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HANDBOOK OF

MAINTENANCE INSTRUCTIONS

or

NAVY MODEL LM-13 CRYSTAL CALIBRATED FREQUENCY INDICATING EQUIPMENT

●

4 AUGUST 1943

WARNING

Notice To Operating and Maintenance Personnel

OPERATION OF THIS EQUIPMENT INVOLVES THE USE OF HIGH VOLTAGES WHICH ARE DANGEROUS TO LIFE.

UNDER CERTAIN CONDITIONS DANGEROUS POTENTIALS MAY EXIST IN CIRCUITS WITH THE POWER CONTROLS IN THE OFF POSITION DUE TO CHARGES RETAINED BY CAPACITORS. ALWAYS, *COMPLETELY* DISCHARGE CIRCUITS AFTER ALL POWER HAS BEEN TURNED OFF.

TURN OFF ALL POWER EQUIPMENT BEFORE ENTERING THE CABINET.

DO NOT DEPEND ON INTERLOCK SWITCHES FOR PROTECTION. THEY MIGHT STICK.

DO NOT CHANGE TUBES WHEN ELECTRIC POWER IS SUPPLIED TO THE EQUIPMENT.

PARTICULAR CARE MUST BE TAKEN TO KEEP AWAY FROM LIVE CIRCUITS WHEN MAKING ADJUSTMENTS FOR ALIGNMENT OF THE EQUIPMENT.

ALL OPERATING PERSONNEL SHALL OBSERVE *ALL* SAFETY REGULATIONS, AT *ALL* TIMES.

THE ATTENTION OF OFFICERS AND OPERATING PERSONNEL IS DIRECTED TO THE BUREAU OF ENGINEERING CIRCULAR LETTER NO. 5a OF OCTOBER 3, 1934, OR SUBSEQUENT REVISION THEREOF ON THE SUBJECT OF "RADIO-SAFETY PRECAUTIONS TO BE OBSERVED."

Published under joint authority of the United States War and Navy Departments and the Air Council of the United Kingdom.

REPLACEMENT OF DEFECTIVE MATERIAL

The contractor guarantees that the articles provided for under this contract will conform to the specifications herein, will be suitable for the purposes intended and will be free from any defects in material and workmanship.

It is agreed that the contractor shall make at his own expense, such changes involving correction of defective design, material, and/or construction in each of the articles as the Navy Department may decide should be incorporated prior to final acceptance. Where any of the articles concerned have already been finally accepted, material and services for correction of such defects in design, material and/or construction, are to be furnished by the contractor without cost to the Government provided that the Government must notify the contractor of such defects not later than six (6) months after final acceptance of the articles delivered. This time is to be the guarantee period. If defective design, material and/or construction are of such nature that the Navy Department considers such action desirable, entire articles will be returned to the contractor at Government expense for complete rebuilding at contractor's expense. The contractor agrees to proceed without delay with the correction of these defects in a manner satisfactory to the Navy Department and to deliver such articles to the original point of final acceptance. If the articles are returned for rebuilding the guarantee period shall be extended to six (6) months after final acceptance of such rebuilt articles.

UNSATISFACTORY REPORT

FOR U. S. NAVY PERSONNEL:

Report of failure of any part of this equipment during its guaranteed life shall be made on Form N. Aer. 4112 "Report of Unsatisfactory or Defective Material" or a report in similar form and forwarded in accordance with the latest instruction of the Bureau of Aeronautics. In addition to other distribution required, one copy shall be furnished to the Inspector of Naval Material (location to be specified) and the Bureau of Ships. Such reports of failure shall include:

1. Reporting activity.
2. Nameplate data.
3. Date placed in service.
4. Part which failed.
5. Nature and cause of failure.
6. Replacement needed (yes—no).
7. Remedy used or proposed to prevent recurrence.

FOR U. S. ARMY PERSONNEL:

In the event of malfunctioning, unsatisfactory design or unsatisfactory installation of any of the component units of this equipment, or if the material contained in this book is considered inadequate or erroneous, an Unsatisfactory Report, AAF Form No. 54 or a report in similar form shall be submitted in accordance with the provisions of Army Air Force Regulation No. 15-54, listing:

1. Station and organization.
2. Nameplate data (type number or complete nomenclature if nameplate is not attached to the equipment).
3. Date and nature of failure.
4. Airplane model and serial number.
5. Remedy used or proposed to prevent recurrence.
6. Handbook errors or inadequacies, if applicable.

FOR BRITISH PERSONNEL:

Form 1022 procedure shall be used when reporting failure of radio equipment.

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SECTION I

1. INTRODUCTION.

1-1. FUNCTION.

The Model LM-13 Crystal Calibrated Frequency Indicating Equipment has been specially designed to provide a simple, accurate and reliable frequency indicating equipment of the crystal calibrated type for use in the Naval radio service. It is adaptable for adjusting adjacent radio transmitters and receivers to any desired frequency in the range from 125 to 20,000 Kcs. The equipment provides accuracies of 0.02 per cent in the 125- to 2000-Kcs band, and 0.01 per cent in the 2000- to 20,000-Kcs band, at any ambient temperature in the range from minus 32 to plus 65 degrees Centigrade.

1-2. COMPARISON BETWEEN MODELS OF MODEL LM SERIES.*

The following tabulation indicates similarity between various revisions of the Model LM Series Equipment:

Model	*Freq. Measuring Unit Type*	*Het. Osc. Freq. Range-Kcs*	*Operating Voltage*	*Mechanical Design*	*Remarks*
LM	None	195–400 2000–4000	12/14 200/260		
LM-1	None	195–400 2000–4000	External battery supply	Same as LM	
LM-2	None	195–400 2000–4000	12–14 200/260-260/475	General minor improvements throughout	Voltage regulator circuit added
LM-3	None	195–400 2000–4000	External battery supply	Same as LM-2	
LM-4	None	195–400 2000–4000	12/14 200/260-260/475	Same as LM-2	Symbol designations reassigned
LM-4a	None	195–400 2000–4000	24/28 200/260-260/475	Same as LM-4	
LM-5	None	195–400 2000–4000	12/14 200/260-260/475	Same as LM-4	
LM-6	CRR-74023	195–400 2000–4000	Rectifier Power Unit Type CRR-20104	Same as LM-4	
LM-7	CRR-74024	195–400 2000–4000	12/14-24/28 200/260-260/475	Redesigned shockmount base and capacitor and drive assembly	
LM-8	CRR-74024	195–400 2000–4000	Rectifier Power Unit Type CRR-20104	Same as LM-7	
LM-9	CRR-74024	195–400 2000–4000	12/14-24/28 200/260-260/475	Same as LM-7	Included in Type CRR-10086 Waterproof Carrying Case
LM-10	CRR-74028	125-250 2000–4000	12/14-24/28 200/260-260/475	Minor mechanical revisions	LF Het. Osc. fund. freq. range changed
LM-11	CRR-74028	125-250 2000–4000	Rectifier Power Unit Type CRR-20104 or Rectifier Power Unit Type CRR-20104A	Same as LM-10	

* For comparison of Models LM-14 to LM-19 see addenda in front of book.

Model	*Freq. Measuring Unit Type*	*Het. Osc. Freq. Range-Kcs*	*Operating Voltage*	*Mechanical Design*	*Remarks*
LM-12	CRR-74028	125-250 2000-4000	12/14-24/28 200/260-260/475	Same as LM-10	Included in Type CRR-10086 Waterproof Carrying Case
LM-13	CRR-74028	125-250 2000-4000	Self contained batteries	Same as LM-10 less shock-mount base	Mounted in Type CRR-10111 Carrying Case with batteries

All units of the series are completely interchangeable electrically and mechanically with the exception of the Model LM and Model LM-1 Equipments, which are not designed for operation with 260/475-volt plate supplies.

1-3. COMPOSITION.

Each Model LM-13 Crystal Calibrated Frequency Indicating Equipment consists of the following component units:

Item	*Quantity*	*Description*	*Lbs.*
A	1	Type CRR-74028 Heterodyne Frequency Meter. Dimensions 8-5/8" x 8-1/8" x 8-1/2" Including: 1 each of Navy Types -76, -77, -6A7 vacuum tubes 2 neon regulator tubes 1 crystal, Navy Type CRR-40023B 1 Calibration Book (typed)	11.50
B	1	Type CRR-10111 Carrying Case. Dimensions 9-5/8" x 9-3/4" x 15-7/16". Set of vacuum tubes and crystal to be drawn from spare parts and mounted in carrying case	13.50
C	1	Type CMQ-10110 Canvas Bag and Strap	4.00
D	1	Instruction Book	..
E	1 Set for each 3 equipments	Set of Operating Spare Parts (not shipped with equipment—shipped to supply base in bulk)	..

The total weight of the case with frequency meter, tubes, and batteries installed is 38.90 lbs.

1-4. ADDITIONAL EQUIPMENT REQUIRED.

The following equipment, not furnished on this order, is required to complete the Model LM-13 Crystal Calibrated Frequency Indicating Equipment.

Quantity	*Description*
1 Pr.	Headphones (600 ohms at 1000 cycles)
4	CNC-19021 45V "B" Batteries
2	CNC-19020 6V "A" Batteries

1-5. POWER CONSUMPTION.

All power required for the operation of this equipment is supplied by the batteries listed in paragraph 1-4. The current drains at the specified voltage limits are as follows:

Filaments: 12 volts, 0.67 ampere
Plates: 180 volts, 0.005 ampere

These values are typical for operation with the MODULATION switch on the ON position, under which condition maximum plate current is drawn.

SECTION II

2. DESCRIPTION OF UNITS.

2-1. TYPE CRR-74028 HETERODYNE FREQUENCY METER.

The Type CRR-74028 Heterodyne Frequency Meter contains a crystal controlled oscillator used as a reference standard; a heterodyne oscillator having two fundamental tuning ranges which, with their useful harmonics, provide continuous coverage from 125 to 20,000 Kcs; a 500-cycle modulator; a high gain detector provided with independent means for coupling to each of three sources of excitation; an audio frequency amplifier; and a voltage regulator circuit which provides essentially constant plate voltage to the heterodyne oscillator for the plate supply between the limits of 260 and 475 volts. There are eight operating controls; a filament power switch S-102A, B, which breaks both the filament and plate supplies; a plate power switch S-103, for standby filament operation without plate load; a crystal oscillator switch S-104A, B; a two-position frequency band switch S-101A, B, C, D, for the heterodyne oscillator; a heterodyne oscillator worm and gear drive tuning control, together with its dial units and dial hundreds scales; a corrector control; an RF coupling control R-106; and a modulation on-off switch S-105A, B, C, D. All of these controls are mounted on the front panel together with an RF coupling terminal, a calibration card on which the settings for seven important frequencies may be logged, and an output phones jack J-101. Two swinging cover plates near the corrector control allow access to the adjusting screws for the low and high band trimmer capacitors C-103 and C-104, respectively. A power input receptacle J-102 is located on the right hand side of the frequency meter near the lower front corner. Link switches on a terminal panel behind transformer T-101 permit the filament circuits to be arranged for either 12-volt or 24-volt low voltage sources. Similarly, the high-voltage supply regulator circuit can be arranged to permit operation within the ranges 200-260/260-475 volts. All parts are mounted on an aluminum panel and chassis assembly and housed in an aluminum cabinet which is provided with a pocket at the bottom for stowing the calibration book. The external surfaces are finished in a durable black wrinkle lacquer. Figures 1 and 5 to 14, inclusive, show the general construction and arrangement of parts.

The cathode, inner grid, and anode grid of the Navy Type -6A7 vacuum tube V-102 (see Figures 17-A and 18) constitute the active elements of the crystal-controlled oscillator, which operates at the fixed frequency of 1000 Kcs when the crystal switch S-104A, B is on. In certain models of the Model LM-13 Equipments the crystal oscillator circuit is provided with a trimmer capacitor C-118 inserted across the crystal. It is then possible to set the frequency of the crystal oscillator more closely to 1000 Kcs, should this adjustment be necessary. The circuit is of a design which generates considerable harmonic energy in order that the crystal oscillator may be employed to calibrate the heterodyne oscillator at several points over its entire range. The necessary plate circuit impedance is built up across an untuned inductor L-103, which is housed in a bakelite case ruggedly constructed and thoroughly sealed against moisture. Likewise, the crystal Y-101 is supplied in a hermetically sealed and evacuated metal holder which provides permanent protection against humidity, corrosion, and dirt intrusion. One of the smaller type metal tube envelopes is employed in the construction of this holder, so that it plugs into a standard octal tube socket X-106. The cut of the crystal and the internal construction of the holder are such that, under any conditions of barometric pressure, humidity, voltage, vibration, shock, or tilt, only the specified output frequency and the harmonics thereof are obtained. The crystal is ground for operation at a normal temperature of plus 10°C. The temperature coefficient of the combined crystal, holder, and circuit, as expressed in percentage of the frequency, is less than 0.0001 per cent per degree Centigrade as measured over an ambient range of 80°C.

The Navy Type -77 vacuum tube V-101 is used in electron coupled circuit as a heterodyne oscillator (Figures 17 and 18). As previously stated, there are two continuously variable ranges which may be manually selected by the frequency band switch S-101A, B, C, D. In the low frequency position, a fundamental range of 125 to 250 Kcs is employed; which, by calibrating the first, second, fourth, and eighth harmonics, gives continuous coverage over the range from 125 to 2000 Kcs. In the high frequency position of switch S-101A, B, C, D, the fundamental range of 2000 to 4000 Kcs is calibrated over the first, second, fourth, and part of the fifth harmonics to give continuous coverage throughout the range from 2000 to 20,000 Kcs. The two inductors L-101 and L-102, in the tuned circuits, are wound on ceramic forms and thoroughly sealed against moisture. Tuning over both fundamental ranges is accomplished by the variable capacitor C-101, which is designed throughout to have a low temperature coefficient. This is augmented by the variable corrector capacitor C-102, the thermal compensator C-116, inserted in the circuit parallel with capacitors C-101 and C-102, and the adjustable trimmer capacitors C-103 and C-104 which permit separate adjustments to the low and high bands to compensate for extreme conditions of humidity. Capacitor C-101 is capable of continuous rotation in either direction without stops, and the dial assembly includes a 100/1 ratio worm gear drive mechanism so that 50 revolutions of the vernier dial are required for 180° rotation of the main scale (on the capacitor shaft). The main, or dial hundreds scale is engraved with 50 divisions over its useful 180° sector; and the vernier is marked with 100 dial units divisions over the entire 360°. The arrangement thus provides 5000 effective readable divisions, of which the calibrated ranges occupy approximately the portion between 175 and 4450. Backlash in the gear mechanism has been reduced to less than three-tenths of one division on the dial units scale.

The calibration data for the heterodyne oscillator circuit are corrected to absolute frequency for a temperature of plus 10°C, and the dial settings of the successive harmonics (crystal check points) are noted along the calibration. The temperature coefficient of each range of the heterodyne oscillator, expressed in percentage of frequency, is less than 0.002 per cent per degree Centigrade, as measured over a range of 97°C. The corrector capacitor C-102, which is connected in parallel with capacitor C-101, makes it possible to reset the heterodyne oscillator to agree with the crystal calibration at any harmonic for any ambient temperature between the limts of minus 32° and plus 65°C. Thus, after the tube filaments have been lighted for at least ten minutes, and the heterodyne oscillator has been corrected to the nearest crystal check point, the heterodyne oscillator is capable of being reset to within 0.02% of the absolute for any frequency in the range of 125 to 2000 Kcs, and to within 0.01% for any frequency between 2000 and 20,000 Kcs. These accuracies are obtainable under the most unfavorable combined influences due to 10% changes in filament and/or plate voltage, errors in calibration, changing tubes, crystal grinding errors, and variations of ambient temperature between minus 32° and plus 65°C.

It was previously stated that the three inner elements of the Navy Type -6A7 tube V-102 are used in the crystal oscillator circuit. The remaining elements of this tube, comprising the control grid, screen grid, and plate, are used as a high-gain screen-grid detector; to which; by structure, the crystal oscillator is electronically coupled. The RF voltage developed across the load resistor R-104 in the plate output circuit of the electron coupled heterodyne oscillator is introduced into the control grid circuit of this detector through a small fixed capacitor C-105. The RF coupling terminal, mounted on the front panel, is also coupled to the control grid of the detector, through the RF coupling control potentiometer R-106, and the coupling capacitor C-106. This connection is made through section S-104B of the crystal switch when set in the off position only. As a result of these three coupling means, and dependent on the position of the crystal switch, the detector functions to mix the heterodyne oscillator output either with the fundamental and successive harmonics of the crystal oscillator, or with the transmitter frequency to be measured. When the crystal switch is thrown to the on position, section S-104B of the crystal switch grounds the RF coupling terminal through resistor R-106, and opens the circuit to the detector control grid through capacitor C-106, thereby preventing interference from external sources while correcting the heterodyne oscillator to the crystal calibrator.

The detector plate works into an audio choke L-104 and the beat frequency voltages built up across it are coupled through capacitor C-108 to the grid of the Navy Type -76 vacuum tube V-103, provided the modulation switch S-105A, B, C, D is in the off position. The grid of tube V-103 returns to ground through grid leak resistor R-112, the desired bias potential being obtained from the IR drop across the series cathode resistor R-111. The plate of tube V-103 returns to the positive plate supply through the primary of the output transformer T-101 and the filter resistor R-108, the latter being bypassed to the cathode through capacitor C-112. Cathode bypass to ground is provided through capacitor C-110A. The secondary of transformer T-101 is completely insulated from the primary, so that no DC potentials are present in the output. This transformer and the audio choke L-104 are both completely enclosed in evacuated metal containers, insuring permanent protection against humidity. The secondary of transformer T-101 is connected to the phones jack J-101 through sections S-105C, D of the modulation switch (off position), the winding ratio being designed to match the plate impedance to 600-ohm phones (see A and B, Figure 17).

The detector and audio amplifier combination is so designed that the output impressed across the phones is essentially a linear function of the input voltage for the output range 0.06 to 50.0 milliwatts (beat frequency of 250 cycles). The audio system is peaked at 250 cycles. At frequencies of 100 cycles and 500 cycles the output is approximately 1.5 DB below the 250-cycle reference.

As previously stated, the heterodyne oscillator and the RF coupling terminal are coupled to the control grid of the detector through capacitors C-105 and C-106, respectively, when the crystal switch is in the off position. Therefore, under the same conditions, the heterodyne oscillator is coupled to the RF coupling terminal through capacitors C-105 and C-106 connected in series. Thus, the RF coupling terminal serves the dual purpose of detector input terminal for the measurement of frequencies of external origin, and a heterodyne oscillator output terminal for use in calibrating receivers. When the frequency meter is employed for the latter purpose, 2500 microvolts or more of radio frequency energy will be available between the RF coupling terminal and ground at any frequency within the calibrated range. In the heterodyne oscillator fundamental ranges, where outputs of several thousand microvolts are available, the RF coupling potentiometer provides means for attenuation to a minimum of approximately 100 microvolts.

MCW receivers may also be calibrated from this RF source, if the modulation switch S-105A, B, C, D is thrown to the on position. Under this condition, the grid of vacuum tube V-103 is disconnected from the audio coupling capacitor C-108 by switch section S-105A, and connected to the primary of transformer T-101, through the modulator feedback capacitor C-114 (the primary of transformer T-101 remains connected to the positive plate supply through the filter resistor R-108, this resistor being bypassed to the cathode through capacitor C-112). The plate of tube V-103 then returns to the positive plate supply through switch section S-105B, the secondary of transformer T-101, and switch section S-105D. The plate is also connected through switch section S-105C to the capacitor C-113 (which tunes the secondary of transformer T-101 to approximately 500 cycles), and through the modulator coupling capacitor C-107 to the suppressor grid of the heterodyne oscillator tube V-101. Thus, in the on position of the modulation switch, the output phones jack is rendered inoperative while the vacuum tube V-103 and its associated circuits function as an audio oscillator. This oscillator provides approximately 40% modulation of the RF output throughout the calibrated range (see C, Figure 17).

All power required for the operation of the frequency meter is introduced through the power input receptacle J-102. The common filament and negative plate supply lead to vacuum tubes V-102 and V-103 connects to terminal 27 thereof, which is grounded to the chassis. Section S-102A of the filament power switch closes the 12.6-volt supply terminal (25) to the filament of vacuum tube V-101 (which is connected in series with the filament of tube V-102) and through dropping resistor R-113 to the filament of tube V-103. Section S-102B of this switch connects the positive high voltage input terminal (26) through the series plate power switch S-103 to the plate and screen circuits of vacuum tubes V-102 and V-103 and to the voltage regulator resistor R-103. Thus with the filament switch in the on position, and the plate switch turned off, the filaments of all tubes may be maintained at operating temperature without any drain from the high voltage supply.

It will be noted that the plate and screen power supply connections for the heterodyne oscillator tube V-101 are not mentioned in the previous paragraph. In order to maintain the calibration accuracy specified for the heterodyne oscillator, it is necessary that the plate and screen voltage supply to vacuum tube V-101 be held within certain limits. A special voltage regulator circuit and output switch has therefore been included to permit the use of the frequency meter with a range of supply voltages. In the frequency meter the voltage regulator circuit comprises the two neon glow tubes V-104 and V-105, the regulator cutout resistor R-116 shunted by the regulator link switch, and the regulator limiting resistor R-103, all of which are connected in series across the power supply output terminals (when both power switches are turned on). The two neon tubes in series strike at about 210 volts and, because of their variable resistance characteristics, the arcing voltage thereafter remains fixed at approximately 130 volts. The plate and screen circuits of tube V-101 are fed from the constant voltage drop across these tubes when the power supply input is between the limits of 260 and 475 volts, and the link switch located on the link panel is set to correspond.

For those installations where the high voltage source supplies voltage in the range from 200 to 260 volts, by setting the link switch to correspond with this range, the self biasing resistors R-101 or R-102 in combination with resistors R-103, R-104, R-105, R-114, and R-116 are arranged to regulate the electrode voltages of the heterodyne oscillator tube within limits that will maintain stability and calibration accuracy.

By reason of extreme refinements involving the type and design of the basic circuits, the relative arrangement of parts, character of intercircuit couplings, shielding, etc., the performance of the frequency meter has been developed to a degree where no locking-in will occur between the heterodyne oscillator and either source of RF with which it may be coupled, at any difference or beat frequency down to 5 cycles per second. Although the phones become rapidly less efficient in audibly reproducing beat tones below 100 cycles per second, characteristic "rushes" coincident with the rise and fall of the beat frequency pulses are aurally recognizable well below the low frequency limit of audibility.

2-2. TYPE CRR-10111 CARRYING CASE.

In the Model LM-13 Equipment the Type CRR-74028 Heterodyne Frequency Meter, six batteries are mounted in the Type CRR-10111 Carrying Case. A set of spare tubes and a spare crystal, if available, may be mounted in the carrying case by the operator. The carrying case is constructed of sheet steel and the external surfaces are finished in a durable black wrinkle lacquer. Figures 1, 2, 3, 4 and 15 show the general construction and overall dimensions. A wing Dzus fastener on the front of the carrying case opens the door protecting the frequency meter controls. The power plug fits in a clamp in the upper right-hand corner of the frequency meter compartment. A cover plate, secured by a Dzus fastener, on the right hand side of the carrying case permits easy access to the power receptacle. On the top of the carrying case is a handle and an antenna coupling terminal. A lead from the coupling terminal is clamped to the left side of the frequency meter compartment. A compartment directly below the frequency meter compartment contains clamps for a spare set of vacuum tubes and a spare crystal. Directly behind the spare parts, and opening to the rear is the battery box. On each side of the carrying case is a ring provided for use with a carrying strap.

2-3. TYPE CMQ-10110 CANVAS BAG AND STRAP.

Type CMQ-10110 Canvas Bag is made of olive drab cotton duck which has been treated to make it water repellent and mildew resistant. The bag is reinforced with leather at the points of greatest wear. A pocket is provided on the top of the bag for the purpose of carrying the headphones. A metal ring is securely attached to each side of the bag. To these rings an olive drab, cotton webbing strap, 2 inches wide and 65″ long, with a snap bolt on each end, is fastened.

2-4. CALIBRATION BOOK.

The low frequency fundamental range of the heterodyne oscillator is calibrated at each one-tenth kilocycle between 125 and 250 Kcs, or a total of 1251 points. Likewise, the high frequency fundamental range is calibrated in increments of one kilocycle between 2000 and 4000 Kcs, or a total of 2001 points. These fundamental frequencies are legibly printed in columnar formation on the successive pages of the calibration book, together with associated columns listing the second, fourth, and eighth harmonics in the low frequency range and the second, fourth, and portions of the fifth harmonics in the high frequency range. The dial settings, as determined by individual calibration, are then typed in opposite each such group. All figures representative of ordinary frequencies and their dial settings are both printed and typed in black, while those which refer to the crystal oscillator and its harmonics (crystal check points) are shown in red. The nearest crystal check points are also shown in red across the bottom of each page; and the first and last frequencies and dial settings tabulated thereon are indicated across the top. There are 34 inside pages, thumb tabbed as to page number. The calibration comprises pages 2 to 34 inclusive: page 1 being an index to the dial settings. In addition, an index of frequencies in the high range is printed on the front cover, and another for the low frequency range is given on the rear cover. A brief summary of the essential steps in operating the equipment is given on the inside of the front cover. A table is printed on the inside rear cover by which dial settings and frequencies not covered by the calibration pages may be arrived at by interpolation. Instructions for using this table are printed just above the table. The calibration book is printed on high quality white rag index paper which is both oil- and waterproof, and the cover boards are specially selected for durability. A spiral spring type of binding is employed, so that the book lies flat when open to any page.

Provision is made for stowing the calibration book in a metal pocket provided at the bottom of the frequency meter.

SECTION III

3. INSTALLATION.

As shipped from the factory the Type CRR-74028 Heterodyne Frequency Meter is enclosed in the Type CRR-10111 Carrying Case and all vacuum tubes are inserted in their respective sockets and clamped. After unpacking, remove the frequency meter from the carrying case by pulling the two snapslides forward and lifting it off the mounting studs. Inspect for possible damage which may have occurred during shipment. Also, test the grid clips for firm contact with the grid terminals, and make sure the crystal holder is pushed well into its socket. Prior to replacing the frequency meter, check to see that the VOLTAGE SELECTOR links are in the right positions. Set these links to correspond most closely to the voltages with which the equipment will be used. As shipped from the factory the links are set for battery operation.

If operating spares are available with the equipment, the spare set of tubes and spare crystal may be mounted in the spare parts compartment of the carrying case.

Since this is a portable equipment practically no installation is required. However, the four "B" batteries and the two "A" batteries must be installed in accordance with the battery label in the back of the battery compartment and the cable plugs inserted before the equipment is ready for use (see Figure 16).

To connect the cable to the frequency meter, set the power, crystal, and modulation switches to their off positions, and insert the power plug in the power input receptacle located on the lower right hand side of the frequency meter.

The Model LM-13 Equipment may be operated from an external power source by opening the cover plate on the side of the carrying case and inserting a suitable plug and assembly so wired that the terminals are connected as follows:

Terminal	*Connection*
26	+200/475V
25	+12/24V
27, 36	−12/24V, −200/475V
35	None

The junction boxes used with the Model GF or Model RU Series Aircraft Radio Equipment may be modified to provide operating power for the Model LM-13 Crystal Calibrated Frequency Indicating Equipment. Briefly the required modification comprises 2 additional connections to the spare outlet as follows:

(a) Connection of terminal 36 to the negative high voltage dynamotor input terminal, and
(b) Connection of terminal 26 to the positive high voltage dynamotor input terminal.

These required modifications and the corresponding settings for the voltage selector links in the frequency meter are shown specifically in the following tabulation for each usable model of the Model GF and Model RU Series Equipments:

Equipment Model	*Junction Box Type No.*	*Outlet to be Modified*	*Connection to be Added:*		*Voltage Selector Link Position LM-13*
			(a)	*(b)*	
RU-2	CBY-23011A	74	36 to 14	26 to 18	200-260
GF-1 RU-3	CBY-62003	74	36 to 14	26 to 18	260-475
GF-2 RU-3A	CBY-62004	74	36 to 14	26 to 18	260-475
RU-4	CBY-62007	76	36 to 14	26 to 35 or 18	260-475
GF-3 RU-4A	CBY-62008	76	36 to 14	26 to 18	260-475
RU-5	CBY-62007	76	36 to 14	26 to 35 or 18	260-475
GF-4 RU-5A	CBY-62008	76	36 to 14	26 to 18	260-475
RU-6	CBY-62007A	76	None	26 to 35 or 18	260-475

The Model GF/RU and Model RU Series Equipments later than those appearing in the accompanying table, do not require modification of outlets.

If the Type CRR-20104 or Type CRR-20104A Rectifier Power Unit is used as the power supply in the Model LM-13 Equipment, connect the five-contact plug attached to the remote end of the shielded power cable to the POWER OUTPUT receptacle on the panel of Type CRR-20104 or Type CRR-20104A Rectifier Power Unit.

The Model LM-13 Equipment may be used in conjunction with Model RBM Equipment using either battery or AC power sources. In the event the Model LM-13 Equipment is so used, connect the plug at the remote end of the power cable to the receptacle marked C.F.I. on the particular power supply unit used with the Model RBM Equipment.

The lead from the antenna terminal on the top of the carrying case must be plugged into the R.F. coupling terminal on the front of the frequency meter.

A short antenna must now be provided for coupling to the receivers and transmitters which are to be adjusted. This should preferably be a fixed wire (not over 4 or 5 feet long overall) secured to the antenna coupling terminal on the top of the carrying case; provided, it may be so installed that about two feet of its remote end will run parallel, and close, to the transmitter or receiver antenna leads. Where these conditions cannot be realized, such as in an airplane, a flexible insulated pick-up wire may be employed, with means provided to prevent its becoming a hazard during flight. One end should be skinned and secured to the antenna coupling terminal on the carrying case. Then, if the remote end be fitted with a completely taped test clip (jaws dulled), it will be possible to secure the lead at various coupling points, as desired, without grounding or contacting thereto. Under no circumstances should the antenna coupling terminal be conductively coupled to any part of the transmitter or receiver being measured, unless a special coupling terminal is provided on the equipment for this purpose.

Plug a pair of low-impedance headphones (600 ohms at 1000 cycles) into the phone jack; then turn the filament switch to the on position.

When using the Model LM-13 Equipment in conjunction with Model GF/RU Series Equipment, prior to setting the frequency meter FILament switch to the ON position apply filament and plate voltage to the receiver by closing the proper switches. When using the Model LM-13 Equipment with a Type CRR-20104 Rectifier Power Unit, set the rectifier POWER switch to ON and adjust COMPensation switches 1 and 2 to provide proper voltage indication on the input voltmeter of the rectifier power unit. In place of a Type CRR-20104 Rectifier Power Unit, it may be necessary to employ Type CRR-20104A Rectifier Power Unit; in which case an alternating-current voltmeter (0-150V) must be connected external to the power unit to determine the correct settings for COMPensation switches 1 and 2. When using the Model LM-13 Equipment in conjunction with Model RBM Equipment, turn the main power switch ON to apply filament voltage to the frequency meter, turn the receiver power switch to the PLATE ON position to apply plate voltage to the frequency meter.

Allow the vacuum tube filaments to warm for at least ten minutes then the equipment will be ready for use.

SECTION IV

4. OPERATION.

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.

4-1. CORRECTING TO CALIBRATION.

Before attempting to make any frequency adjustments, the heterodyne oscillator should always be corrected to agreement with the calibration through comparison with the crystal oscillator at the crystal check point nearest to the frequency desired. Comparison between the crystal and heterodyne oscillator may be made at many points over the calibrated range through the employment of the fundamental or harmonic frequencies of either or both oscillators. Comparison between the two oscillators is effected by rotating the heterodyne tuning control through a portion of the scale range corresponding to the crystal check point desired, and noting the beat tones as heard in a pair of 600-ohm headphones plugged into the PHONES jack (the MODULATION switch must be set to the OFF position).

To correct the heterodyne oscillator preparatory to setting on any desired frequency within the calibrated range, proceed as follows:

A. From the HIGH or LOW frequency indices on the front and rear covers of the calibration book, determine in which band the desired frequency is located, and set the FREQuency BAND switch to correspond.

B. Also, from the frequency indices, ascertain on which page the desired frequency is listed, and turn thereto. The crystal check point nearest the desired frequency, together with the dial setting thereof, will be found noted in red at the bottom of this page.

C. Set the heterodyne oscillator scales to agree with this crystal check point dial setting (CRYSTAL and both POWER switches ON; MODULATION switch OFF). A beat note will most probably be heard in the phones, as complete absence of beat tone can result only from four possible conditions, as follows: when the heterodyne oscillator is exactly on calibration, when it is so far off calibration that the beat frequency is above audibility, when the MODULATION switch is set to ON, and when the equipment is defective. However, should no beats be heard, which of the first two of these conditions may exist can be determined by rotating the CORRECTOR dial to where the beats become audible, and noting the direction of change. If the third or fourth condition is the cause, no beats should be heard at any point in the complete heterodyne oscillator range.

D. With the heterodyne oscillator dials on the desired crystal check point setting, the heterodyne oscillator frequency should be adjusted as close to the crystal oscillator frequency as possible, by rotation of the CORRECTOR dial only. Adjust the CORRECTOR to produce zero beat at the strongest beat point within its range. After the operator has become familiar with the equipment, it will be found that this adjustment can be precisely made to practically zero beat. This is possible because the design is such that all "locking-in" tendencies have been minimized, and characteristic "rushes" due to the rise and fall of the beat frequency peaks are aurally recognizable well below the lower limit of audible tone.

NOTE: In making the first correction to calibration immediately after any installation or physical modification thereof, the DIAL HUNDREDS scale should be read from a position directly in line therewith.

When so corrected, the heterodyne oscillator frequency will agree with the calibration (to within the reset accuracies previously quoted) throughout the range of frequencies included on all the pages to which this particular crystal check point applies, provided: that the ambient temperature remains constant, and the filament and/or plate supply voltages do not vary by more than 10% (see Section 4-2).

4-2. READJUSTMENT OF TRIMMER CAPACITORS.

It may be found that the heterodyne oscillator cannot be corrected to agree with the calibration as explained in Section 4-1, particularly if the frequency meter is installed in a locality where either extreme condition of humidity prevails. Under such conditions, and then only, it becomes necessary to reset the heterodyne trimmer capacitors C-103 and C-104. Access to the trimmer adjusting screws may be had through the holes in the upper right hand corner of the frequency meter panel after swinging aside the L and H cover plates. An ordinary screwdriver will be required to make these adjustments, the necessary procedure being as follows:

A. Place the frequency meter in operation, with the FREQuency BAND switch set to LOW and MODULATION switch to OFF. Allow the frequency meter to warm for a period of at least ten minutes before proceeding.
B. Set the DIAL UNITS and DIAL HUNDREDS scales to agree with the reading given for 250 Kcs on page 14 of the calibration book. Set the CORRECTOR dial at midscale (4.5 divisions).
C. After determining that the dials are set correctly as in (B), insert the screwdriver through the L hole in the panel and rotate the trimmer capacitor C-103 toward the right, while listening in the phones, until the heterodyne oscillator is set to zero beat with the crystal calibrator.
D. Check the ability of the CORRECTOR to reset the heterodyne oscillator to zero beat at all crystal check points listed on the back cover of the calibration book, proceeding as outlined in Section 4-1.
E. If the frequency meter cannot be corrected at all crystal check points in the LOW band with the trimmer adjustment that was made with the CORRECTOR set at 4.5 for 250 Kcs, the processes outlined in (C) and (D) should be repeated, with the CORRECTOR set to 6 divisions for 250 Kcs.
F. By thus progressing, a setting of the L trimmer will be found where it will be possible with the CORRECTOR to reset the frequency meter to zero beat at all crystal check point readings given for the LOW band in the calibration book.
G. Cover the L trimmer, and repeat the above described processes with the FREQuency BAND switch set to HIGH and the DIAL UNITS and DIAL HUNDREDS scales set to agree with the reading given for 4000 Kcs on page 34 of the calibration book. Adjust the trimmer capacitor C-104 through the H hole to the position where it is possible with the CORRECTOR to reset the heterodyne oscillator to zero beat at all crystal check points listed for the HIGH band.

4-3. BEAT POINT IDENTIFICATION.

It was stated in Section 4-1 that "comparison between the crystal and heterodyne oscillator may be made at many points over the calibrated range through the employment of the fundamental or harmonic frequency of either or both oscillators." When correcting the heterodyne oscillator to calibration, it will be found that there are numerous beat points at various harmonic combinations which are not listed as crystal check points in the calibration book. In most cases, the intensity of these unlisted beat points is relatively low. In order that there may be no confusion as to the actual crystal check points, however, the beat points encountered at the various lowest harmonic combinations of the two oscillators (and their relative outputs for a typical heterodyne frequency meter connected to its companion power source) are given in the following tabulations (the calibrated crystal check points are marked with asterisks):

Low Band

Beat Point (Het. Fund. Freq.)	*Lowest Het. Harmonic*	*Lowest Crys. Harmonic*	*Relative Output (500 Cycle Beat)*
125.00*	8	1	Strong
128.21	39	5	Weak
129.03	31	4	Weak
130.43	23	3	Weak
131.57	38	5	Weak
133.33	15	2	Strong
135.13	37	5	Weak
136.36	22	3	Weak
137.93	29	4	Weak
138.88	36	5	Very weak
142.85	7	1	Strong
147.05	34	5	Weak
148.14	27	4	Weak
150.00	20	3	Weak
151.51	33	5	Weak
153.84	13	2	Strong
156.25	32	5	Weak
157.89	19	3	Weak
160.00	25	4	Weak
161.29	31	5	Weak
166.67*	6	1	Strong
172.41	29	5	Weak
173.91	23	4	Weak
176.47	17	3	Strong
178.57	28	5	Weak
181.81*	11	2	Strong
185.18	27	5	Weak
187.50	16	3	Strong
190.47	21	4	Weak
192.31	26	5	Weak
200.00*	5	1	Strong
208.33	24	5	Weak
210.53	19	4	Weak
214.28	14	3	Strong
217.39	23	5	Weak
222.22*	9	2	Strong
230.76	13	3	Strong
235.29	17	4	Strong
238.09	21	5	Weak
250.00*	4	1	Strong

High Band			
Beat Point (Het. Fund. Freq.)	*Lowest Het. Harmonic*	*Lowest Crys. Harmonic*	*Relative Output (500 Cycle Beat)*
2000*	1	2	Very strong
2125	8	17	Weak
2143	7	15	Strong
2166	6	13	Strong
2200	5	11	Strong
2250*	4	9	Strong
2286	7	16	Weak
2333	3	7	Very strong
2375	8	19	Weak
2400	5	12	Strong
2428	7	17	Weak
2500*	2	5	Very strong
2571	7	18	Weak
2600	5	13	Strong
2625	8	21	Weak
2667	3	8	Very strong
2714	7	19	Weak
2750*	4	11	Strong
2800	5	14	Strong
2833	6	17	Weak
2857	7	20	Weak
2875	8	23	Very weak
3000*	1	3	Very strong
3125	8	25	Weak
3143	7	22	Weak
3167	6	19	Weak
3200	5	16	Strong
3250*	4	13	Strong
3286	7	23	Weak
3333	3	10	Strong
3375	8	27	Very weak
3400	5	17	Weak
3420	7	24	Very weak
3500*	2	7	Very strong
3571	7	25	Very weak
3600	5	18	Weak
3625	8	29	Very weak
3667	3	11	Strong
3714	7	26	Very weak
3750*	4	15	Strong
3800	5	192	Weak
3833	6	23	Weak
3857	7	27	Very weak
3875	8	31	Very weak
4000*	1	4	Very strong

NOTE: The relative output values when changed to milliwatts are as follows:

very strong—100 milliwatts
strong —10-100 milliwatts
weak —1.0-10 milliwatts
very weak —0.1-1.0 milliwatts

Therefore under actual operating conditions, those beat points which are listed as very weak and many of those listed as weak (levels of 5.0 milliwatts or less) will probably not be heard.

4-4. TRANSMITTER ADJUSTMENTS.

Briefly, the method of adjusting a transmitter to a desired frequency consists of zero beating the transmitter frequency with the proper heterodyne oscillator frequency, effecting the comparison by means of a pair of headphones plugged into the PHONES jack located on the front panel of the frequency meter.

Specifically the procedure is as follows:

A. Correct the heterodyne oscillator to calibration at the crystal check point nearest to the desired frequency, as explained in Section 4-1 (MODULATION Switch should be OFF).
B. Turn the CRYSTAL switch to OFF.
C. Turn the frequency meter tuning control to the dial setting of the desired frequency, or by interpolation as given in the calibration book. Do not disturb the CORRECTOR adjustment as made in (A) above.
D. With the frequency meter pick-up lead loosely coupled to the transmitter output, tune the transmitter to give an audible beat in the phones.
E. Adjust the RF COUPLING control to obtain a comfortable signal level in the headphones.
F. Tune the transmitter to zero beat with the frequency meter.

NOTE: Operations (B) to (F) should be accomplished in the shortest possible interval following operation (A), otherwise voltage and/or temperature changes may cause the frequency meter to drift.

4-5. RECEIVER ADJUSTMENTS.

4-5-1. General.

The method of adjusting a receiver to a desired frequency consists of tuning the receiver to the proper heterodyne oscillator output frequency, effecting the comparison by means of a pair of headphones connected to the receiver output circuit. The method varies with the character of signal reception involved.

4-5-2. CW Receiver Adjustment.

To tune a CW receiver to a desired frequency, proceed as follows:

A. Correct the heterodyne oscillator to calibration at the crystal check point nearest the desired frequency, as explained in Section 4-1 (the MODULATION switch must be set to OFF).
B. Turn the CRYSTAL switch to OFF, and transfer the phones from the frequency meter to the receiver output jack.

C. Turn the frequency meter tuning control to the dial setting of the desired frequency, as given in the calibration book or by interpolation. Do not disturb the CORRECTOR adjustment as made in (A) above.
D. With the frequency meter pick-up lead loosely coupled to the receiver antenna lead, tune the receiver to give an audible signal in the phones.
E. Adjust the RF COUPLING control to obtain a comfortable signal.
F. Adjust the receiver tuning to that side of zero beat which results in best reception conditions for the particular operator concerned.

NOTE: The notation at the end of Section 4-4 applies to this and all other operations for which the Model LM-13 Crystal Calibrated Frequency Indicating Equipment may be employed.

4-5-3. MCW Receiver Adjustment.

To tune an MCW receiver to a desired frequency, the following procedure applies:

A. Correct the heterodyne oscillator to calibration at the crystal check point nearest to the desired frequency, as explained in section 4-1 (the MODULATION switch must be set to OFF).
B. Turn the CRYSTAL switch to OFF, and transfer the phones from the frequency meter to the receiver output jack.
C. Turn the frequency meter tuning control to the dial setting of the desired frequency, as given in the calibration book or by use of the interpolation table. Do not disturb the CORRECTOR adjustment as made in (A) above.
D. Turn the MODULATION switch to ON.
E. With the frequency meter pick-up lead loosely coupled to the receiver antenna lead, tune the receiver to give an audible signal in the phones.
F. Adjust the RF COUPLING control to obtain a comfortable signal.
G. Adjust the receiver tuning for maximum response.

4-6. FREQUENCY MEASUREMENTS.

The Model LM-13 Crystal Calibrated Frequency Indicating Equipment may also be employed for accurately measuring a frequency emitted from an external source, whether it be of local or remote origin, provided that such frequency lies within the calibrated range.

If it is desired to accurately measure the emitted frequency of an adjacent transmitter or oscillator, the order of which is approximately known, the heterodyne oscillator is first corrected to the crystal check point nearest to the approximately known frequency, as explained in Section 4-1 (the MODULATION switch must be set to OFF). The actual frequency is then determined (after loosely coupling the frequency meter pick-up wire to the source and turning the CRYSTAL switch to OFF) by turning the frequency meter tuning control to the zero beat point found nearest the setting given for the approximate frequency, and reading from the appropriate frequency column or by use of the interpolation table, in the calibration book.

If the order of the frequency to be measured is absolutely unknown, it may first be determined to an approximation most readily with the aid of an absorption type wavemeter, following which the actual frequency is determined as explained in the preceding paragraph.

When it is desired to accurately measure a frequency of remote origin, the signal is first tuned in on a radio receiver; and the approximate frequency noted from the receiver calibration. The heterodyne oscillator of the frequency meter is next corrected to calibration at the nearest crystal check point. The CRYSTAL switch is then turned to OFF; the phones are transferred back to the receiver output jack; the frequency meter pick-up wire is loosely coupled to the receiver antenna lead; and the frequency meter tuning control is turned until its signal is heard in the phones. If the signal in question is CW in character, the receiver is tuned to zero beat therewith, and the frequency meter is tuned to zero beat with the receiver (MODULATION switch OFF). If the signal is modulated, both the receiver and frequency meter are adjusted for maximum response, and the frequency meter MODULATION switch is turned to ON. In both cases, the frequency read from the appropriate column in the calibration book or by interpolation (for the resultant frequency meter dial setting) is the frequency of the signal in question.

NOTE: THE POWER SWITCHES MUST ALWAYS BE TURNED OFF WHEN THE EQUIPMENT IS NOT IN USE TO AVOID RAPID EXHAUSTION OF THE BATTERIES. A SAFETY DEVICE PREVENTS THE CLOSING OF THE COVER WHEN THE POWER SWITCHES ARE ON.

SECTION V

5. MAINTENANCE.

5-1. GENERAL ROUTINE

The Model LM-13 Crystal Calibrated Frequency Indicating Equipment is ruggedly constructed to withstand the shocks and strains which may be expected in Naval radio service. Nevertheless, this equipment is extremely accurate and sensitive, and is therefore deserving of the careful handling normally accorded to instruments of precision.

All material used in the construction of this equipment is of the highest quality, and parts are rigidly inspected before and after assembly. In addition, all units such as resistors, capacitors, tubes, etc., which are subject to rapid deterioration through overloading, are operated at varying safety factors between the orders of from 3 to 10.

Normally, the only servicing required will be the occasional replacement of batteries and vacuum tubes. This should be done at regular intervals, dependent on the amount of usage to which the equipment is subjected. Do not lubricate any part of the equipment.

5-2. SERVICING DATA.

5-2-1. General.

Any of the Navy Model OE Series of Radio Receiver Analyzing Equipments may be used for the location of electrical faults throughout the Model LM-13 Equipment.

5-2-2. Resistors and Capacitors.

The cartridge resistors and small moulded capacitors supplied in the equipment are marked in accordance with the following RMA Standard Color Code.

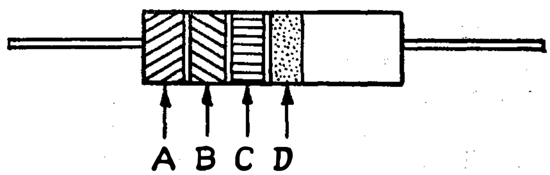
RMA Color Code for Resistors and Capacitors

Color	*Significant Figure*	*Decimal Multiplier*	*Tolerance*	**Voltage Rating*
Black	0	1	..	..
Brown	1	10	*1%	100 Volts
Red	2	100	*2%	200 Volts
Orange	3	1,000	*3%	300 Volts
Yellow	4	10,000	*4%	400 Volts
Green	5	100,000	*5%	500 Volts
Blue	6	1,000,000	*6%	600 Volts
Violet	7	10,000,000	*7%	700 Volts
Gray	8	100,000,000	*8%	800 Volts
White	9	1,000,000,000	*9%	900 Volts
Gold	..	0.1	±5%	1000 Volts
Silver	..	0.01	±10%	2000 Volts
No Color	..	..	±20%	500 Volts

* Applies to capacitors only.

RESISTORS

The nominal resistance value of fixed composition resistors is indicated in two manners. The one in most common use indicates the value by bands of color as follows:



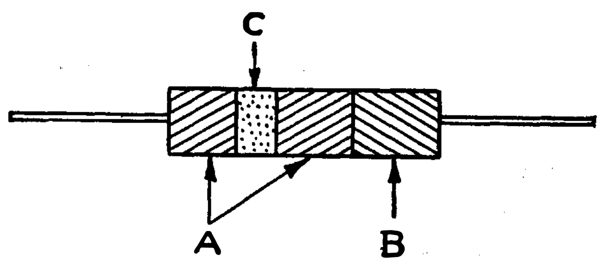
Band A indicates the first significant figure of the resistance of the resistor.

Band B indicates the second significant figure.

Band C indicates the decimal multiplier.

Band D, if any, indicates the tolerance limits about the nominal resistance value.

The less common system used for indicating nominal resistance value is as follows:

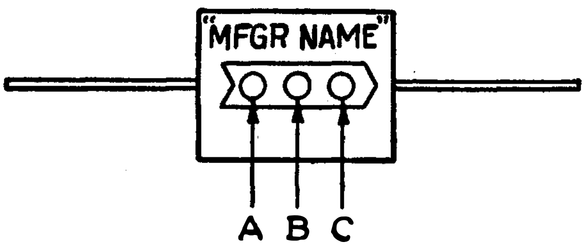


The body (A) of the resistor is colored to represent the first significant figure of the resistance value. One end (B) is colored to represent the second significant figure and a band, or dot (C) of color, located within the body color, indicates the decimal multiplier.

CAPACITORS

Two systems for color coding small fixed capacitors are in use. In either case, capacity is expressed in micromicrofarads and some means to avoid ambiguity in interpretation of colors provided. An arrow pointing from left to right or the manufacturer's name is generally used.

In general, capacitors having a working voltage of 500 volts are coded by means of three dots of color as follows:



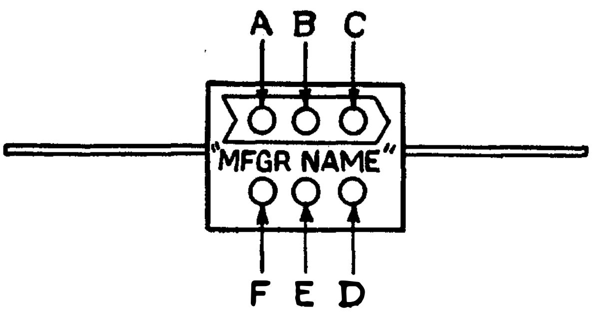
Dot A indicates the first significant figure of the capacitance of the capacitor.

Dot B indicates the second significant figure.

Dot C indicates the decimal multiplier.

An additional dot is sometimes shown when the working voltage is other than 500 volts. This dot indicates the voltage rating of the capacitor.

A second system now coming into common use involves six dots of color as follows:



Dot A indicates the first significant figure of the capacitance of the capacitor.

Dot B indicates the second significant figure.

Dot C indicates the third significant figure.

Dot D indicates the decimal multiplier.

Dot E indicates the tolerance about the nominal capacitance value.

Dot F indicates the voltage rating of the capacitor.

In addition to the individual marking of each resistor and capacitor by one of the foregoing methods, all electrical parts of the Model LM-13 Equipment are marked with symbol designations corresponding to those shown in the diagrams (Figures 18 and 19), and their nominal values can be determined by reference to Table II. Their actual values can readily be measured with ohmmeter portion of the Selective Analyzer and the Capacity Meter units of the Navy Model OE Equipment, respectively, by following the instructions furnished therewith.

5-2-3. Circuit Wiring.

To facilitate tracing of circuits in the Model LM-13 Equipment, various color combinations are used in the insulating coverings of all inter-element wiring. It will be noted that this coding is arranged to permit the character of any circuit to be identified at a glance. Thus the following single colors are assigned to basic circuits:

Circuits	*Color*	*Circuits*	*Color*
Plates	Red	Filaments	Yellow
Screens	Blue	Ground	Black
Grids	Green	Negative "B"	Slate
Suppressors	Orange	Audio Output	Brown
Cathodes	White		

Auxiliary circuits are then wired with mixtures of the above colors, as follows: red and blue for a circuit to a screen dropping resistor from the plate supply, blue from there to the screen, and blue and black to the screen bypass to ground. These combinations, as employed in the wiring of the frequency meter chassis, are shown by symbol letters throughout the wiring diagram (Figure 19) and explained in the legend thereto. The color coding of the conductors from the batteries is shown in the battery box wiring diagram (Figure 16). The ohmmeter portion of the Selective Analyzer and the test prods furnished with the Navy Model OE Equipment may be used in testing for continuity, grounds, etc., in all such circuits. All power supply circuits to the Model LM-13 Equipment should be opened while the ohmmeter is being used.

5-2-4. Voltage Analysis.

In general, any abnormality in voltage or currents, as measured at the individual vacuum tube elements, will serve as a guide to the underlying causes of operation faults. The following tabulation, showing vacuum tube terminal voltages with respect to ground (chassis), is typical for a Model LM-13 Crystal Calibrated Frequency Indicating Equipment.

Cable Terminal Number	Socket Terminal	VOLTAGE TO GROUND, 12 Volt Supply				
		V-101	V-102	V-103	V-104	V-105
25	Filament 1	6	12	0		
27	Filament 2	0	6	6		
27	Cathode	10	6	6.5		
27	Inner Grid		−3			
26	Anode Grid		110			
36	Control Grid	−12	−2.2	0		
26	Screen	123	45			
36	Suppressor	10.5				
26	Plate 1	82	117	126	120	0

The above values were obtained with a voltmeter having a resistance of 20,000 ohms per volt, and with the various switches on the Model LM-13 Equipment set to the following positions:

Switch	*Position*
FREQ. BAND	LOW
CRYSTAL	ON
MODULATION	OFF
HIGH VOLTAGE SELECTOR	260-475
LOW VOLTAGE SELECTOR	12V
POWER (FIL. & PLATE)	ON

Similar measurements may be taken for comparison with these values, using the Selective Analyzer and the Socket Selector units of the Navy Model OE Equipment; the meter used in the equipment has a sensitivity of 20,000 ohms per volt. All such measurements should be made in accordance with the procedures outlined in the instructions furnished with the particular analyzing equipment in use, and the values obtained, for a normal equipment, should agree with the above to within plus or minus 5%.

5-3. INDUCTOR DATA (WINDING INFORMATION) (Fig. 21).

A. L-101; Low Frequency Coil Assembly
B. L-102; High Frequency Coil Assembly
C. L-103; RF Choke Coil
D. L-104; AF Choke Coil, Navy Type CRP-30380, Manufacturer #14, No drawing.

5-4. CRYSTAL SPECIFICATIONS.

The crystal for use in the Model LM-13 Equipment is so ground as to prevent the possibility of oscillation on any frequency other than the desired fundamental or harmonics of the fundamental, when operating at a temperature of 20° Centigrade. The temperature coefficient does not exceed 0.0001 per cent (1 cycle) per degree Centigrade measured over a range of 80°C. The crystals provide a high degree of oscillation activity and freedom from spurious frequencies when installed in random selected frequency meters of the same group at all temperatures in the range of −32°C to +65°C. The crystals are within 0.001 per cent (10 cycles) of the specified frequency when installed in random selected frequency meters of the same group.

The crystals are mounted in the holder so as not to vary more than 0.001 per cent (10 cycles) for:

A. Prolonged vibration under simulated airplane conditions, i.e. vibration of 1/16 inch amplitude and with frequencies up to 3600 cycles per second.
B. After violent shaking by hand.
C. After turning equipment in any position, i.e. upside down or on side, etc., and returning to normal operating position.

The crystals are ground to a frequency of 1000 Kcs with dimensions of $.735'' {}^{+.0005}_{-.001}$ x $.721'' {}^{+.0005}_{-.001}$ x .0658".

5-5. READJUSTMENT OF CRYSTAL TRIMMER CAPACITOR.

On those units of the Model LM-10, LM-11, LM-12 and LM-13 which are provided with an adjustable capacitor C-118 inserted across the crystal, it is possible to set the frequency of the crystal oscillator more closely to 1000 Kcs absolute, should it be necessary to replace the original crystal supplied with the unit. This adjustment is possible provided there is available a frequency standard of acceptable accuracy. In general the accuracy of the frequency standard should be at least .0005% or five parts per million. If it becomes necessary to replace, or interchange crystals, the following procedure should be followed.

A. Remove the chassis from its cabinet (see section 3) and set it in an upright position on a bench or table top. A square of sheet metal somewhat larger than the unit should be placed under the chassis so that the crystal oscillator circuit will be in the same relative position with respect to ground as it is when normally operated in the cabinet.

B. Turn the plate, filament and crystal switches to their on positions and let the frequency meter warm up for at least fifteen minutes. Be sure that the modulation switch is in the off position. The frequency band switch may be in either position.

C. Connect the antenna post to a receiver which is associated with a frequency standard, or couple the receiver with a wire placed near the crystal oscillator circuit. When the operator is facing the front panel, the crystal oscillator may be found at the lower left hand rear corner of the chassis.

D. Obtain a beat note in the output of the receiver, which has been previously tuned to 1000 Kcs and also coupled to the frequency standard, and snap the crystal switch to its off position. If the signal does not disappear, the heterodyne frequency oscillator is undoubtedly beating with the standard instead of the crystal oscillator. In this event turn the units dial of the crystal frequency meter to a point on the scale at which no signal is heard. Then turn the crystal switch to its on position and adjust receiver sensitivity until the signal from the crystal oscillator is heard.

E. With the reception of a loud signal, insert a screw driver in the head of the slotted screw of the trimmer capacitor and adjust in such a direction that the pitch of the beat note decreases. The slotted screw is under the terminal board and at the lower left hand rear corner of the chassis and is easily found by inspection. After the beat note has been reduced to as near zero as possible, the screw should be locked in position by the application of a small amount of lacquer to the threads. Crystals may be replaced in the field without requiring adjustment of the trimmer and the resulting accuracy will still be within normal tolerance; even though maximum use is not made of the adjustable feature of the trimmer in the event a frequency standard is not available.

SECTION VI

6. VACUUM TUBE DATA.

The following tabulation shows the maximum operating characteristics for the tubes employed in the Model LM-13 Crystal Calibrated Frequency Indicating Equipment:

Symbol:	V-101	V-102	V-103	V-104 & V-105
Function:	Heterodyne Oscillator	Crystal Osc. and Detector	AF Amp. and Modulator	Voltage Regulators
Name:	Triple Grid Amplifier	Pentagrid Converter	Super Triode	Neon Glow
Navy Type No:	−77	−6A7	−76	None
Nearest Com'l Equivalent	77	6A7	76	T-4-1/2
Base:	Small 6 pin	Small 7 pin	Small 5 pin	2-Contact Bayonet
Heater Voltage (Ef):	6.3 V	6.3 V	6.3 V	..
Control Grid Voltage (Eg_1):	−3.0 V	−3.0 V	−13.5 V	..
Screen Voltage (Eg_2):	100.0 V	100.0 V	..	..
Plate Voltage (Ep_1):	250.0 V	250.0 V	250.0 V	90.0 V
Anode Grid Voltage (Ep_2):	..	200.0 V	..	..
Heater Current (If):	300.0 MA	330.0 MA	330.0 MA	..
Screen Current (Ig_2):	0.8 MA	2.2 MA	..	..
Plate Current (Ip_1):	15.0 MA	3.5 MA	6.8 MA	30.0 MA
Anode Grid Current (Ip_2):	..	4.0 MA	..	..
Transconductance (Sm):	1475 Micromho.	520 Micromho.	1640 Micromho.	..

NOTE: 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.

SECTION VII

NOTE: As a result of shortages of critical materials, it may be necessary for the contractor to substitute less critical materials in some instances. The data supplied in this book regarding electrical parts is correct as of the date of publication.

To assure that adequate replacement parts are obtained, it is imperative that replacement parts be ordered not only by the contractor's drawing number as it appears in the instruction book but also by the circuit symbol assigned to the particular part.

TABLE I
List of Major Units for
Model LM-13 Crystal Calibrated Frequency Indicating Equipment

Navy Type Number	*Name*	*Quantity*	*Weight, Lbs.*
CRR-74028	Heterodyne Frequency Meter	1	11.50
CRR-10111	Carrying Case	1	13.50
Accessories			
•	Calibration Book	1	•
•	Instruction Book	1	•
•	Operating Spare Parts (not shipped with equipment—shipped to supply base in bulk)	1 set for each 3 equipments	
CMQ-10110	Canvas Bag and Strap	1	4.00

TABLE II
Parts List by Symbol Designations for
Model LM-13 Crystal Calibrated Frequency Indicating Equipment

Symbol Desig.	*Function*	*Description*	*Navy Type Number*	*Navy Dwg. or Spec. Number*	*Mfr.*	*Mfr's. Desig.*	*Bendix Dwg. Number*
		SECTION 1 (101 TO 199)—TYPE CRR-74028 HETERODYNE FREQUENCY METER					
		CAPACITORS					
C-101	Heterodyne Tuning	Min. cap. 10-13 Mmf, Max. cap. 185 Mmf, Var., Air	.	.	1		AL73588-2
C-102	Heterodyne Corrector	Max. cap. 3-4 Mmf, Var., Air	.	.	12	Special	C59347
C-103	LF Het. Trimmer	Max. cap. 8-10 Mmf, Adj., Air	.	.	12	Special	C59348
C-104	HF Het. Trimmer	Same as C-103	.	.	.	.	.
C-105	Heterodyne Coupling	25 Mmf ±10%, 500V DCW, Mica	-48711-10	RE 48A 148	4	5WS-5Q25	A26112-2
C-106	Antenna Coupling	Same as C-105					
C-107	Modulator Coupling	.04 Mfd +10% −3%, 200V DCW, Paper	-48430	RE 13A 488C	4	HC507	A212
C-108	Audio Coupling	.02 Mfd ±10%, 600V DCW, Mica	-48428-10	RE 13A 389K	4	6S2	A26111-1
C-109A	Het. RF Bypass	0.1/0.1/0.1 Mfd, +10% −3%, 400V DCW, Oil-paper	-48713A	RE 48AA 129	4	"D"	A205-2
C-109B	Het. Pl. & Ser. Bypass						
C-109C	Het. Negative Bypass						
C-110A	Audio Cathode Bypass	0.1/0.1/0.1 Mfd +10% −3%, 400V DCW, Oil-paper	-48709	RE 48AA 138	4	"D"	A207-2
C-110B	Plate Supply Bypass						
C-110C	Negative HV Bypass						
C-111A	Det. Screen Bypass	Same as C-109	-48713A	.	.	.	.
C-111B	Crystal Anode Bypass						
C-111C	Det. Plate Bypass						
C-112	Audio Plate Bypass	0.5 Mfd +10% −3%, 400V DCW, Oil-paper	-48704	RE 48AA 138A	4	"D"	A203-2
C-113	Modulator Tuning	Same as C-107	-48430	.	.	.	.
C-114	Modulator Feedback	.0005 Mfd ±10%, 500V DCW, Mica	-48691-10	RE 48A 148B	4	5WS-5T5	A26112-3
C-115	Audio Choke Bypass	.001 Mfd ±10%, 600V DCW, Mica	-48645-10	RE 48AA 112	4	4-12010	A62111-2

Symbol Desig.	Function	Description	Navy Type Number	Navy Dwg. or Spec. Number	Mfr.	Mfr's. Desig.	Bendix Dwg. Number
C-116	Het. Padder	5 Mmf ±.5 Mmf, 500V DCW, Silver on ceramic	.	.	19	N250K5	A107158-050
C-117	Het. Grid Blocking	100 Mmf ±10%, 500V DCW, Mica	-48674-B10	.	20	.	C56306-101
C-118	Crystal Oscillator Trimmer	Part of Resistor and Capacitor assembly includes adjustable plate, bracket and bracket mounting	.	.	1	.	AC60920-1
C-119	Anti-resonator	50 Mmf ±10%, 500V DCW, Mica	-48695-B10	.	20	.	C56306-500
		MISCELLANEOUS ELECTRICAL PARTS					
E-101A	Push Post Assembly	Brass, Nickel-plated	.	.	18	.	A29383
E-101B	Terminal Post Ins.	Ceramic pair	.	RE 13A 317F	9	.	A11092
E-102	Wire Clamp	Ceramic pair	.	RE 13A 317F	9	.	A1693
E-103	Wire Clamp	Same as E-102	.	.	.	.	.
E-104	Wire Clamp	Same as E-102	.	.	.	.	.
E-105	Wire Clamp	Same as E-102	.	.	.	.	.
E-106	Wire Clamp	Same as E-102	.	.	.	.	.
E-107	Wire Clamp	Same as E-102	.	.	.	.	.
E-108	Grid Clip	Spring release type	.	.	11	.	A221-1
E-109	Feed Through Bushing	Ceramic pair	.	RE 13A 317F	9	.	A11319
E-113	Grid Clip	Same as E-108	.	.	.	.	.
		JACKS AND RECEPTACLES					
J-101	Telephone Jack	Open circuit, Short	-49025	.	2	#1	A219
J-102	Power Receptacle	5-cont., for 1-1/4" plug	-49036	RE 49AA 122B	1	.	AA306-1
		INDUCTORS AND REACTORS					
L-101	LF Coil	9.5 MH ±1%, 525 turns, 6 pies, 7-42 Litz, Ceramic form	.	.	1	.	AL73577
L-102	HF Coil	36.95 μH ±1%, 31-1/4 turns, 7-42 Litz	.	.	1	.	AL74209
L-103	RF Choke	1.7 MH ±3%, Universal winding, Sealed, 40Ω DC	-47110	.	1	.	AA1665-1

TABLE II (*Continued*)

Symbol Desig.	*Function*	*Description*	*Navy Type Number*	*Navy Dwg. or Spec. Number*	*Mfr.*	*Mfr's. Desig.*	*Bendix Dwg. Number*
		SECTION 1 (101 TO 199)—TYPE CRR-74028 HETERODYNE FREQUENCY METER (*Continued*)					
		INDUCTORS AND REACTORS—(Continued)					
L-104	AF Choke	600 H at 1.0 MA DC, Evacuated	-30380	•	14	•	A1716
		RESISTORS					
R-101	Het. LF Cathode	7500Ω ±10%, 1/4W, Comp, Pigtail	-63433	RE 13A 372G	19	•	A18002-752
R-102	Het. HF Cathode	100Ω ±10%, 1/4W, Comp, Pigtail	-62433	RE 13A 372G	19	•	A18002-101
R-103	Voltage Regulator	25,000Ω ±5%, 2.91W, WW, Lug terminals	-63606	RE 13A 372J	13	•	A15679-3
R-104	Heterodyne Plate	50,000Ω ±10%, 1/2W, Comp, Pigtail	-63360	RE 13A 372G	8	BT 1/2	A11207-42
R-105	Het. Negative HV	5000Ω ±10%, 1/2W, Comp	-63360	RE 13A 372G	8	BT 1/2	A11207-23
R-106	RF Coupling Control	500Ω ±10%, 1W, Impregnated strip potentiometer	-63500	•	3	72-118-Mod.	A2033
R-107	Detector Grid Leak	1 Megohm ±10%, 1/2W, Comp, Pigtail	-63360	RE 13A 372G	8	BT 1/2	A11207-57
R-108	Audio Plate	20,000Ω ±10%, 1W, Comp, Pigtail	-63288	RE 13A 372G	8	BT 1	A3527-5
R-109	Crystal Osc. Grid	.1 Megohm ±10%, 1/2W, Comp	-63360	•	8	BT 1/2	A11207-47
R-110	Detector Screen	Same as R-104	-63360	•	•	•	•
R-111	Audio Cathode	3,000Ω ±10%, 1/2W, Comp, Pigtail	-63360	RE 13A 372G	8	BT 1/2	A11207-20
R-112	Audio Grid	Same as R-107	-63360	•	•	•	•
R-113	Audio Filament	20Ω ±5%, 2.91W, WW, Lug terminals	-63501c	RE 13A 372J	13	•	A15679-1
R-114	Heterodyne Suppressor	Same as R-105	-63360	•	•	•	•
R-115	V-102 Positive HV	15,000Ω ±5%, 2.91W, WW, Lug terminals	-63571	RE 13A 372J	13	•	A15679-2
R-116	Regulator Cutout	25,000Ω ±10%, 1/2W, Comp, Pigtail	-63360	RE 13A 372G	8	BT 1/2	A11207-38
R-117	Het. Grid Leak	.15 Megohm ±10%, 1/4W	-63433	RE 13A 372G	19	•	A18002-154
		SWITCHES					
S-101A, B, C, D	Frequency Band	4PDT, Rotary, 1-section	•	•	12	•	C59061
S-102A, B	Power On-Off	DPST, Toggle	-24025	RE 24AA 118B	7	•	A100457

Symbol Desig.	Function	Description	Navy Type Number	Navy Dwg. or Spec. Number	Mfr.	Mfr's. Desig.	Bendix Dwg. Number
S-103	Standby	SPST, Toggle	-24041	RE 24AA 118B	7	•	A100456
S-104A, B	Crystal On-Off	DPDT, Toggle	-24033	RE 24AA 118B	7	•	A100455
S-105A, B, C, D	Modulation On-Off	4PDT, Rotary, 1-section	-24024A	•	12	H	C59363
		TRANSFORMERS					
T-101	Output & Modulator	20,000/600Ω Imp. ratio, Evacuated, Pri. Ind. 45 Henries ±10%	-30315A	•	14	U-3239	A1717
		VACUUM TUBES AND SOCKETS					
V-101	Het. Oscillator	Triple Grid	-77	RE 13A 600B	15	77	•
V-102	Crystal Osc. & Det.	Pentagrid Converter	-6A7	RE 13A 600B	15	6A7	•
V-103	Audio Amp. & Mod.	Super-Triode	-76	RE 13A 600B	15	76	•
V-104	Voltage Regulator	2-element, 1/4W, Neon, Bayonet base	•	•	5	T-4-1/2 Special	A9879
V-105	Voltage Regulator	Same as V-104	•	•	•	•	•
X-101	V-101 Socket	6-contact, Ceramic	-49329	RE 49AA 311	11	•	AA12336-1
X-102	V-102 Socket	7-contact, Small, Ceramic	-49333	RE 49AA 311	11	•	AA12337-1
X-103	V-103 Socket	5-contact, Ceramic	-49328	RE 49AA 311	11	•	AA12335-1
X-104	V-104 Socket	2-contact, Bayonet type	•	•	10	A3946A	A11586
X-105	V-105 Socket	Same as X-104	•	•	•	•	•
X-106	Crystal Receptacle	8-contact, Octal, Ceramic	-49326	RE 49AA 310	•	XC8	AA12338-1
		CRYSTAL AND HOLDER					
Y-101	Crystal	1 Kc, A-cut, ±.0001%/1°C, Evacuated holder, Octal tube base mounting	-40023B	•	1	•	AL73284-1
		SECTION 2 (201 TO 299)—ACCESSORIES					
		MISCELLANEOUS ELECTRICAL PARTS					
E-201A	Push Post Assembly	Brass, Nickel-plated	•	•	18		A29383
E-201B	Term. Post Ins.	Ceramic, Pair	•	RE 13A 317F	9	•	A11092
		PLUGS					
P-201	Cable Plug	5-contact, 1-1/4" OD, with cap	•	•	•	•	AC59588-1
P-202	"B" Bat. Plug	3 prong	•	•	21	30-3B	A107971
P-203	"A" Bat. Plug	2 prong	•	•	21	30-2M-3	A107973

ALL TOLERANCES PLUS OR MINUS 10 PER CENT EXCEPT WHEN OTHERWISE NOTED

TABLE III
Parts List by Navy Type Numbers for
Model LM-13 Crystal Calibrated Frequency Indicating Equipment

Quantity	*Navy Type Number*	*All Symbol Designations Involved*	*Description*
		MISCELLANEOUS—CLASS 10	
2	•	E-101A, E-201A	Push post, Nickel-plated brass
2	•	E-108, E-113	Grid clip, Spring release type
		SWITCHES—CLASS 24	
1	•	S-101A, B, C, D	4PDT, Rotary, 1-section
1	-24024A	S-105A, B, C, D	•
1	-24025	S-102A, B	•
1	-24033	S-104A, B	•
1	-24041	S-103	•
		AF TRANSFORMERS AND REACTORS—CLASS 30	
1	-30315A	T-101	•
1	-30380	L-104	•
		VACUUM TUBES—CLASS 38	
1	-6A7	V-102	Pentagrid Converter
1	-76	V-103	Super Triode
1	-77	V-101	Triple Grid
2	•	V-104, V-105	2 element, 1/4 watt, Neon, Bayonet base
		CRYSTALS—CLASS 40	
1	-40023B	Y-101	•
		RF TRANSFORMERS—CLASS 47	
1	-47110	L-103	•
1	•	L-101	9.5 MH ±1%, 525 turns, 6 pies, 7-42 Litz
1	•	L-102	36.95 μH ±1%, 7-42 Litz, 31-1/4 turns
		CAPACITORS—CLASS 48	
1	-48428-10	C-108	•
2	-48430	C-107, C-113	•
1	-48645-10	C-115	•
1	-48674-B10	C-117	•
1	-48691-10	C-114	•
1	-48695-B10	C-119	•
1	-48704	C-112	•
1	-48709	C-110A, B, C	•

TABLE III (Continued)

Quantity	*Navy Type Number*	*All Symbol Designations Involved*	*Description*
2	-48711-10	C-105, C-106	•
2	-48713A	C-109A, B, C C-111A, B, C	• •
1	•	C-101	Min. capacity 10-13 Mmf, Max. capacity 185 Mmf, Var., Air
1	•	C-102	Max. capacity 3-4 Mmf, Var., Air
2	•	C-103, C-104	Max. capacity 8-10 Mmf, Adj., Air
1	•	C-116	5 Mmf ±.5 Mmf, 500V DCW, Silver on ceramic
1	•	C-118	Crystal trimmer, part of assembly dwg. no. AC60920-1 includes adjustable plate, bracket and bracket mounting
		PLUGS AND RECEPTACLES—CLASS 49	
1	-49025	J-101	•
1	-49036	J-102	•
1	-49326	X-106	•
1	-49328	X-103	•
1	-49329	X-101	•
1	-49333	X-102	•
2	•	X-104, X-105	2 contact, Bayonet type
1	•	P-201	5 contact, 1-1/4" OD
1	•	P-202	3 prong plug
1	•	P-203	2 prong plug
		INSULATORS—CLASS 61	
2	•	E-101B, E-201B	Insulator, Ceramic pair
6	•	E-102 to E-107	Wire clamp, Ceramic pair
1	•	E-109	Feed through bushing, Ceramic pair
		RESISTORS—CLASS 63	
1	-63288	R-108	20,000Ω
1	-63360	R-111	3,000Ω
2	-63360	R-105, R-114	5,000Ω
1	-63360	R-116	25,000Ω
2	-63360	R-104, R-110	50,000Ω
1	-63360	R-109	0.1 Megohm

TABLE III (Continued)

Quantity	Navy Type Number	All Symbol Designations Involved	Description
2	-63360	R-107, R-112	1 Megohm
1	-63433	R-101	7500Ω
1	-63433	R-102	100Ω
1	-63433	R-117	0.15 Megohm
1	-63500	R-106	500Ω
1	-63501C	R-113	20Ω
1	-63571	R-115	15,000Ω
1	-63606	R-103	25,000Ω

TABLE IV
Operating Spare Parts List by Navy Type Numbers for Model LM-13 Crystal Calibrated Frequency Indicating Equipment

Quantity Per Unit	Navy Type Number	All Symbol Designations Involved	Description	Bendix Drawing No.
			VACUUM TUBES INCLUDING VOLTAGE REGULATORS—CLASS 38	
1	CRC-76	V-103	Audio Amplifier and Modulator, Super Triode	•
1	CRC-77	V-101	Heterodyne Oscillator, Triple Grid	•
1	CRC-6A7	V-102	Crystal Oscillator and Detector, Pentagrid Converter	•
1	None	V-104 V-105	Voltage Regulator, 2 element, 1/4 W, Neon Bayonet Base, T-4-1/2 Mod.	A9879

TABLE V
Bulk Spare Parts List by Navy Type Numbers for Model LM-13 Crystal Calibrated Frequency Indicating Equipment

Quantity Per Unit	Navy Type Number	All Symbol Designations Involved	Description	Bendix Drawing No.
			MISCELLANEOUS—CLASS 10	
1	None	None	Bristol wrench #6	A18223-3
1	None	None	Bristol wrench #8	A18223-2
1	None	None	Knob, Bakelite, Pointer	A100228
1	None	None	Ring, Vernier ring for tuning dial	A2059
1	None	None	Knob, Heterodyne oscillator tuning	C59470
1	None	None	Scale, Tuning dial	A29580
1	None	None	Knob, Heterodyne oscillator corrector	A29555
1	None	None	Card, Spot calibration	A10170
1	None	None	Post assembly, Push post type	A29383

TABLE V (*Continued*)

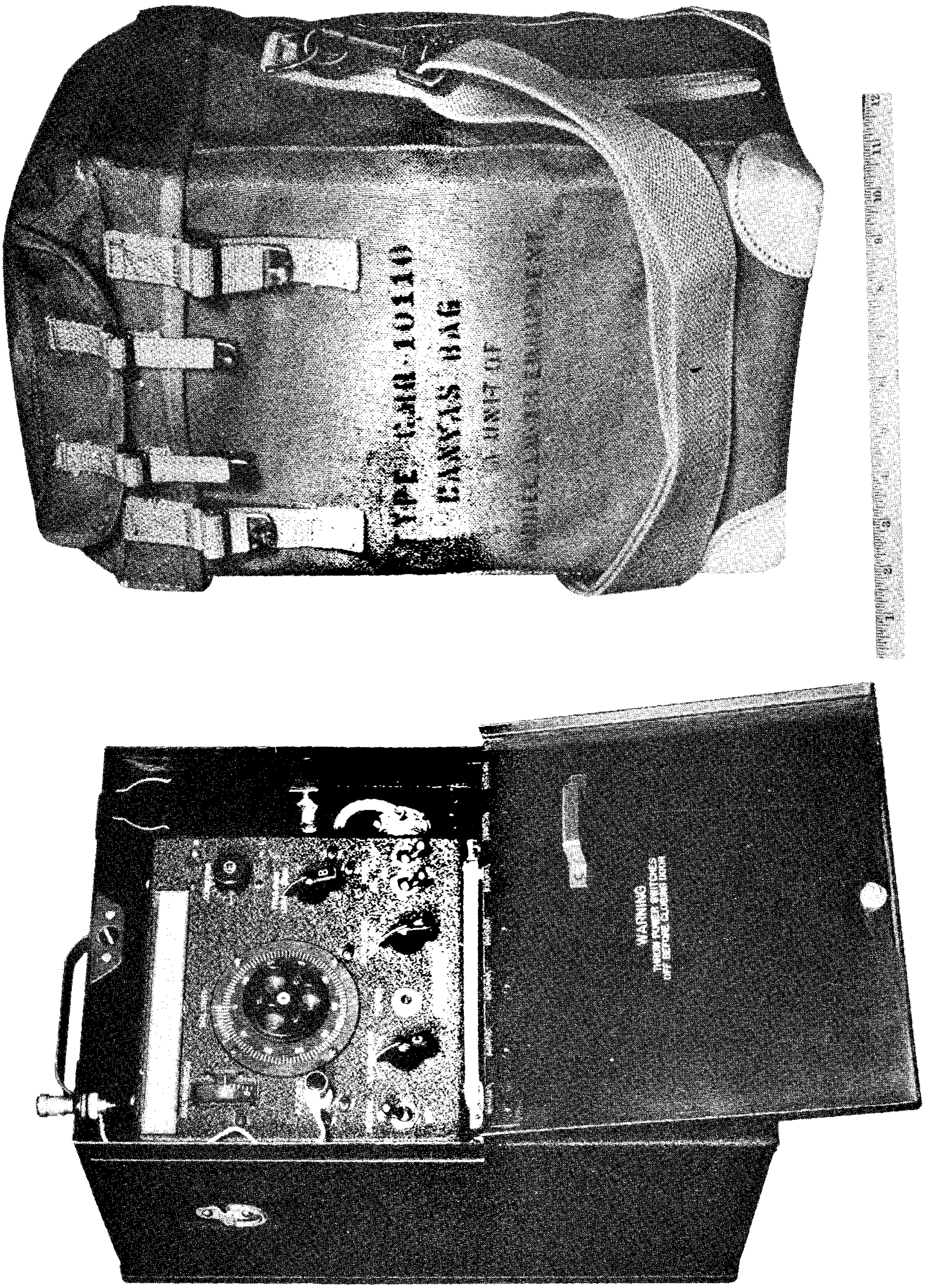
Quantity Per Unit	Navy Type Number	All Symbol Designations Involved	Description	Bendix Drawing No.
			SWITCHES—CLASS 24	
1		S-101A, B, C, D	Switch, Rotary, 4PDT	C59061
1	CHH-24025	S-102A, B	Switch, DPST, Toggle, Black nickle	A100457
1	CHH-24041	S-103	Switch, SPST, Toggle, Black nickle	A100456
1	CHH-24033	S-104A, B	Switch, DPDT, Toggle, Black nickle	A100455
1	COC-24024A	S-105A, B, C, D	Switch, Rotary, 4PDT	C59363
			AF TRANSFORMERS AND REACTORS—CLASS 30	
1	CRP-30315A	T-101	Output and Modulation Transformer, 20,000/600 ohms U-3239	A1717
1	CRP-30380	L-104	Audio Choke, 600 H at 1.0 MA DC, Evacuated case	A1716
			VACUUM TUBES INCLUDING VOLTAGE REGULATORS—CLASS 38	
4	CRC-76	V-103	Audio Amplifier and Modulator, Super Triode	•
4	CRC-77	V-101	Heterodyne Oscillator, Triple Grid	•
4	CRC-6A7	V-102	Crystal Oscillator and Detector, Pentagrid Converter	•
4	None	V-104, V-105	Voltage Regulator, 2 element, 1/4 W, Neon	A9879
			CRYSTALS—CLASS 40	
4	CRR-40023B	Y-101	Crystal and Holder, 1000 Kcs, A-cut	AL73284-1
			RF TRANSFORMERS—CLASS 47	
1	CRR-47110	L-103	Choke Assembly, 1.7 MH ±3%, Sealed	AA1665-1
1	None	L-101	Coil Assembly, 9.5 MH, Ceramic form, Wax impregnated	AL73577-1
1	None	L-102	Coil Assembly, 36.95 μH, Ceramic form, Wax impregnated	AL74209-1
			CAPACITORS—CLASS 48	
4	CD-48428-10	C-108	.02 Mfd ±10%, 600V DCW, Mica, 4-6S2	A26111-1
4	CD-48430	C-107, C-113	.04 Mfd +10% −3%, 200V DCW, Oil-paper	A212
4	CD-48645-10	C-115	.001 Mfd ±10%, 600V DCW, Mica 4-601	A26111-2
4	CAW-48674-B10	C-117	100 Mmf ±10%, 500V DCW, Mica	C56306-101
4	CD-48691-10	C-114	.0005 Mfd ±10%, 500V DCW, Mica, 5WS-5T5	A26112-3
4	CAW-48695-B10	C-119	50 Mmf ±10%, 500V DCW, Mica	C56306-500
1	CD-48704	C-112	0.5 Mfd +10% −3%, Hermetically sealed, 400V DCW, Oil-paper	A203-2
1	CD-48709	C-110A, B, C	0.1/0.1/0.1 Mfd +10% −3%, Hermetically sealed, 400V DCW, Oil-paper	A207-2
4	CD-48711-10	C-105, C-106	.000025 Mfd ±10%, 500V DCW, Mica, 5WS-5Q25	A26112-2

TABLE V *(Continued)*

Quantity Per Unit	*Navy Type Number*	*All Symbol Designations Involved*	*Description*	*Bendix Drawing No.*
1	CD-48713A	C-109A, B, C C-111A, B, C	0.1/0.1/0.1 Mfd +10% −3%, Hermetically sealed, 400V DCW, Oil-paper	A205-2
4	•	C-116	5 Mmf ±.5 Mmf, 500V DCW, Silver on ceramic	A107158-050
1	None	C-102	Max. capacity 3-4 Mmf, Var., Air	C59347
1	None	C-103, C-104	Max. cap. 8-10 Mmf, Adj., Air	C59348
			PLUGS AND RECEPTACLES—CLASS 49	
1	CRA-49026	J-101	Telephone jack, Open circuit, Short	A219
1	CRR-49036	J-102	Power receptacle, 5-contact for 1-1/4″ plug	AA306-1
1	CNA-49326	X-106	Crystal receptacle, 8-contact, Octal, Ceramic	AA12338-1
1	CNA-49328	X-103	V-103 socket, 5-contact, Ceramic	AA12335-1
1	CNA-49329	X-101	V-101 socket, 6-contact, Ceramic	AA12336-1
1	CNA-49333	X-102	V-102 socket, 7-contact, Small, Ceramic	AA12337-1
1	None	X-104, X-105	V-104, V-105 socket, Bayonet, 2-contact	A11586
			INSULATORS—CLASS 61	
4 pr.	None	E-101B	Terminal post insulator, Ceramic, Pair	A11092
4 pr.	None	E-102 to E-107	Wire clamp, Ceramic, Pair	A1693
4 pr.	None	E-109	Feed through bushing, Ceramic, Pair	A11319
			CONNECTING CABLES—CLASS 62	
1	None	None	Complete power cable assembly	AL73803-1
			RESISTORS—CLASS 63	
4	CIR-63288	R-108	20,000 ohms ±10%, 1 watt, BT1	A3527-3
4	CIR-63360	R-109	100,000 ohms ±10%, 1/2 watt, BT 1/2	A11207-47
4	CIR-63360	R-105, R-114	5,000 ohms ±10%, 1/2 watt, BT 1/2	A11207-23
4	CIR-63360	R-104, R-110	50,000 ohms ±10%, 1/2 watt, BT 1/2	A11207-42
4	CIR-63360	R-107, R-112	1.0 Megohm ±10%, 1/2 watt, BT 1/2	A11207-57
4	CIR-63360	R-111	3,000 ohms ±10%, 1/2 watt, BT 1/2	A11207-20
4	CIR-63360	R-116	25,000 ohms ±10%, 1/2 watt, BT 1/2	A11207-38
4	CER-63433	R-102	100 ohms ±10%, 1/4 watt	A18002-101
4	CER-63433	R-117	0.15 Megohm ±10%, 1/4 watt	A18002-154
4	CER-63433	R-101	7500 ohms ±10%, 1/4 watt	A18002-752
4	CBN-63500	R-106	500 ohms ±10%, 72-118 Mod.	A2033
4	COM-63501C	R-113	20 ohms ±5%, 2.91 watt	A15679-1
4	COM-63571	R-115	15,000 ohms ±5%, 2.91 watt	A15679-2
4	COM-63606	R-103	25,000 ohms ±5%, 2.91 watt	A15679-3

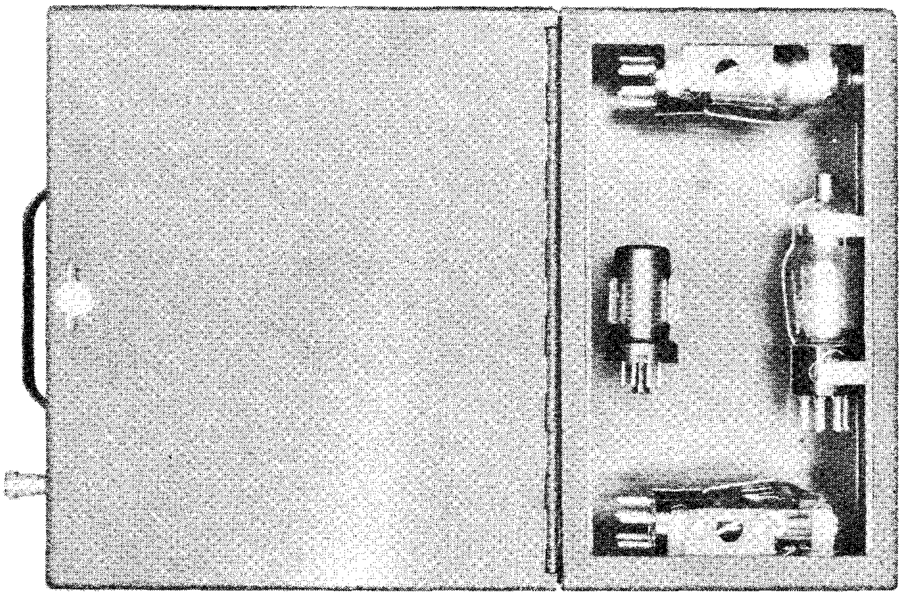
TABLE VI
List of Manufacturers

Code No.	*Mfr's. Prefix*	*Name*	*Address*
1	CRR	Bendix Radio Division of Bendix Aviation Corporation	Baltimore, Maryland
2	CRA	Carter Division, Utah Radio Products Co.	812 Orleans Street, Chicago, Illinois
3	CBN	Centralab	900 E. Keefe Avenue, Milwaukee, Wis.
4	CD	Cornell Dubilier Elec. Corporation	1000 Hamilton Blvd., S. Plainfield, N. J.
5	CG	G.E. Vapor Lamp Co.	Hoboken, N. J.
6	CHC	Hammarlund Mfg. Co.	424 W. 33rd Street, New York, N. Y.
7	CHH	Hart and Hegeman Div., Arrow-Hart & Hegeman	Hartford, Conn.
8	CIR	International Resistance Co.	401 N. Broad Street, Philadelphia, Penna.
9	CBU	Isolantite, Inc.	343 Courtland Street, Belleville, N. J.
10	•	Frank W. Morse	301 Congress Street, Boston, Mass.
11	CNA	National Company, Inc.	Malden, Mass.
12	COC	Oak Manufacturing Co.	1260 Clybourn Avenue, Chicago, Illinois
13	COM	Ohmite Manufacturing Co.	4835 W. Flournoy Street, Chicago, Illinois
14	CRP	Raytheon Manufacturing Company	190 Willow Street, Waltham, Mass.
15	CRC	RCA Radiotron Division RCA Manufacturing Co., Inc.	Harrison, N. J.
16	•	Simplex Wire & Cable Co.	79 Sidney Street, Cambridge, Mass.
17	CLT	Lundquist Tool and Mfg. Co.	57 Jackson Street, Worcester, Mass.
18	•	American Radio Hardware Co.	476 Broadway, New York, N. Y.
19	CER	Erie Resistor Corp.	Erie, Penna.
20	CAW	Aerovox Corp.	New Bedford, Mass.
21	•	Hugh H. Eby, Inc.	Philadelphia, Penna.
22	CKB	Mission Bell Radio Mfg. Corp.	Los Angeles, Calif.



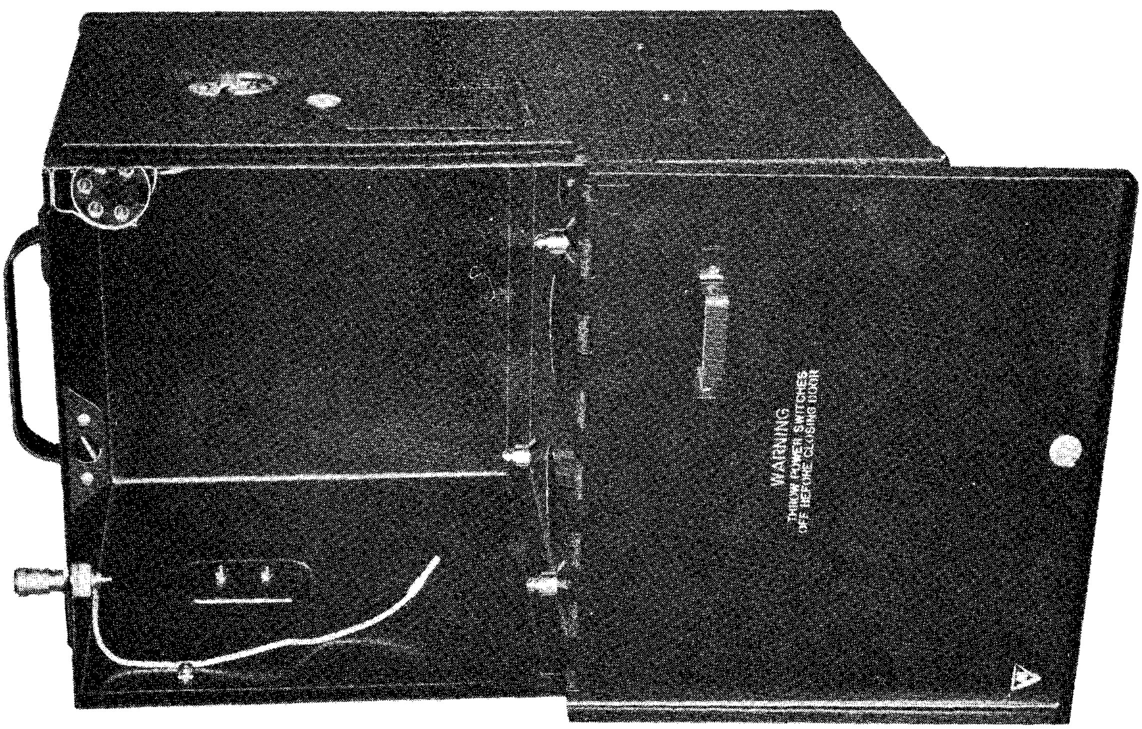
3978

Figure 1. Composite View, Model LM-13 Equipment



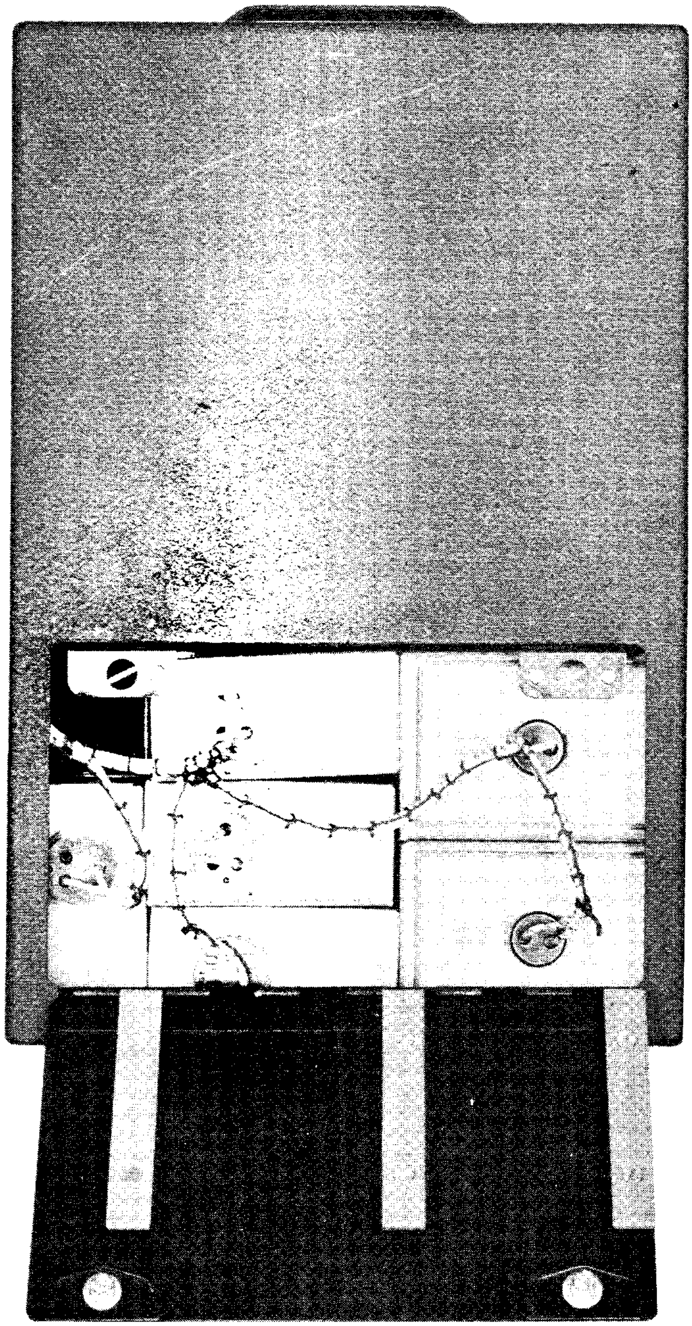
3959

Figure 2. Front View of Carrying Case, Showing the Spare Parts Compartment



3960

Figure 3. Front View of Carrying Case, Showing the Frequency Meter Compartment



4611

Figure 4. Rear View of Carrying Case, Showing the Battery Compartment

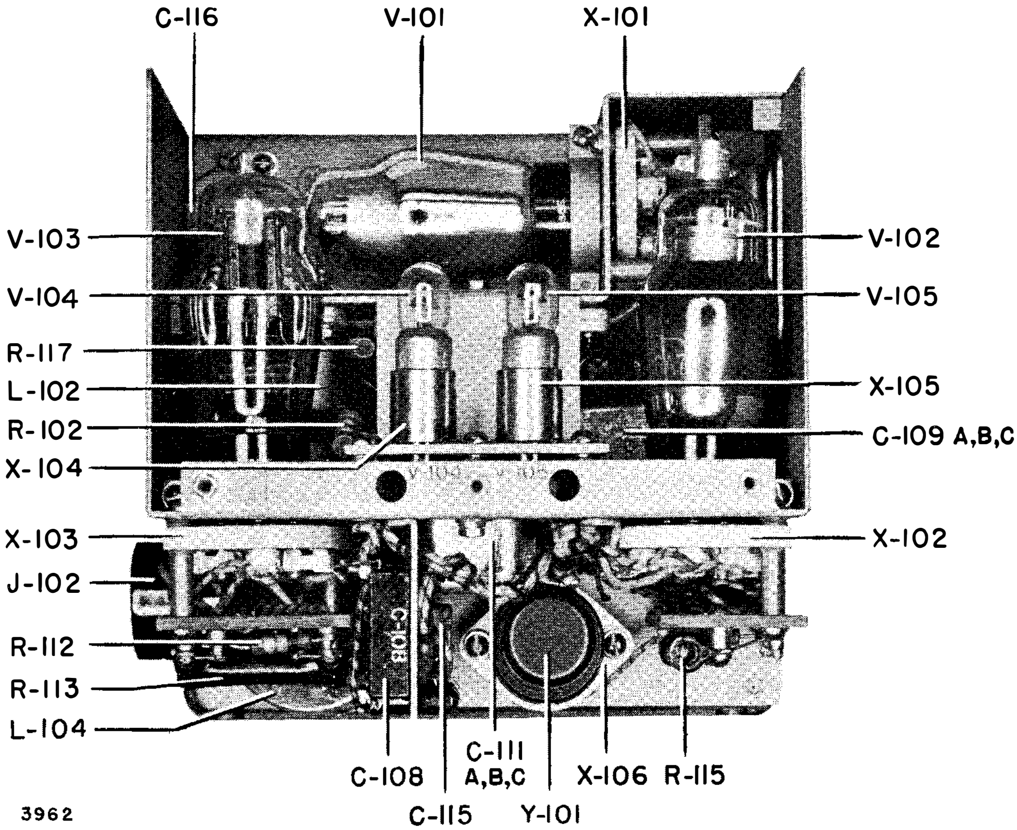


Figure 5. Rear View of Chassis

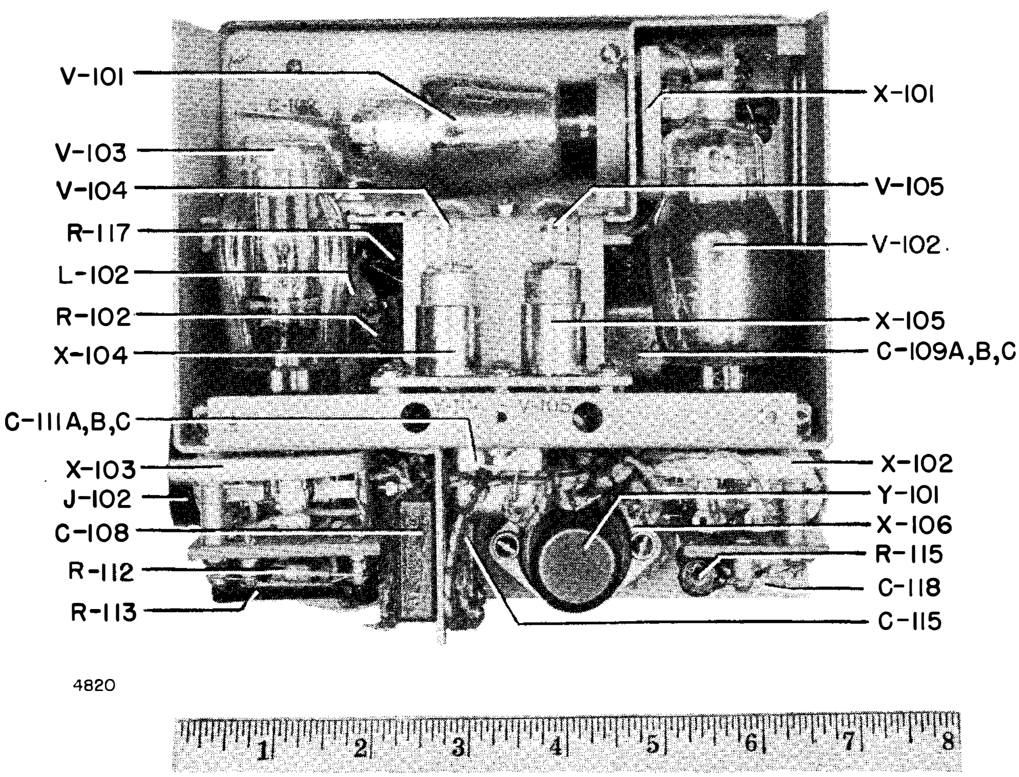
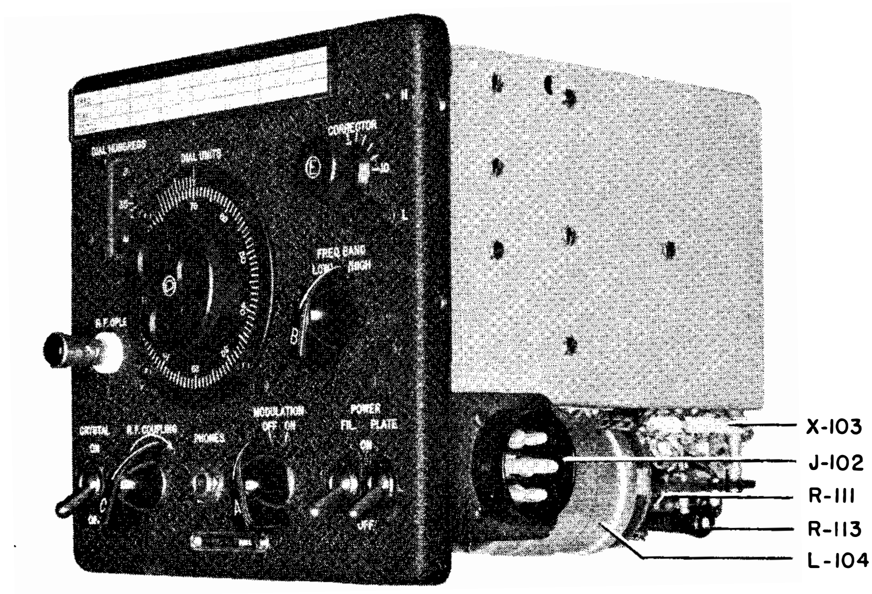
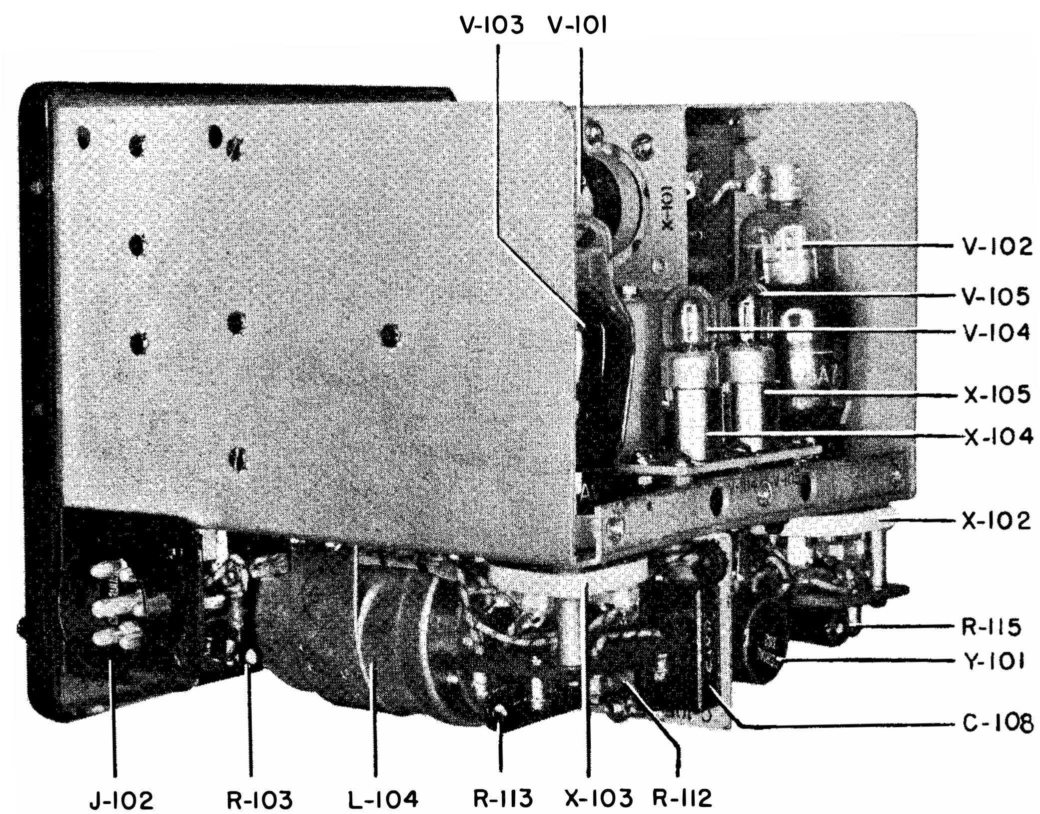


Figure 6. Rear View of Chassis (Model with Crystal Trimmer)



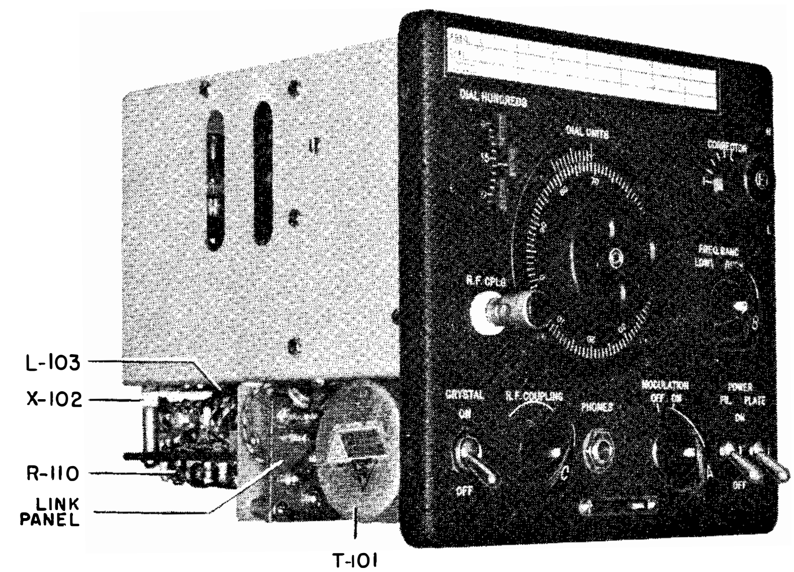
3734

Figure 7. Left Front Oblique of Chassis



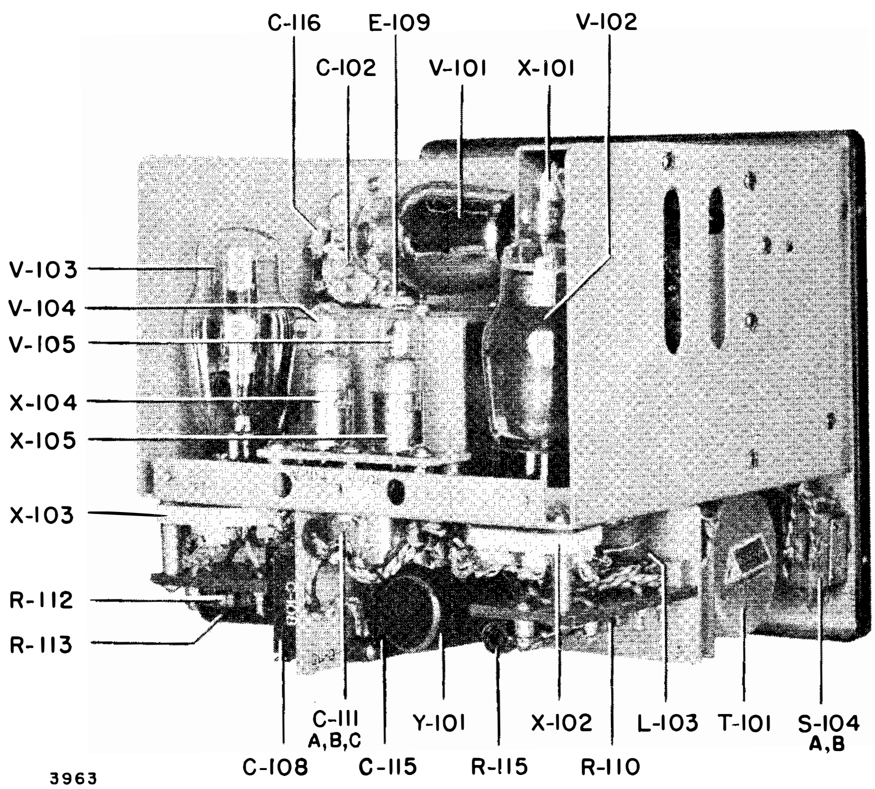
3735

Figure 8. Left Rear Oblique of Chassis



3732

Figure 9. Right Front Oblique of Chassis



3963

Figure 10. Right Rear Oblique of Chassis

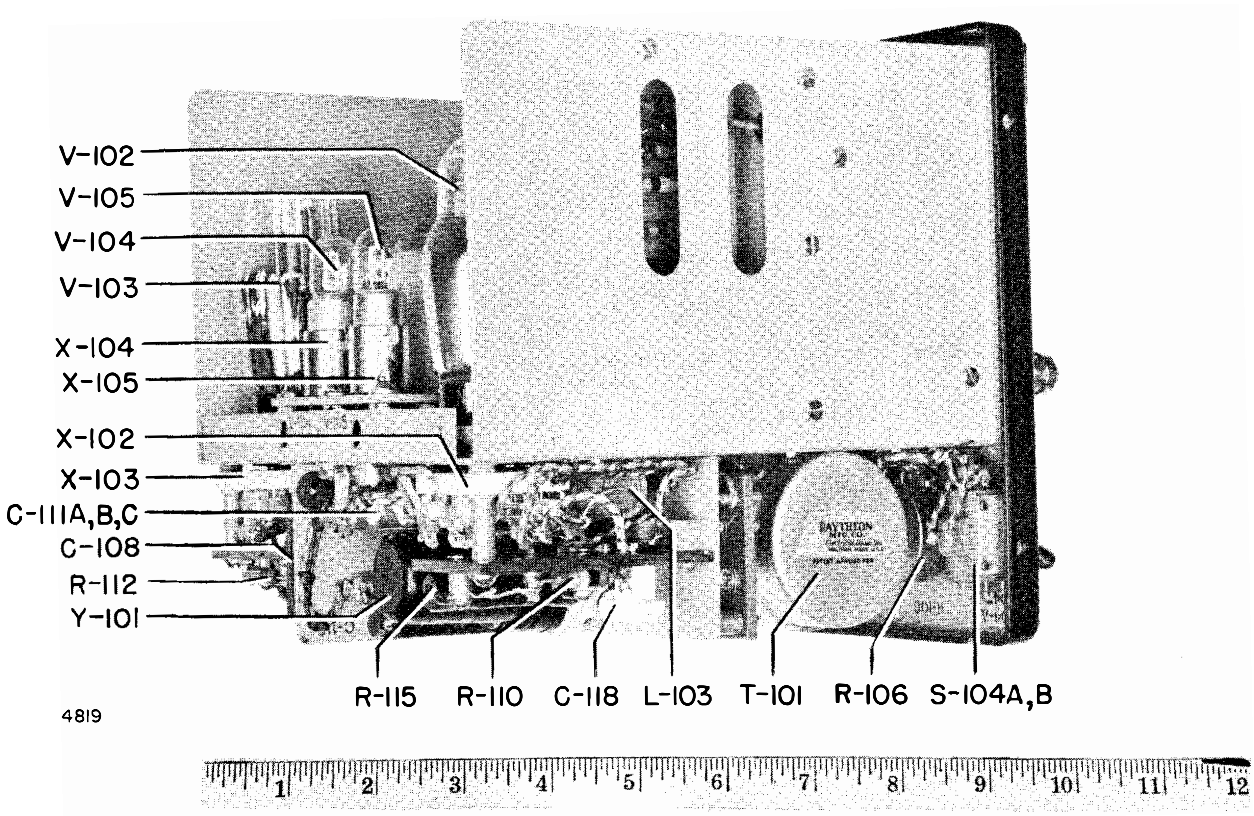


Figure 11. Right Rear Oblique of Chassis (Model with Crystal Trimmer)

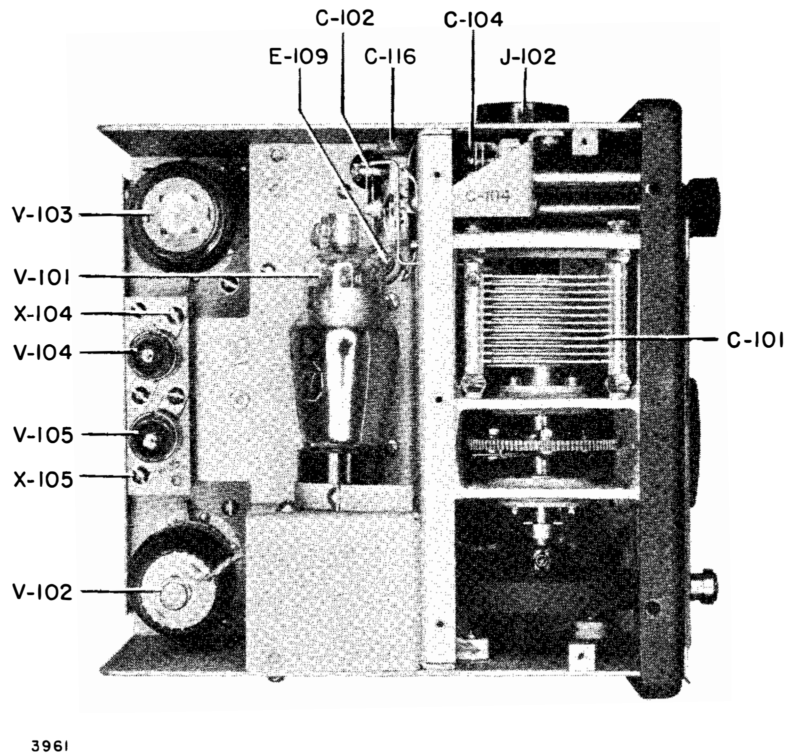


Figure 12. Top View of Chassis, Condenser Shield Removed

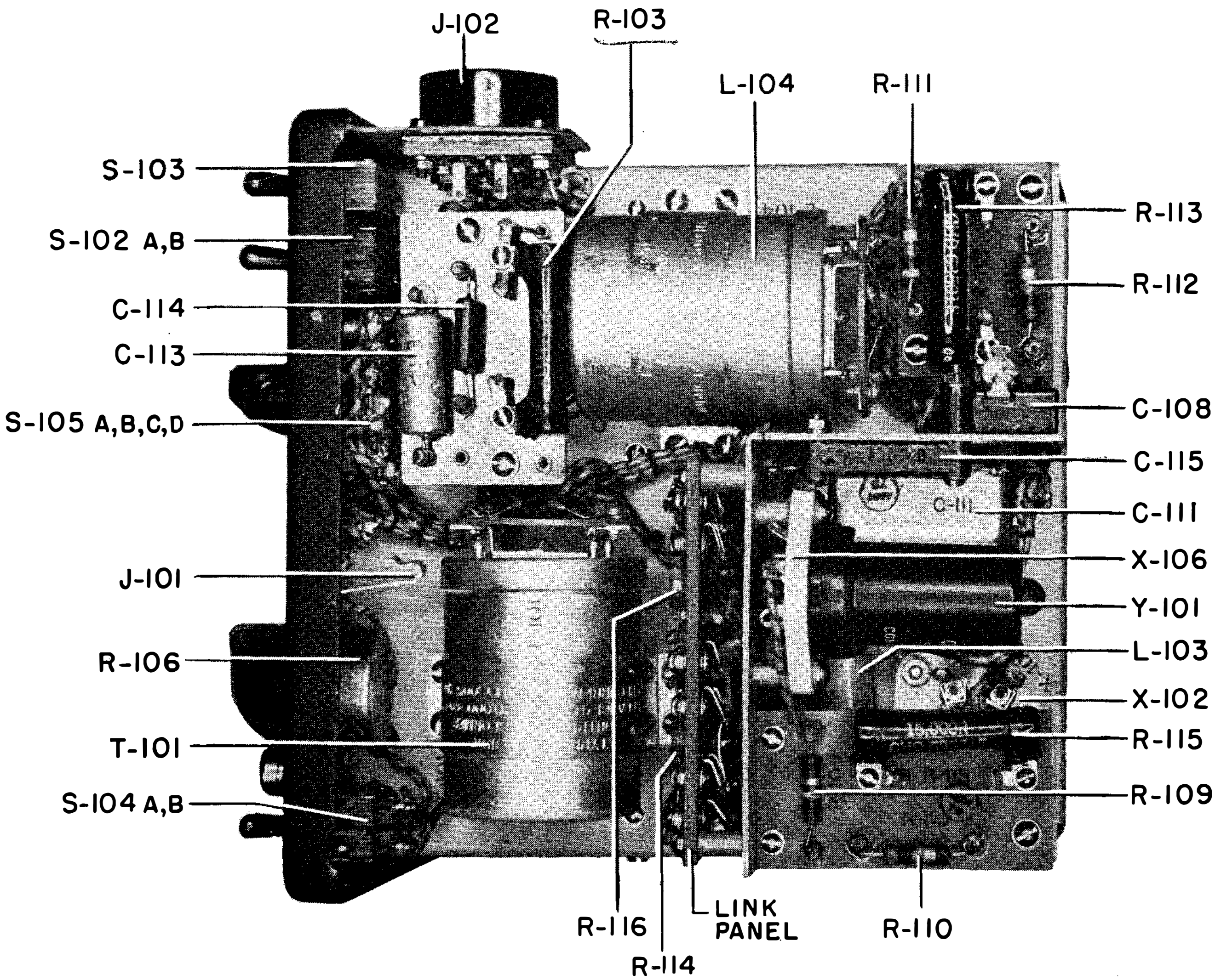


Figure 13. Bottom View of Chassis

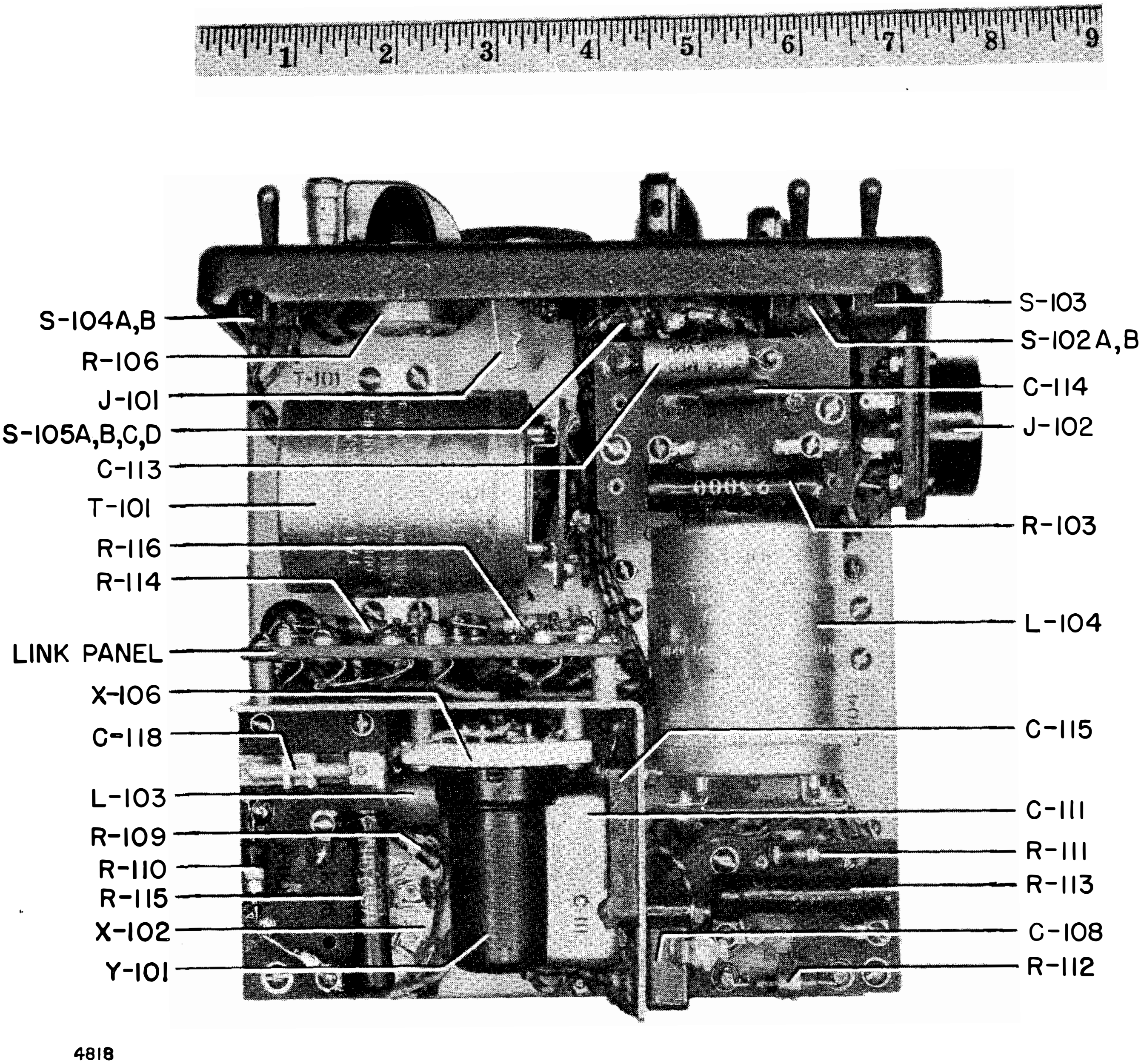


Figure 14. Bottom View of Chassis (Model with Crystal Trimmer)

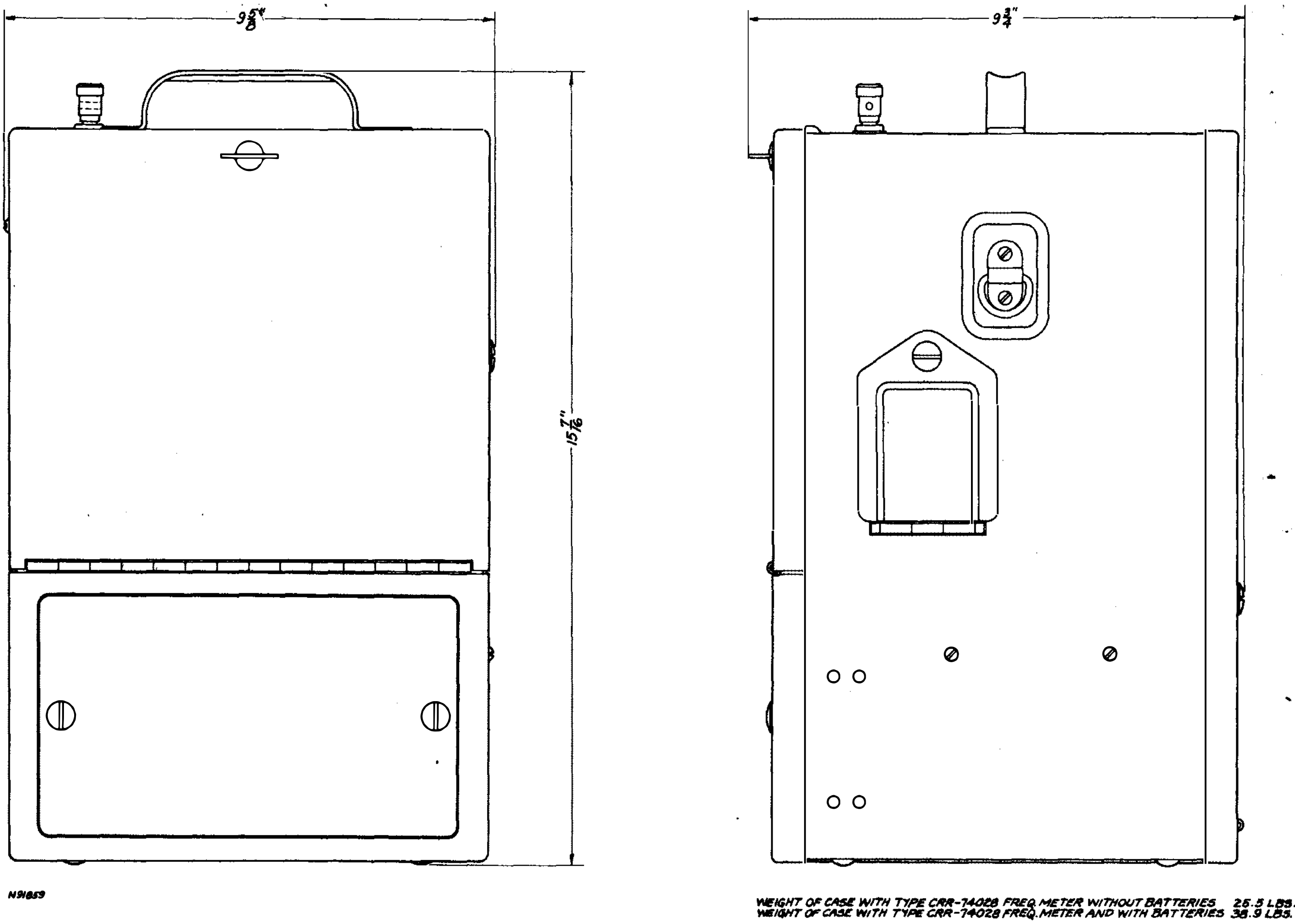


Figure 15. Outline Dimensions

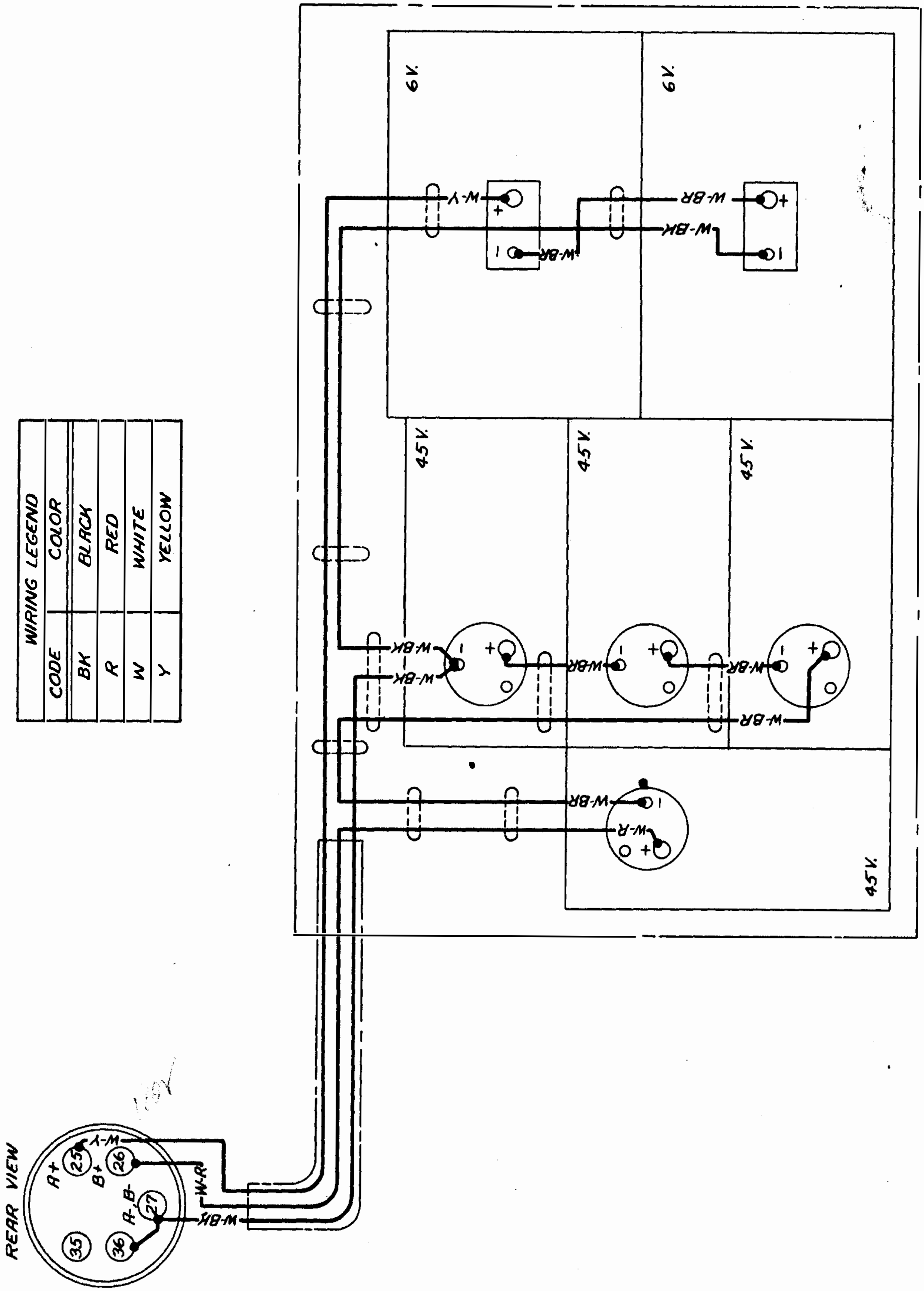
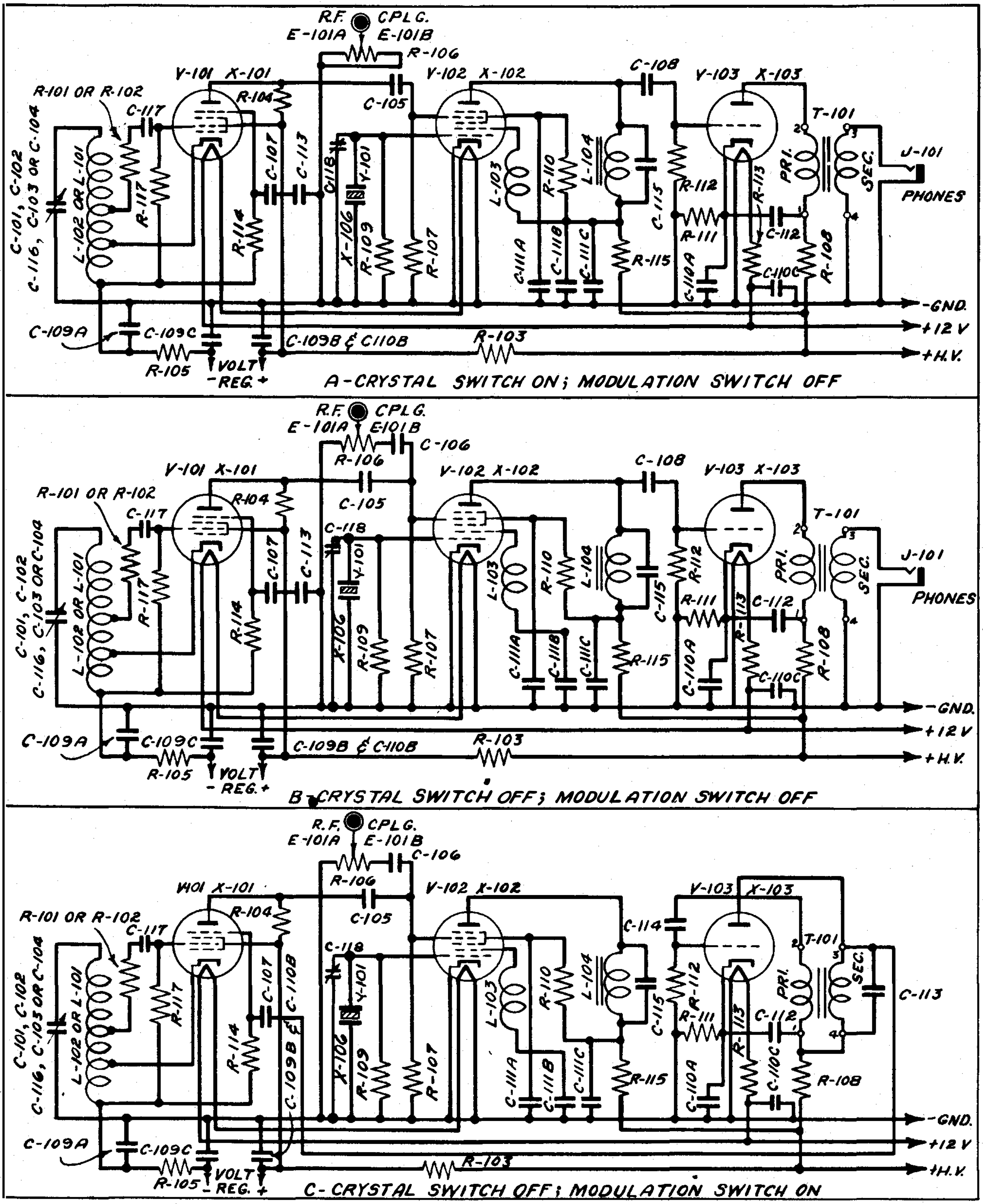


Figure 16. Wiring Diagram, Battery Box

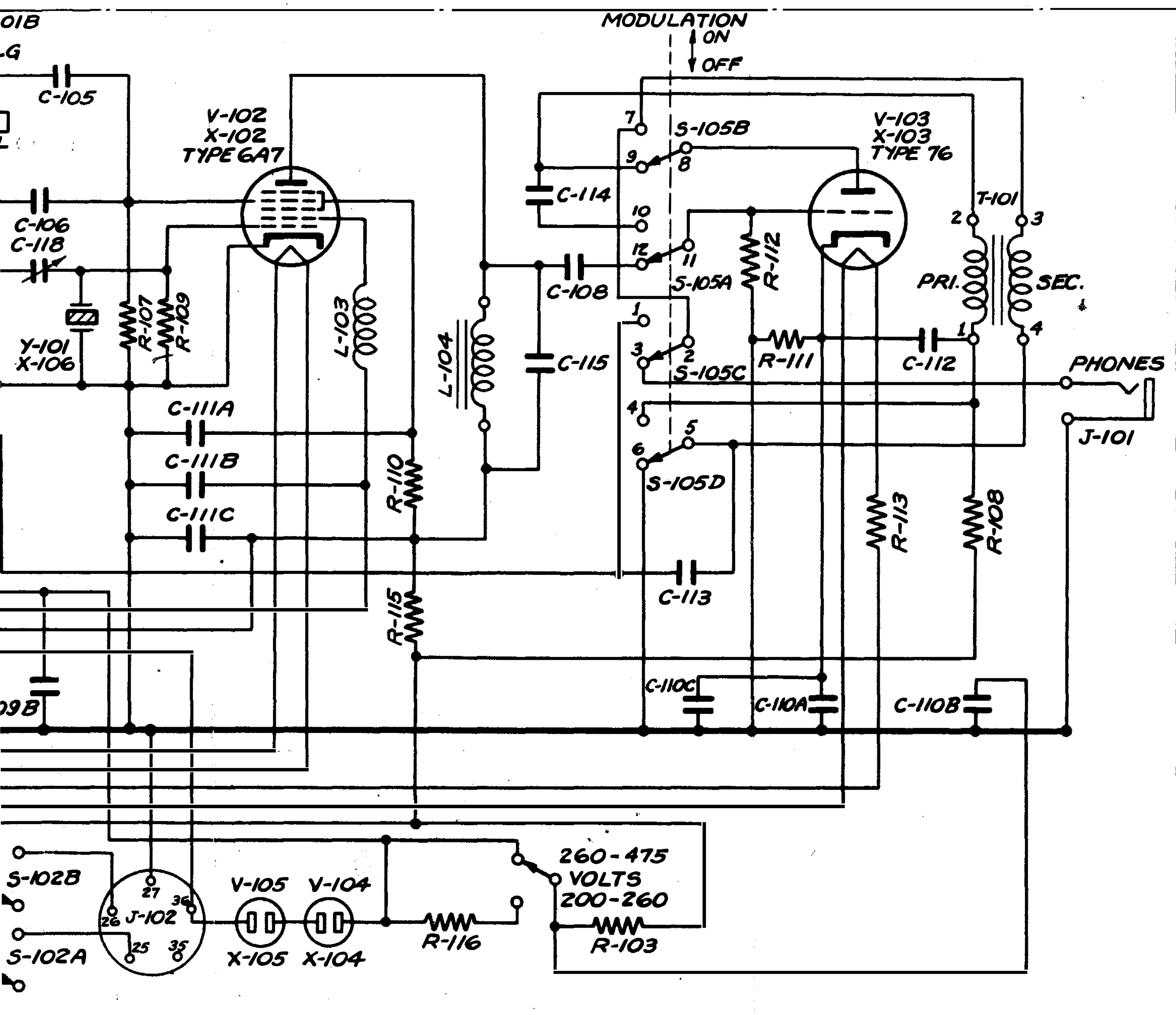


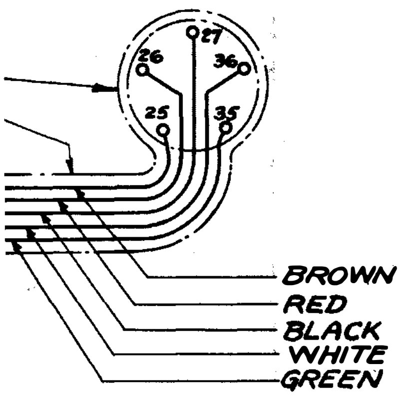
NOTE:

CAPACITOR C-118, CRYSTAL TRIMMER MAY NOT BE USED IN ALL LM SERIES EQUIPMENTS FOR WHICH THIS INSTRUCTION BOOK IS SUPPLIED.

Figure 17. Fundamental Circuits

RESTRICTED
NAVAER 08-5Q-38





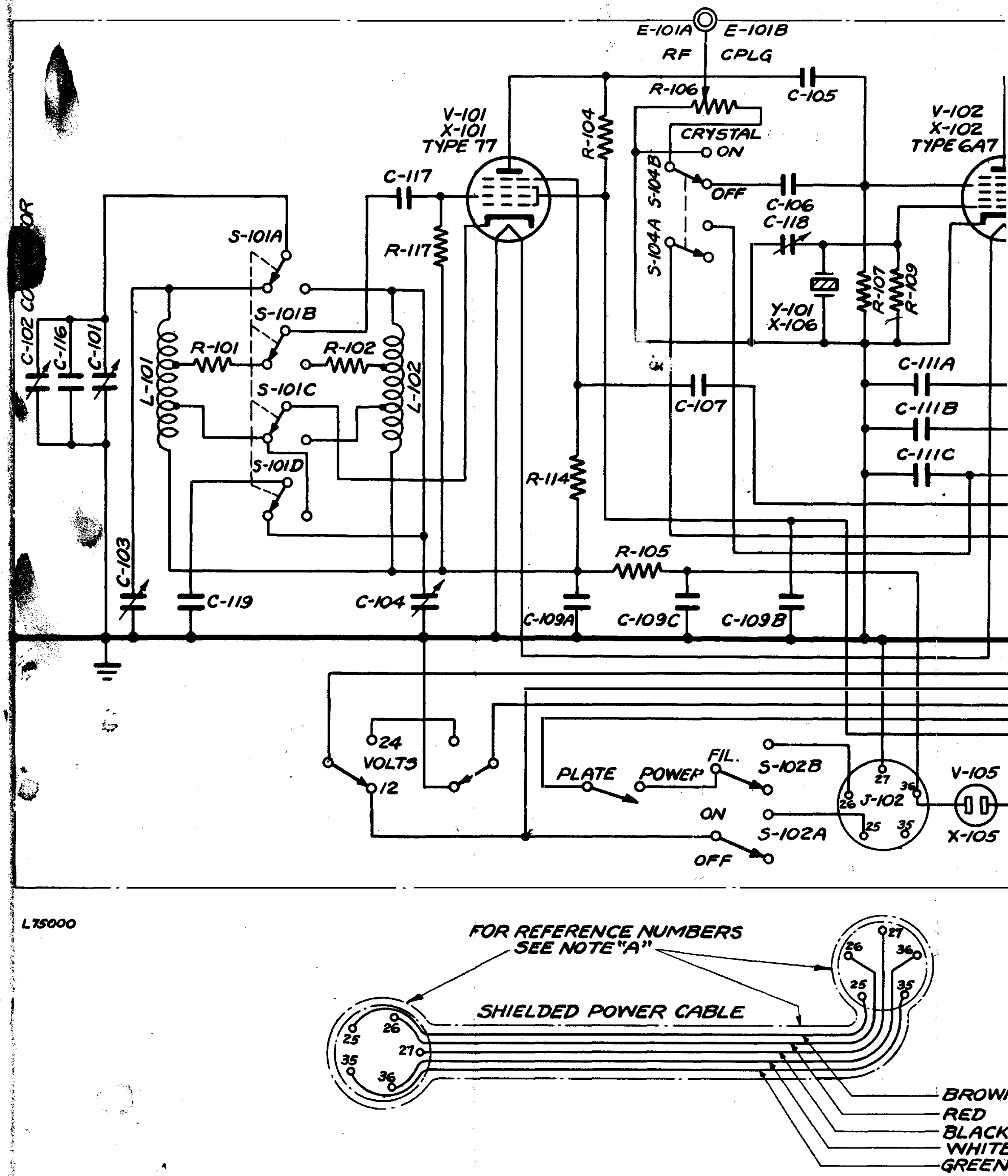
REFERENCE DRAWING
AR95897-1 DETAIL WIRING DIAGRAM

NOTE "A"-IN LM-10, LM-12, LM-13 AND LM-19 REFERENCE NUMBERS OF THESE PLUGS ARE P-201 AND P-202, CABLE IS W-201. IN LM-11 AND LM-18, PLUGS ARE P-301 AND P-302, CABLE IS W-301.

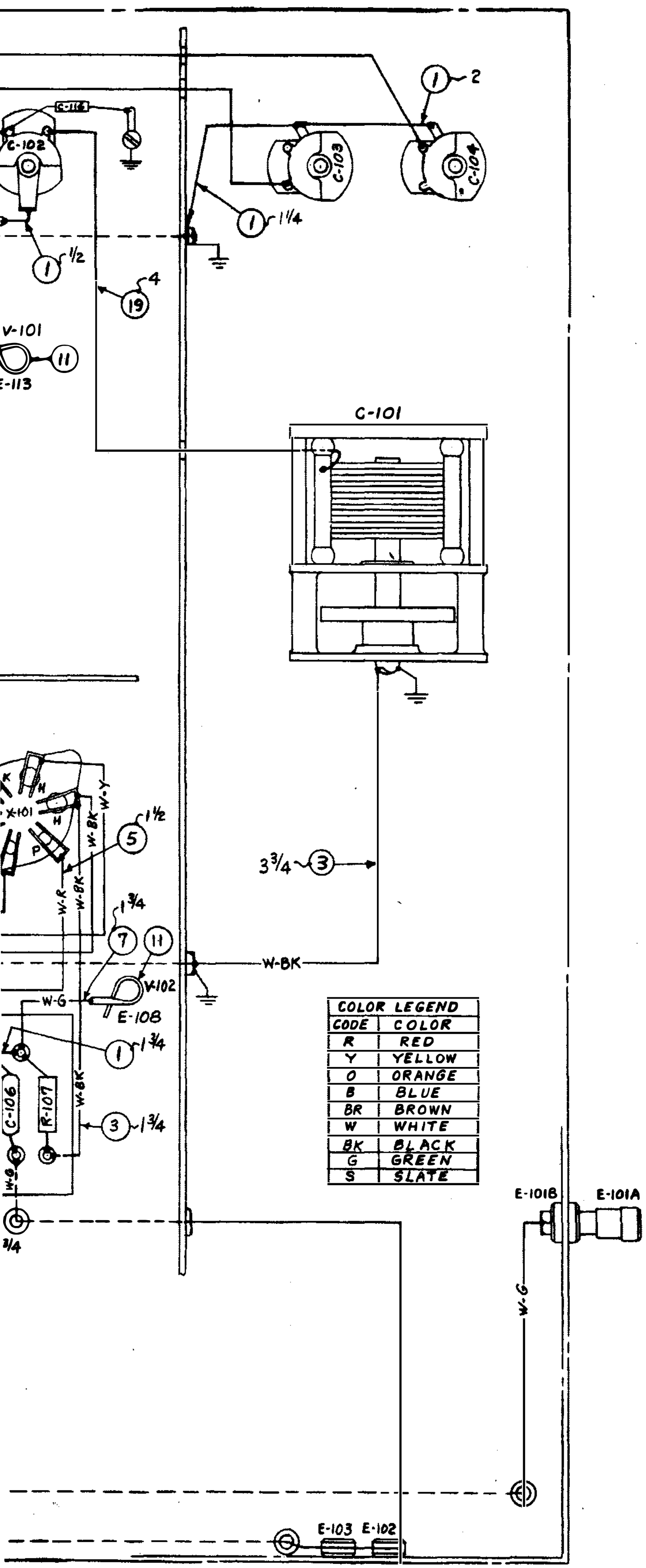
"B."—SOME EQUIPMENTS WILL NOT INCLUDE CAPACITOR C-118, CRYSTAL TRIMMER AND CAPACITOR C-119, ANTI-RESONATOR IN THE FREQUENCY BAND CIRCUIT.

Figure 18. Full Schematic Diagram

RESTRICTED
NAVAER 08-5Q-38



RESTRICTED



COLOR LEGEND	
CODE	COLOR
R	RED
Y	YELLOW
O	ORANGE
B	BLUE
BR	BROWN
W	WHITE
BK	BLACK
G	GREEN
S	SLATE

NOTES:

"A" 1. ALL JOINTS TO BE MECHANICALLY SECURE BEFORE SOLDERING. PAINT ALL JOINTS WITH CHINESE RED LACQUER.

2. LACING SHOWN IS PART OF CABLE ASSEMBLIES.

3. CUT LEADS TO LENGTHS SHOWN. STRIP & TIN EACH END OF LEAD ¼" EXCEPT WHERE OTHERWISE SPECIFIED.

"B."—SOME EQUIPMENTS WILL NOT INCLUDE CAPACITOR C-118, CRYSTAL TRIMMER AND CAPACITOR C-119, ANTI-RESONATOR IN THE FREQUENCY BAND CIRCUIT.

SYMBOLS:

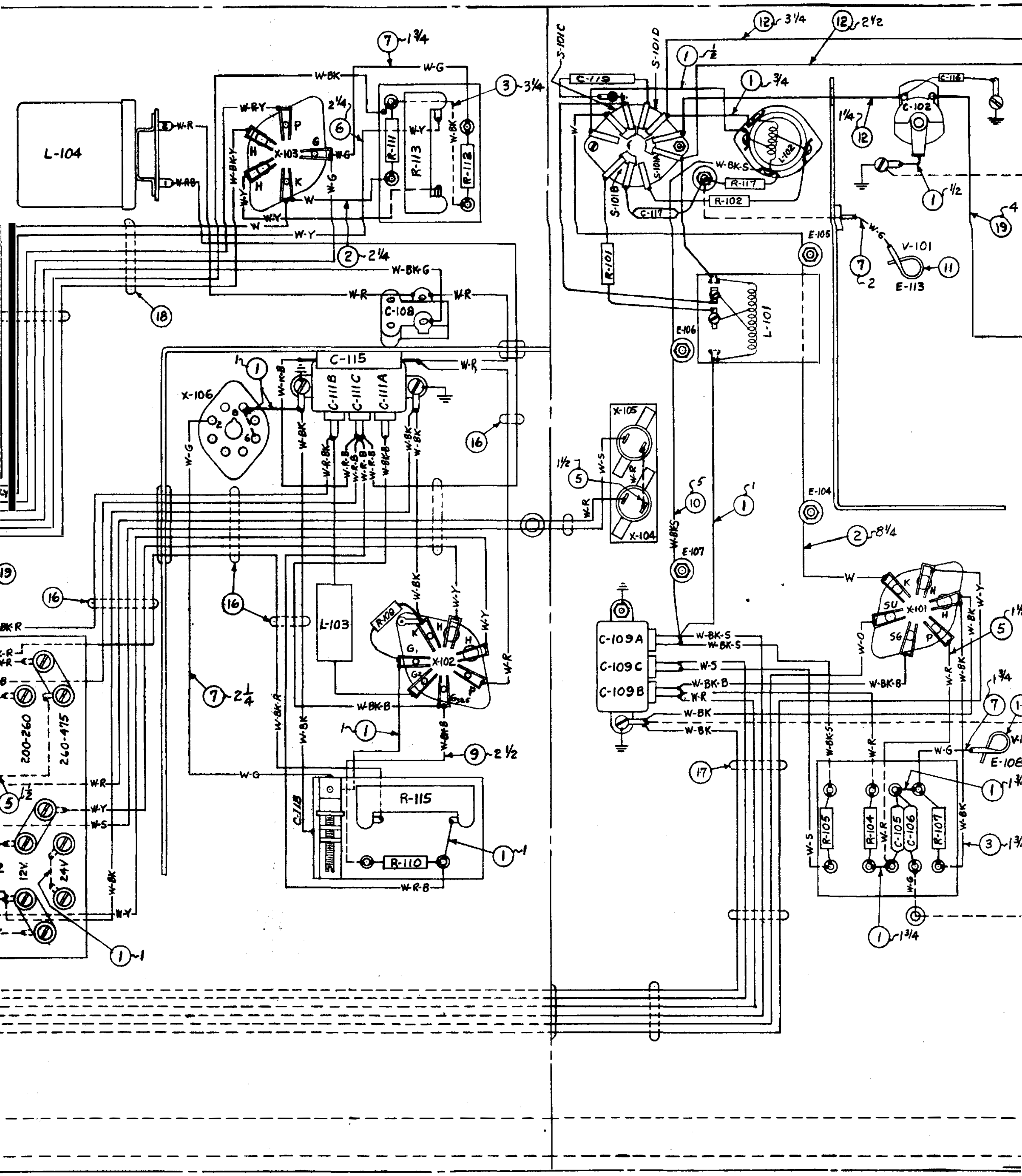
(3) 3¼ ← TOTAL LENGTH OF LEAD.
← ITEM

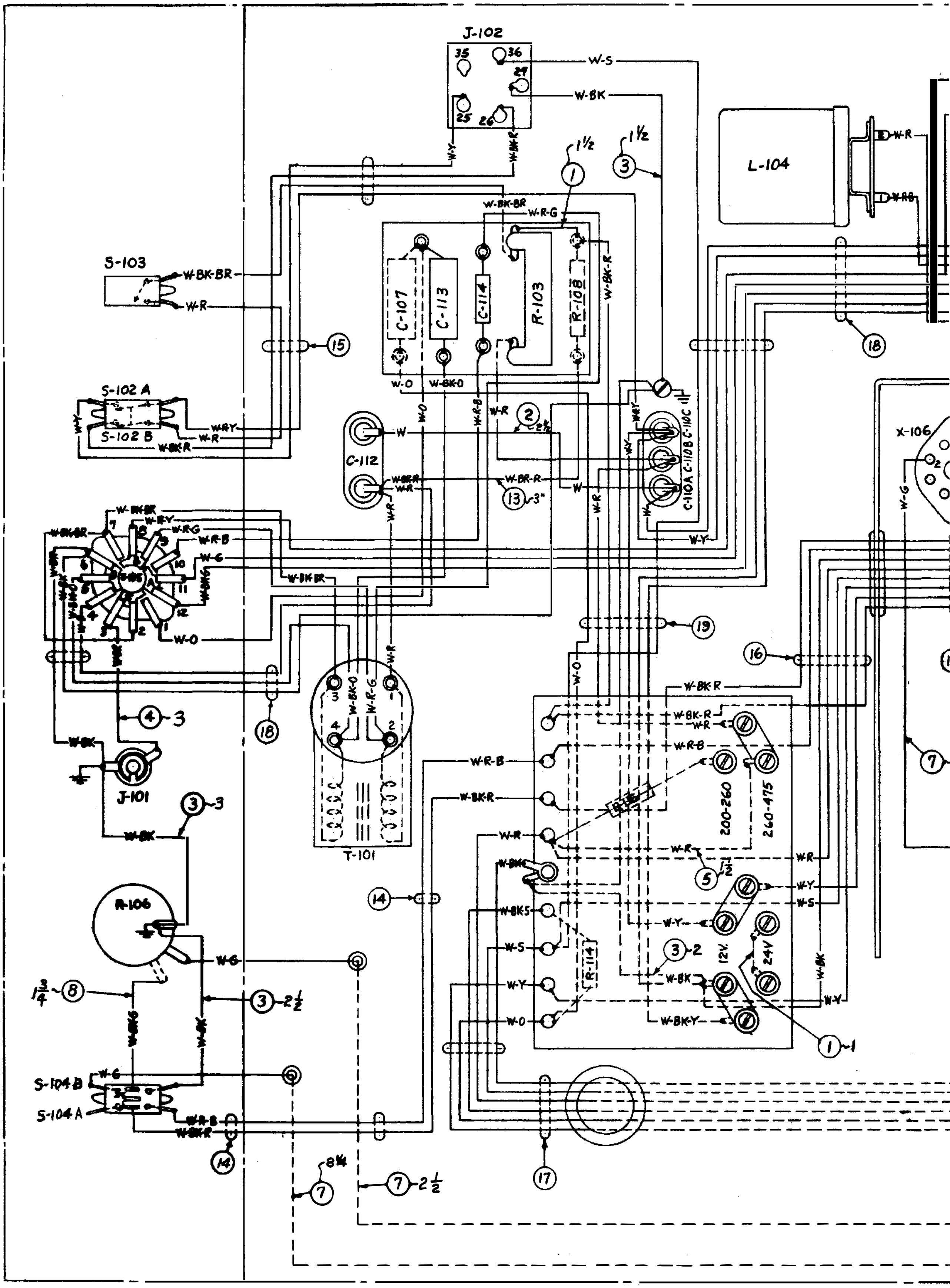
⏚ ← INDICATES CHASSIS GROUND.

REFERENCE DRAWING:

L 73754 SCHEMATIC DIAGRAM.

Figure 19. Wiring Diagram




J-102
35
36
29
25
26
W-S
W-BK
W-Y
W-BK-R
L-104
W-R
W-RB
S-103
W-BK-BR
W-R
S-102 A
S-102 B
W-R-Y
W-BK-R
C-107
C-113
C-114
R-103
R-108
W-BK-BR
W-R-G
W-BK-R
W-O
W-BK-O
C-112
W
W-BR-R
W-R
C-110A C-110B C-110C
X-106
W-G
W-BK-R
W-R-B
W-R
W-BK
W-BKS
W-S
W-Y
W-O
R-114
200-260
260-475
12V.
24V
W-Y
W-BK-Y
J-101
R-106
W-G
W-BK
W-BK-G
S-104 B
S-104 A
W-R-B
W-BK-R
T-101
W-BK-O
W-R-G

A110096

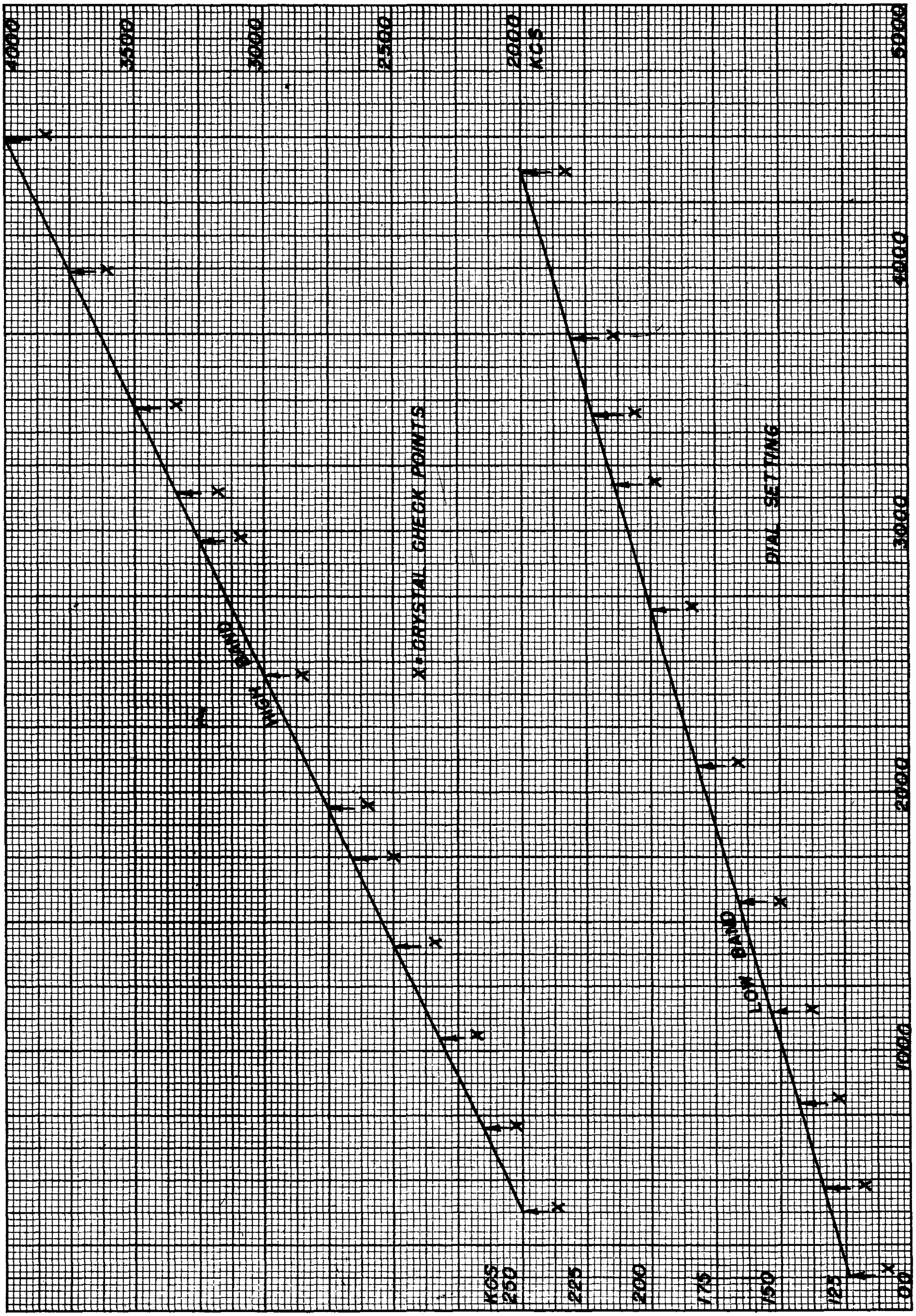
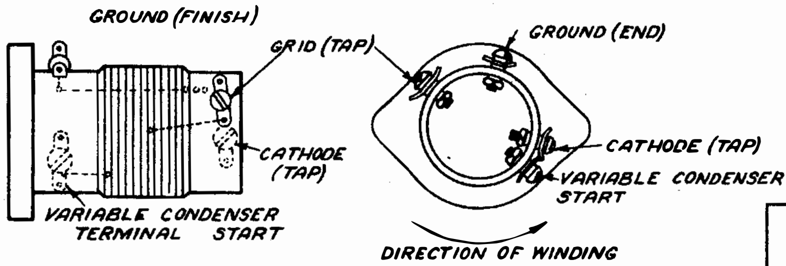
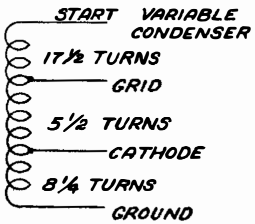
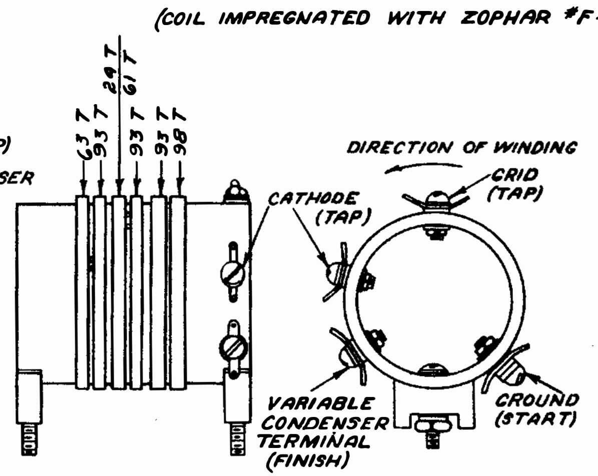


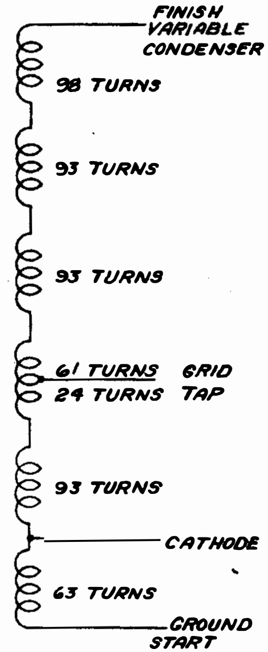
Figure 20. Typical Heterodyne Oscillator Tuning Curves



HIGH FREQUENCY COIL L-102
31¼ TURNS OF #7-42 LITZ S.S.E. WIRE.
CLOSE WOUND, GRID TAP 13¾ TURNS FROM GROUND END, CATHODE TAP 8¼ TURNS FROM GROUND END. TAPS MUST BE HELD AT EXACT TURNS SPECIFIED FROM GROUND END (FINISH) OF COIL.
INDUCTANCE = 36.95 μH ±1%, "Q" 148 AT 2500 KC AND 98 AT 1250 KC +10% -5%
DISTRIBUTED CAPACITY = 5.3 MMF. ±20%

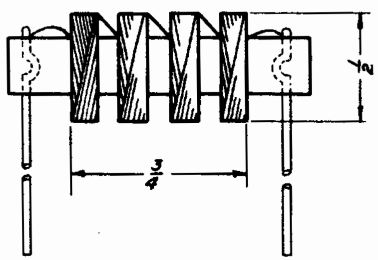






LOW FREQUENCY COIL L-101
525 TURNS OF #7-42 LITZ SCE COPPER WIRE, WOUND IN SIX PIES, TAP CATHODE 63 TURNS FROM GROUND (START) BETWEEN 1ST & 2ND PIES, TAP GRID 180 TURNS FROM GROUND IN THE 3RD PIE.
INDUCTANCE WHEN MEASURED AT 1000 CYCLES ON TYPE 667-A BRIDGE = 9.25MH ±1%
INDUCTANCE WHEN MEASURED WITH A "Q" METER = 9.5 MH ±1%
DISTRIBUTED CAPACITY WHEN MEASURED WITH A "Q" METER = 8 MMF. +10% -20%
"Q" AT 72KC = 72 +10% -5%,
"Q" AT 144KC = 108 +10% -5%

GEARS 119-40
GAINER 28
⅛ DOUBLE THROW CAM



RF CHOKE COIL L-103
UNIVERSAL MACHINE SETTING S.T. ⅛ CAM 116-60
GAINER 25 4 PI WINDING EACH PI 189 TURNS.
INDUCTANCE 1.7 MH ±3% D.C. RESISTANCE 40 Ω
MAXIMUM CURRENT CARRYING CAPACITY .125 A.
DISTRIBUTED CAPACITY A MINIMUM.

C60667

Figure 21. Coil Winding Data

ADDENDA

COMPARISON OF MODELS LM-14 TO LM-19

Model	*Frequency Measuring Unit Type*	*Het. Osc. Freq. Range-Kcs.*	*Operating Voltage*	*Mechanical Design*	*Remarks*
LM-14	CKB-74028	125-250 2000-4000	12/14-24/28 200/260-260/475	Same as LM-10	
LM-15	CKB-74028	125-250 2000-4000	Rectifier Power Unit Type CKB-20104 or CKB-20104A	Same as LM-10	
LM-16	CKB-74028	125-250 2000-4000	12/14-24/28 200/260-260/475	Same as LM-10	Included in Type CKB-10086 Waterproof Carrying Case
LM-17	CKB-74028	125-250 2000-4000	Self Contained Batteries	Same as LM-10	Mounted in Type CKB-10111 Carrying Case and CKB-10110 Canvas Bag Complete with Batteries
LM-18	CRR-74028	125-250 2000-4000	Rectifier Power Unit Type CRR-20104A or CRR-20104	Same as LM-10	
LM-19	CRR-74028	125-250 2000-4000	12/14-24/28 200/260-260/475	Same as LM-10	Included in Type CRR-10214 Waterproof Carrying Case