OPERATING INSTRUCTIONS
FOR
TYPE 615-A
HETERODYNE FREQUENCY
METER
Form 322A

GENERAL RADIO COMPANY

CAMBRIDGE A, MASSACHUSETTS

TABLE OF CONTENTS

PURPOSE

This instrument is intended for use as a calibrated frequency meter in measuring the frequencies of radio transmitters, receivers, and received signals. It will hold its calibration within close limits over a long period of time, but for accurate results it is recommended that the calibration be checked frequently. Suggestions for checking the calibration will be found in Section 5, page 5. It can also be used as an interpolation device in conjunction with a harmonic frequency standard.

1. ELECTRICAL CHARACTERISTICS

1.1 Frequency Range

This instrument consists of a heterodyne oscillator and detector. The oscillator covers the frequency range from 275 kc to 5000 kc in 11 steps. A precision-type balanced condenser giving straight-line-frequency variation is used to adjust the frequency of the oscillator.

1.2 Oscillator: Frequency Stability with Supply Voltage Variation

The oscillator tube is a UX-232 screen-grid tube, employed in a voltage-compensated circuit so that fluctuations in supply voltages produce only minor changes in frequency. Changes in plate-supply voltage of ±9 volts result in frequency changes of less than ±0.01 per cent. Changes in filament voltage of ±0.1 volt produce less than ±0.01 per cent change in frequency. Of the two, the plate-voltage changes are of most interest, since no means are available for regulating this supply. A two-range voltmeter provides means of setting the filament voltage and of determining the condition of the plate battery. Replace plate battery when voltage falls below 80 volts.

1.3 Detector

The detector tube is connected to the oscillator by fairly loose resistance coupling, and is also connected to the "COUPLING 1" binding post on the panel. Connection of any apparatus to the "COUPLING 1" post results in negligible frequency change for the oscillator, at any frequency within its range. The plate-current meter of the detector indicates, by a decrease in reading, whether or not the oscillator is functioning properly. The oscillator may be stopped by turning the coil-selector switch to either of the two blank positions. If the detector plate-current meter reading is then noted, the change when the coil-selector switch is turned to any desired range is easily observed. A change of several milliamperes should be obtained in the lower frequency range; a change of from 0.25 to 1.0 milliampere should be obtained in the high-frequency ranges. When a signal introduced at the "COUPLING 1" post is of sufficient intensity, visual beats are indicated by the detector plate-current meter, if the frequency of the heterodyne is within a few cycles of zero beat with the introduced frequency.

1.4 Temperature Effects

Figure 2 shows the temperature coefficient of frequency and the manner in which this varies over the range of the oscillator coils and tuning condenser. The value read directly from the curve for a given dial setting may be thought of as the change in dial reading produced by one degree C. change in temperature from the calibrating temperature. If the change in temperature is several degrees, the value read from the curve must be multiplied by the number of degrees change in temperature to obtain the correction for the dial readings. An alignment chart Figure 3, page 15 is provided for this purpose. (See paragraphs 5.7 to 5.12 inclusive).

2. ACCESSORIES

2.1 Power Supply

The power supply of this equipment normally consists of batteries contained within the case. Batteries required are as follows:

Filament supply:	Two 6-inch dry cells
Plate supply:	Two 45-volt vertical B batteries (Burgess No. 5308, or equivalent, with standard insulated cap nuts)

3. INSTALLATION

3.1 To Place Equipment in Operation: Using Internal Batteries.

Remove cover.

Remove bright nickel screws around top edge of cabinet.

Lift unit out of cabinet.

Insert tubes, UX-232 in front socket; UX-230 in rear socket. Make certain connection to control-grid tip of UX-232 is made by means of clip provided.

Insert two #6 dry cells for filament battery in space directly under tubes. Have battery terminals toward front.

Remove thumbscrews and place the sheet of duck bakelite over the filament battery terminals.

Replace thumbscrews, making connections to battery by cable provided; black wire is negative, red wire is positive.

Connect batteries in series using connector wire provided.

Tighten all connections.

Insert two Burgess No. 5308 Plate Batteries in space at right end of unit, with terminals toward front.

Connect in series with connector provided.

Connect yellow wire to negative and slate wire to positive.

Test unit by throwing filament switch to "ON". Adjust filament voltage to 2.0 by means of filament rheostat. Check plate-battery voltage by pressing button on voltmeter. Plate-battery voltage should be between 80 and 90 volts for proper operation. When it falls below 80 volts, fresh batteries should be used. The detector-plate meter should read about 7.5 milliamperes when the coil-selector switch is placed on one of the blank switch positions. The meter reading should decrease when the coil switch is thrown to any coil position. The decrease will be a few milliamperes for the low-frequency coils and somewhat less at the higher frequencies. (Blank positions on coil selector switch will be found between taps 4-5 and 8-9).

Throw battery switch to "OFF".

Replace unit in cabinet.

<u>IMPORTANT: Replace and tighten screws holding unit in cabinet.</u>

3.2 To Place Unit in Operation: Using External Batteries.

The unit may be used with external batteries by using the battery cable supplied with the equipment. An access opening is provided in the front of the case.

Remove internal batteries, if these are still in the cabinet.

Remove cover plate.

Remove battery wiring to the three terminals showing through the opening.

Connect battery cable to these three terminals.

Connect the cable to external batteries. The coding of the cable may be used as standard, that is, at the apparatus connect slate to B+, red and yellow to A+, and black to A-. At the batteries connect slate to B+, yellow to B-, red to A+, and black to A-.

When the apparatus is to be moved, disconnect battery cable and cover the access opening.

4. THEORY OF OPERATION

4.1 The apparatus combines two essential elements, a stable oscillator of adjustable frequency and a detector, in a form convenient for use in frequency measurements. The oscillator is especially arranged for permanence (by rugged construction) and freedom from frequency shifts due to changes in supply voltages (by voltage compensation). The detector is used to produce audible beats between the frequencies of the oscillator and some other oscillator, (such as a transmitter or crystal calibrator).

4.2 The oscillator circuit is a modified form of Colpitts oscillator, which is inherently one of the most stable types. The construction of the oscillating circuit is made as rugged as the requirements of size and weight will permit. Voltage compensation is obtained by properly proportioning the plate and screen-grid voltages of the oscillator tube, by means of a voltage divider, so that variations in total plate-supply voltages produce very small variations in frequency.

4.3 If two alternating voltages, of different frequencies, are impressed on a non-linear grid circuit (that is, a circuit which does not follow Ohm's law) the average grid current will undergo variations at a rate equal to the difference of the two frequencies. If the two frequencies are radio frequencies (above audibility) and the difference between them is made small enough (within audibility) then the variations in grid bias take place at an audible rate. These variations are amplified by the tube, and if telephones are connected in the plate circuit, the plate-current variations will produce a tone in the telephones. If the difference between the two frequencies is made very small, only a very few cycles, then the telephones will no longer respond to the difference, or beat, frequency. In such cases, a meter placed in the plate circuit will indicate by pulsations the current variations, or beats.

4.4 In the wiring diagram, the power terminals, by-passes, voltage dividers, meter and regulating rheostats are at the right. The complete oscillator circuit is given in the center of the diagram, showing the coil switching. The detector is at the left, with the "COUPLING 1" post providing the means for introducing a voltage from an external oscillator to the detector grid circuit. The "COUPLING 1" post also provides a means of transferring a voltage from the heterodyne oscillator to an external equipment, such as a receiver. Additional coupling terminals are provided ("COUPLING 2") for obtaining harmonic output. This coupling system consists of a radio-frequency transformer connected in the detector plate circuit. Since the detector is a non-linear device, the radio-frequency current wave in its plate circuit is highly distorted and contains a number of harmonic components, the level of which is sufficient for use in heterodyning in a receiver.

4.5 The compensating condenser C-7, located near the coupling binding post, is provided for adjustment of the initial capacity of the tuned circuit. The condenser is provided with a screw-driver adjustment, access being obtained by means of a removable spring cover. If the heterodyne oscillator has been calibrated and a change in initial circuit capacity takes place, the calibration will of course be in error. Such changes may result from changes in tubes, or changes due to slight displacement of the parts of the instrument relative to each other or relative to the case. Adjustment of the compensating condenser so that the reading of the instrument agrees with the original calibration, will bring all other points into agreement - provided the change in the circuit was a change in initial capacity. The compensator will not realign the instrument against changes in tube characteristics or changes in coil inductances, though adjustment of the compensator will aid materially in reducing shifts to other causes than changes in the initial circuit capacity.

5. OPERATION

5.1 Checking Calibration

While the original calibration of the Type 615-A Heterodyne Frequency Meter is made with a high degree of accuracy, the effects of aging in the tuned circuit prevent this accuracy from being completely realized. For best accuracy, therefore, it is recommended that the calibration be checked frequently. The check may be made against a local frequency standard or by means of standard-frequency radio transmissions or other radio signals of known accuracy.

5.2 Use of Broadcasting Stations as Standards of Frequency.

Radio broadcasting stations provide a ready means of checking and standardizing calibrated apparatus. Since the broadcast stations are required to stay within 50 cycles of their assigned frequencies, the least accurate any one of them can legally be is just under 0.01% (50 cycles at 500 kc is 0.0091%). Actually, broadcast stations are usually much closer than this figure, and 10 cycles would be a better value.

The Type 615-A Heterodyne Frequency Meter covers the entire broadcast band so that several calibration points between 550 kc and 1500 kc can be obtained. This is done by tuning in the broadcast station on a receiver (an oscillating receiver is preferable) and setting the heterodyne-frequency meter to zero beat with it. If the receiver can be made to oscillate (the older types of receivers will all do this), the zero-beat adjustment can be made to within one cycle by using the three-oscillator method described below. If the receiver is of the non-oscillating type, the exact setting can still be made by listening to the hum, noise, or broadcast program in the output as it is modulated by the beat between the broadcast station and the heterodyne.

When using broadcast stations as standards, harmonic methods must be used to calibrate those portions of the frequency range which lie outside the broadcast band. Below the broadcast frequencies, harmonics of the heterodyne-frequency meter can be made to beat with the broadcast station. For example, if the broadcast receiver is set to a 1000-kc station, and the frequency meter is tuned through 500 kc, the second harmonic of the frequency meter will beat with the station in the broadcast receiver. Similarly, the third harmonic of 333.3 kc can be used, the fourth of 250 kc, etc. Using only a few stations, a number of points can be obtained.

Above the broadcast band, it is necessary to use an oscillating receiver.* If the receiver is adjusted to zero beat with the station, its harmonics can be made to beat with the fundamental of the heterodyne-frequency meter.

*Care should be taken to prevent the oscillating receiver from radiating and causing interference.

If the heterodyne-frequency meter is calibrated when used, a fairly high accuracy can be obtained. Since the error in the broadcasting station frequency is probably 0.005% or less, and the precision of scale setting is about 0.001%, the over-all accuracy at the points of calibration will be approximately 0.006%. When interpolating between two calibration points to find scale settings corresponding to other frequencies, an error occurs due to curvature in the frequency versus scale reading characteristic. This error, for small interpolation intervals may be as small as 0.002% and, when the calibration points are widely scattered, can be several times this value. An over-all accuracy in the vicinity of 0.01% is not impossible, and accuracies of 0.02% or 0.03% are easily obtained.

The following table is an example of the calibration points obtained from two broadcasting stations whose frequencies were 990 kc and 590 kc respectively.

HETERODYNE-FREQUENCY METER				BROADCAST STATION	
Frequency	Coil	Scale	Harmonic No.	Frequency	Harmonic No.
990	6	391.1	1	990	1
990	5	2204.0	1		
495	3	809.3	2		
330	1	1507.9	3		
1980	8	11882.6			2
2970	10	546.4			3
3960	11	713.0			4
4950	11	2339.2			5
590	3	2118.0	1	590	1
295	1	755.0	2		
1180	6	1576.1			2
1770	8	239.4			3
2360	9	895.3			4
2950	10	503.9			5

These points were obtained by listening to the broadcast station in an oscillating receiver, and varying the frequency of the heterodyne-frequency meter. Whenever a beat tone was heard, the heterodyne-frequency meter was adjusted to exact zero beat and the reading was recorded. Since the broadcasting station channel frequency was known, the harmonic relations could be determined from the original calibration of the heterodyne-frequency meter.

Calibration data taken in this way are useful in correcting a calibration curve or, if desired, the scale settings corresponding to other frequencies can be determined by interpolating between two calibration points.

5.3 The Five-Megacycle Transmissions

This procedure is not restricted to the use of broadcast stations. Any radio signal known to be accurate may be used. When the five-megacycle signals of the United States Bureau of Standards are on the air, these may be used. In checking against five megacycles, the frequency of the heterodyne-frequency meter is progressively reduced, allowing its harmonics to beat against the five megacycles exactly as when using broadcast stations as described above.

5.4 Coupling

In making these checks of the calibrations, either coupling may be used depending on which is the more satisfactory. In general, "COUPLING 1" is used at the fundamental frequency and "COUPLING 2" at harmonic frequencies.

If the standard frequency is sufficiently strong, the check can be made by listening in the detector of the frequency meter. A wire connected to the "COUPLING 1" terminal will provide sufficient coupling on either fundamental or harmonics.

When using a receiver, a wire connected to the "COUPLING 1" terminal and brought near the antenna is usually satisfactory.

To introduce harmonics from "COUPLING 2" into a receiver, the one coupling terminal may be connected to the antenna terminal of the receiver through a small condenser. The ground terminal of the receiver should be grounded.

5.5 To Set a Receiver to a Desired Frequency

Since the radiation from modern oscillating receivers is small, it is best to listen in the receiver. Start up the portable heterodyne and adjust it to the checked frequency, making correction in the dial reading for any change in temperature of the instrument (see paragraphs 5.7 to 5.12). Adjust the receiver to zero beat with the frequency of the heterodyne. Because of the comparatively great sensitivity of a receiver, very loose coupling between the receiver and the heterodyne may generally be used. A wire connected to the heterodyne "COUPLING 1" post and brought near the receiver antenna terminal is generally sufficient. If necessary, the wire (insulated) may be wrapped a few times around the receiver antenna lead to provide larger capacity coupling.

5.6 To Measure the Frequency of a Transmitter or Receiver

While this heterodyne-frequency meter was not designed particularly for this purpose, ordinary frequency meter operation may be obtained, provided curves are drawn, from suitable calibration points, over the desired range of the instrument as referred to in paragraph 6.1.

Tune the heterodyne to zero beat with the transmitter or receiver and note the dial setting. Correction for any change in temperature of the instrument since calibration should then be applied to this dial reading before referring to calibration curves.

In order to compensate the reading when the heterodyne is used in this manner, it is necessary to REVERSE THE SIGN OF THE CORRECTION, referred to elsewhere in these instructions. If the zero beat setting is 1275, for example, and the temperature has INCREASED over the calibrating temperature, the correction obtained by reference to Figures 2 and 3 should be SUBTRACTED from 1275 before determining the measured frequency on the heterodyne calibration curves. If the temperature has DECREASED, the total correction should be ADDED to 1275 before referring to calibration curves. DO NOT CONFUSE THIS PROCEDURE AND THE APPLICATION OF CORRECTION WITH EXAMPLES GIVEN IN PARAGRAPHS 5.11 and 5.12.

CORRECTION FOR TEMPERATURE CHANGES

5.7 The curves shown in Figure 2 show the change in dial reading of the heterodyne necessary to compensate for one degree Centigrade change in temperature, from the calibrating temperature (Separate curves have been plotted over the range of the variable condenser for groups of coils).

The frequency of the heterodyne DECREASES (for a given dial reading), as the temperature is INCREASED from the calibrating value. And since the instrument is designed to show increase in frequency with increasing coil numbers and increasing dial readings, it is evident that to compensate a given calibrated dial setting for an INCREASE in temperature (which has actually decreased the frequency), the dial setting must be INCREASED (which will increase the frequency), in order to again obtain the correct calibrated frequency. This is easily remembered, IF TEMPERATURE INCREASE IS TAKEN AS A POSITIVE CHANGE, THE CORRECTION TO THE DIAL READING WILL BE POSITIVE, that is, a certain number of dial divisions must be added to the calibration setting in order to compensate the setting and obtain the correct frequency.

If the temperature decreases from the original calibrating value, the temperature change is negative and therefore the dial correction is also negative. (See examples, paragraphs 5.11 and 5.12).

5.8 Since the curves in Figure 2 give only the change in dial reading per one degree Centigrade, it is necessary to multiply the value obtained from the curve (for the coil and condenser values used) by the number of degrees change in temperature, in order to find the total number of dial divisions change required. For this purpose, an Alignment Chart shown in Figure 3 has been furnished for convenience.

5.9 Connect the value of "Divisions per degree C" on the left-hand scale, Figure 3, (as obtained from the curves on Figure 2) with the value of "Degrees C change" on the right-hand scale, by a straight line. (The edge of a sheet of paper may be used for a straight edge). Where the line crosses the "Divisions Correction" scale, read off the total number of divisions correction. If the temperature change is positive, the correction is positive. If the temperature change is negative, the correction is negative.

5.10 The chart as drawn gives the correction directly for temperature changes up to ±10 degrees C. If the temperature change is greater than 10 degrees C, multiply the "Degrees C change" scale by 10 and the "Divisions Correction" scale by 10.

EXAMPLES OF TEMPERATURE CORRECTIONS

5.11 To apply correction for an INCREASE in temperature over that at which calibrated:

In this example it will be assumed that upon using the heterodyne, the temperature of the instrument has increased 8.7 degrees C above the temperature at which calibration was made. The setting of the heterodyne as calibrated, 1418.0 dial divisions on coil 3 for 430 kc. Reference to chart, Figure 2, reveals that temperature correction per degree C on this setting is 1.26 dial divisions.

Now either multiply 1.26 by 8.7 to obtain the total dial correction for this frequency at the new temperature, or for convenience use chart, Figure 3, to get this result. Simply point off 1.26 on the left-hand scale, and 8.7 on the right-hand scale, connecting these two points with a straight edge, the total correction of 11.0 will be indicated on the center scale.

And as this example provides for INCREASE of 8.7 degrees C, the correction is positive, therefore the correct setting of the heterodyne for 430 kc at the increased temperature will be 1418.0 + 11.0 = 1429.0.

5.12 To apply correction for DECREASE in temperature from that at which calibrated:

In this example it will be assumed that upon using the heterodyne, the temperature of the instrument has decreased 7.3 degrees C from the temperature at which calibration was made. The setting of the heterodyne as calibrated, 1757.9 dial divisions on coil 10 for 3650 kc. Reference to chart, Figure 2, reveals that temperature correction per degree C for this setting is 0.89 dial divisions.

By reference to chart, Figure 3, or by multiplication as explained above in paragraph 5.11, it will be evident that the total dial correction in this case will be 6.5 divisions.

But as this example provides for a DECREASE of 7.3 degrees C, the correction is negative, therefore the correct setting of the heterodyne for 3650 kc at the decreased temperature will be 1757.9 - 6.5 = 1751.4.

6. GENERAL

6.1 Care of Instrument

The instrument should be handled with reasonable care if it is expected to give results of best accuracy.

If it is known that the instrument is to be kept in storage for several months, the batteries should be removed to prevent corrosion in battery compartment.

6.2 WARNINGS

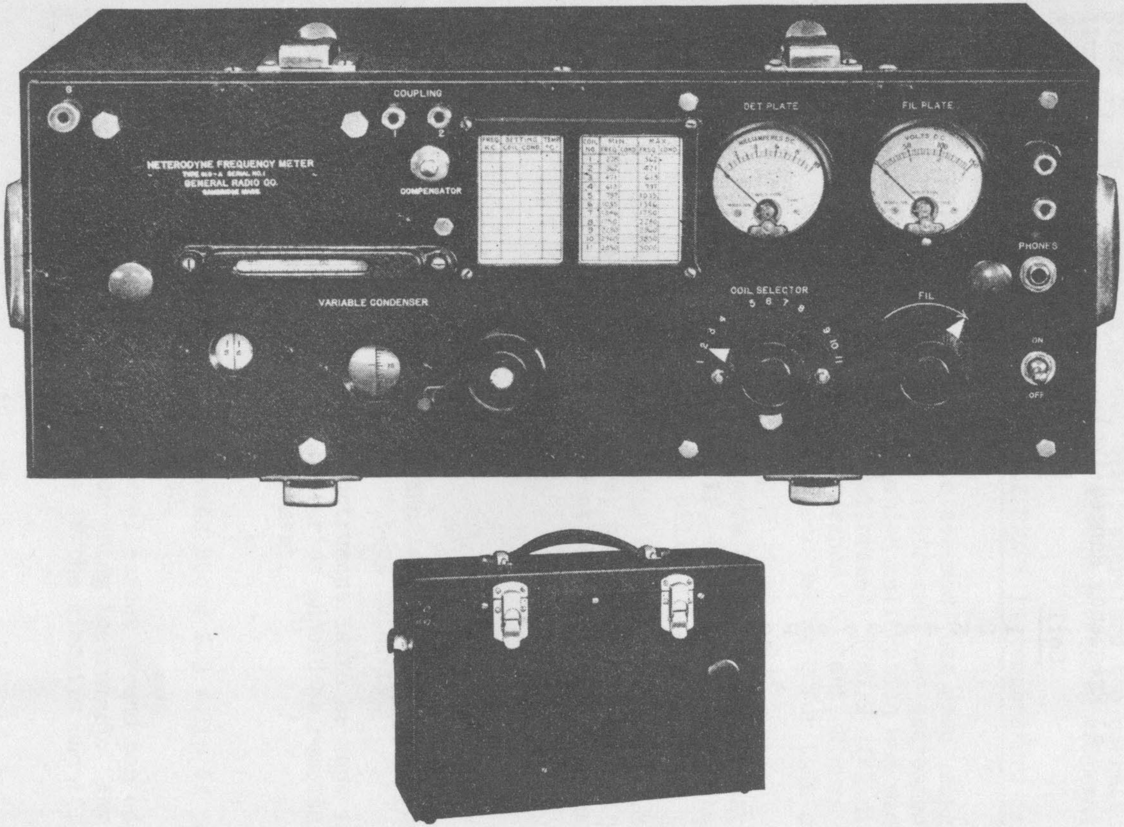
Do not operate tube filaments above 2.0 volts if proper emission and life are to be obtained.

Be certain that bright nickel screws around top edge of cabinet are tight before checking or using instrument. Any looseness involves capacity changes in the circuits and will introduce errors in calibration.

7. TYPICAL PERFORMANCE DATA

a) Frequency Ranges (kc)

Coil	Min	Max
1	275	360
2	360	465
3	465	610
4	610	790
5	790	1030
6	1030	1350
7	1350	1735
8	1735	2200
9	2200	2870
10	2870	3800
11	3800	5000



Type 615-A Heterodyne
Frequency Meter

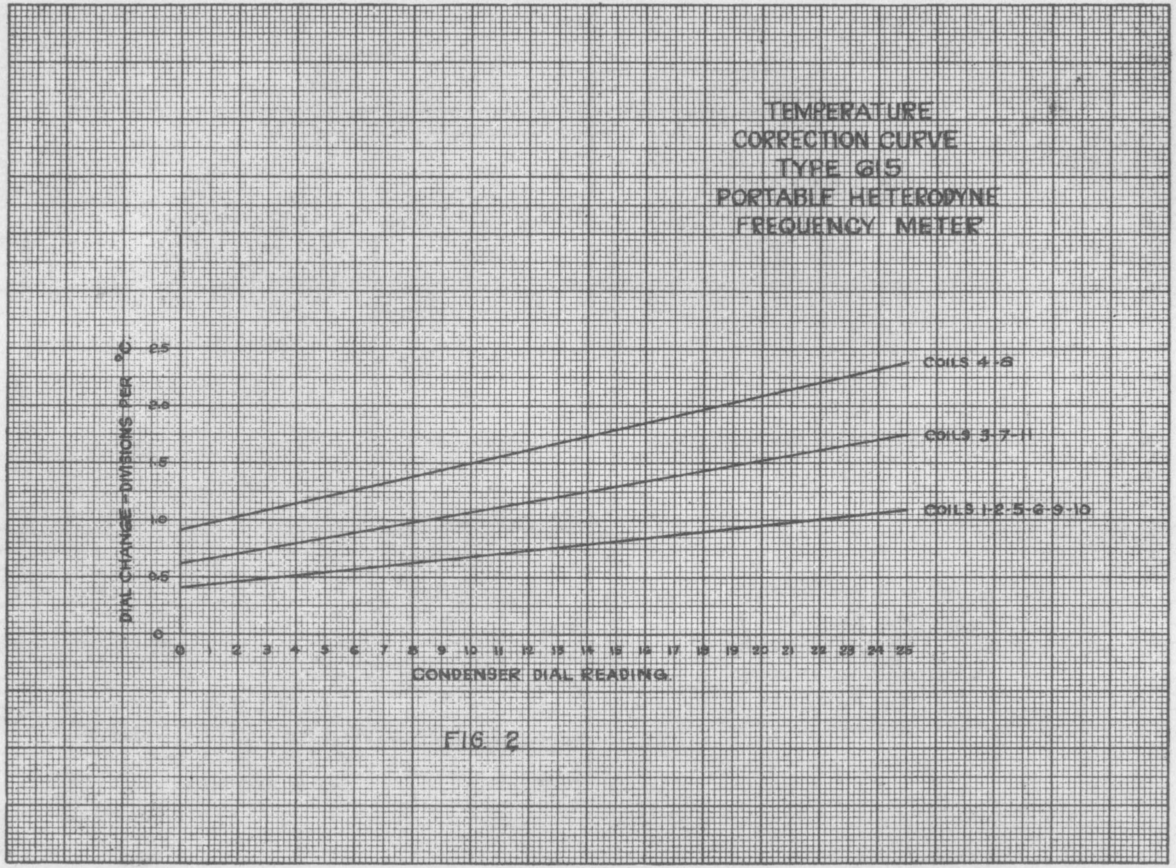

TEMPERATURE
CORRECTION CURVE
TYPE 615
PORTABLE HETERODYNE
FREQUENCY METER
COILS 4-8
COILS 3-7-11
COILS 1-2-5-6-9-10
DIAL CHANGE - DIVISIONS PER °C.
2.5
2.0
1.5
1.0
0.5
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
CONDENSER DIAL READING.

FIG. 2

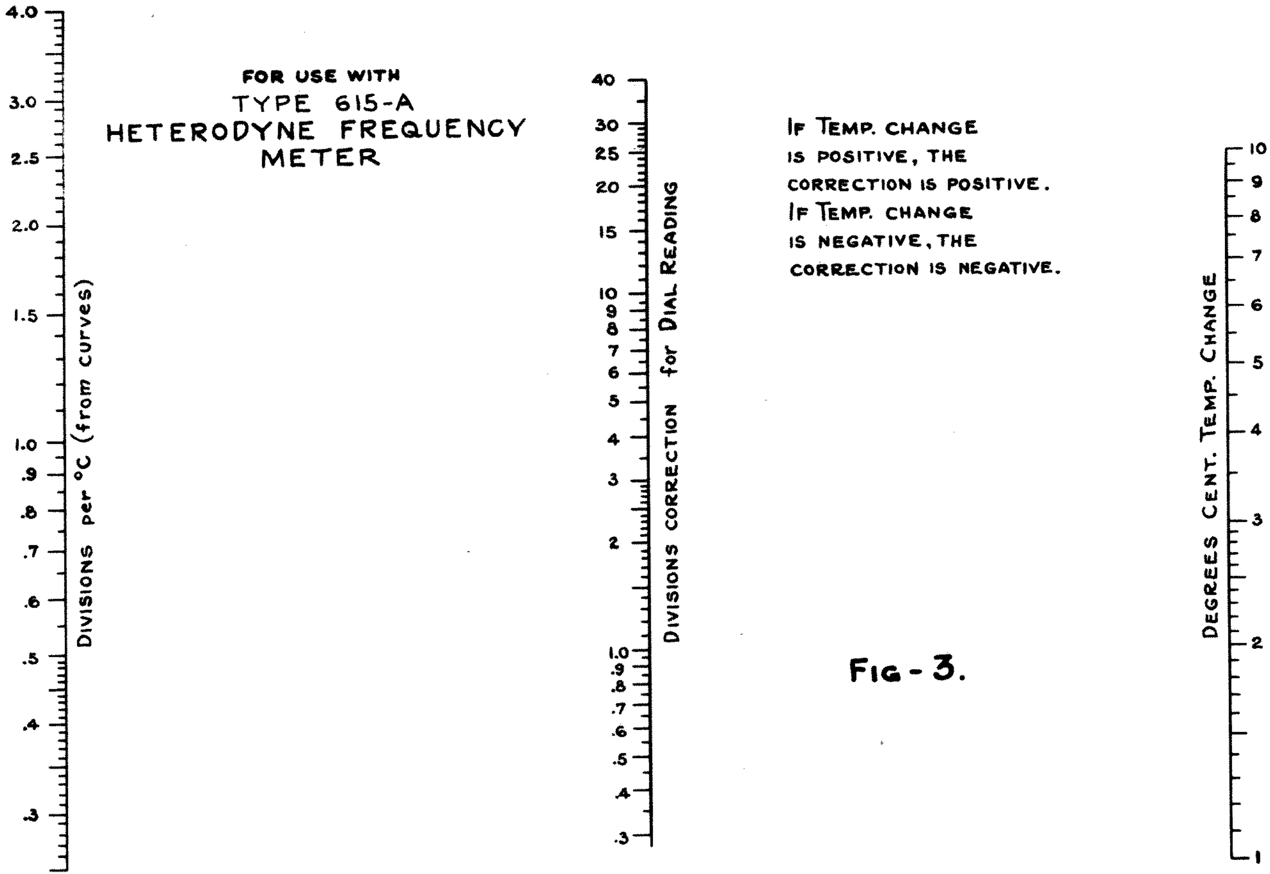


FIG-3.

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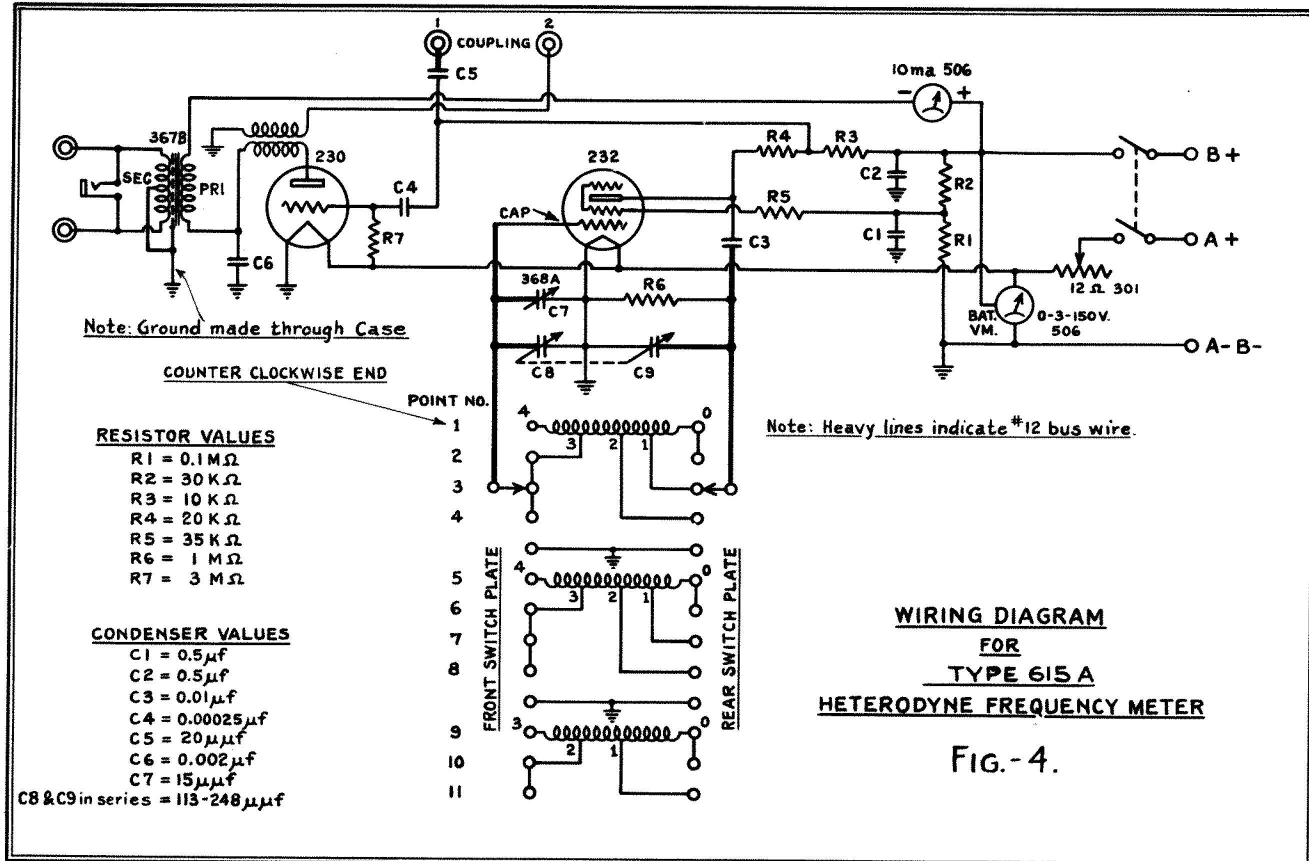

WIRING DIAGRAM FOR TYPE 615 A HETERODYNE FREQUENCY METER

FIG.-4.

Planograph Printed by Spaulding-Moss Company
Boston, Massachusetts, U. S. A.