC</th>
<th>Model OE Analyzer Meter Scale</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-110</td>
<td>6SK7</td>
<td>Hit. Freq. Meter Oscillator</td>
<td>6-7</td>
<td>6.4 ac</td>
<td>8</td>
<td>Ramp Switch on Dead Point Between Ranges 1-2.</td>
</tr>
<tr>
<td>V-111</td>
<td>300H5 (6V-105-50)</td>
<td>H.F.M. Regulator</td>
<td>5-6</td>
<td>100 de</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>V-112</td>
<td>300H5 (6V-105-50)</td>
<td>H.F. Input</td>
<td>3-4</td>
<td>-0.2 ac</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>V-113</td>
<td>300H5 (6V-105-50)</td>
<td>H.F.M. Coupling Tube</td>
<td>1-3</td>
<td>6.5 ac</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>V-114</td>
<td>300H5 (6V-105-50)</td>
<td>Interp. Input Amplifier</td>
<td>3-4</td>
<td>185 de</td>
<td>230</td>
<td></td>
</tr>
<tr>
<td>V-115</td>
<td>300H5 (6V-105-50)</td>
<td>Interp. Freq. Meter Tube</td>
<td>7-8</td>
<td>-2 ac</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>V-116</td>
<td>300H5 (6V-105-50)</td>
<td>Interp. Freq. Meter Tube</td>
<td>7-8</td>
<td>14.3 ac</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>V-117</td>
<td>300H5 (6V-105-50)</td>
<td>Interp. Freq. Meter Switching Tube</td>
<td>5-6</td>
<td>-3.5 de</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>V-118</td>
<td>300H5 (6V-105-50)</td>
<td>Interp. Regulator 1st Stage</td>
<td>3-4</td>
<td>108 de</td>
<td>230</td>
<td></td>
</tr>
<tr>
<td>V-119</td>
<td>300H5 (6V-105-50)</td>
<td>Interp. Regulator 1st Stage</td>
<td>11</td>
<td>108 de</td>
<td>230</td>
<td></td>
</tr>
<tr>
<td>V-120</td>
<td>300H5 (6V-105-50)</td>
<td>Interp. Regulator 1st Stage</td>
<td>3-4</td>
<td>12.2 de</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>V-121</td>
<td>300H5 (6V-105-50)</td>
<td>Plate Voltage Rectifier</td>
<td>1-3</td>
<td>3.6 ac</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

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.
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: 9 inches
Depth: 171/2 inches

1.2 The total weight of the equipment, uncrated and ready for operation, is 153 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 48 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 Me. By harmonic extension, frequencies above 30 Me may be measured.

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

SECTION 2. INSTALLATION

2.1 DRILLING FOR MOUNTING
2.1.1 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
2.2.1 Place the instrument on desk or on a base desk, so that when the slide carriage is drawn forward, the instrument will not tip forward and be damaged.

2.2.2 Unlock the four fasteners, H-102, H-104, 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-109 (left side, rear) with his left hand (remove V-117, with shield, and V-116 for easier access to handle, H-101, 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 desk where it has a good support, and there is no danger of damaging it.

2.3 BOLTING DOWN SHOCK MOUNTINGS
2.3.1 Place the housing in position over the holes drilled for mounting. Place a check hole, as shown, for power leads.

2.4.1 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
CONTRACTUAL GUARANTEE

This equipment, including all parts and spares, 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 or 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 the first period of TWO YEARS from the date of delivery of the equipment 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 this 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 expeditions 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 service due to defective parts 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. 83991  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 ....................................
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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. Sa of October 3, 1934, or subsequent revisions thereof on the subject of "Radio-Safety Precautions to be Observed."

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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.
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. 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 trying to get water out of the stomach. Turn patient's face down and go to work immediately.
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.

**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 stimulate respiration. 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.