OPERATING INSTRUCTIONS
FOR
TYPE 620-A
HETERODYNE FREQUENCY METER AND CALIBRATOR
FORM 431-D

GENERAL RADIO COMPANY
CAMBRIDGE A, MASSACHUSETTS

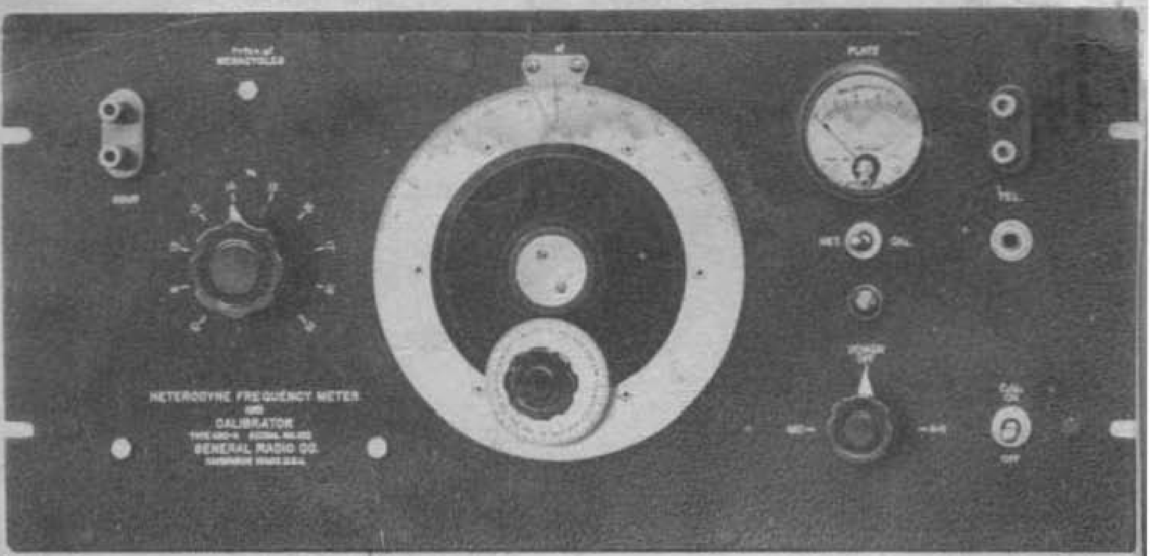

FIGURE 1.

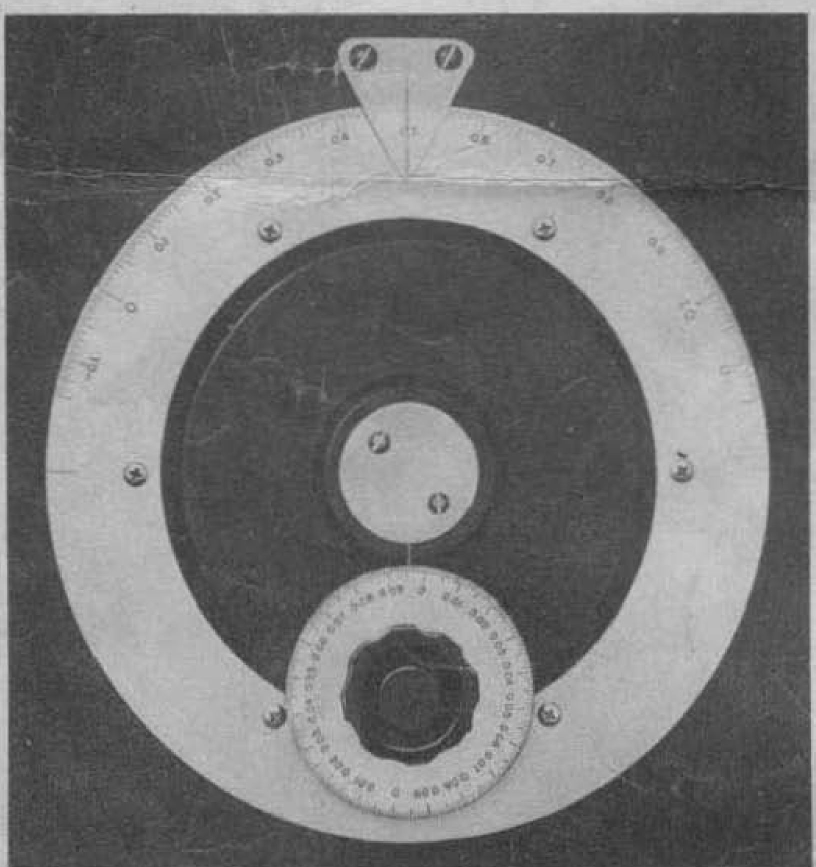

FIGURE 2.

GENERAL RADIO COMPANY

OPERATING INSTRUCTIONS
FOR
TYPE 620-A
HETERODYNE FREQUENCY METER AND CALIBRATOR

PART 1
DESCRIPTION

PURPOSE The Type 620-A Heterodyne Frequency Meter and Calibrator is designed particularly for frequency measurements over a very wide range, 300 kilocycles to 300 megacycles.

ADVANTAGES The heterodyne frequency meter is direct-reading over its fundamental frequency range, which makes it very convenient and simple to use. Provision is made for checking the calibration of the heterodyne frequency meter in terms of a piezo-electric oscillator. Because of the direct-reading feature it is very easy to utilize harmonic methods for extending the frequency range to both lower and higher frequencies.

PRINCIPLES OF OPERATION The instrument contains the heterodyne frequency meter, covering the frequency range from 10 to 20 megacycles in 10 steps; a one-megacycle piezo-electric oscillator for checking the calibration of the heterodyne oscillator; a detector and audio-frequency amplifier for obtaining beats between the heterodyne and the calibrator or between the heterodyne and unknown. The heterodyne may be set to any frequency in the range from 10 to 20 megacycles and any error corrected by reference to the calibrator. By harmonic methods, frequencies between 300 kc and 300 Mc are readily measured.

DIRECT-READING SCALE The condenser dial is graduated to read fractions of a megacycle directly, the smallest division on the scale corresponding to 0.01 megacycle (10 kc). The auxiliary scale on the driving shaft effectively subdivides each main scale division into 10 parts. Each auxiliary scale division is, therefore, 1 kilocycle. The frequency for any scale setting is given by the sum of the coil switch reading and the reading of the dial. For example, in Figure 1 and Figure 2 the frequency is 14.496 Mc.

PART 2
INSTALLATION

SHIPPING LIST With each Type 620-A Heterodyne Frequency Meter and Calibrator are packed the following accessories and spare parts:

- 1 - Instruction Book
- 1 - 115-volt Attachment Cord
- 2 - Mazda 40 Lamps (6-volt)
- 1 - Box Fuses (0.2 amp.) } For 115-volt operation.
- 1 - Box Fuses (1.0 amp.) } For 115-volt operation.
- 1 - Box Fuses (3.0 amp.) } For 115-volt operation.
- 1 - Box Fuses (0.2 amp.) } For 230-volt operation.
- 1 - Box Fuses (0.5 amp.) } For 230-volt operation.
- 1 - Box Fuses (3.0 amp.) } For 230-volt operation.
- 3 - RCA Type 955 "Acorn" Triodes
- 1 - RCA Type 954 "Acorn" Tetrode
- 1 - RCA Type 84 Rectifier
- 2 - Multipoint Connectors

TUBES

Install as follows:

955 in oscillator socket (on end of coil assembly)

955 in detector socket } (on top of sub-shelf)
955 in amplifier socket } (on top of sub-shelf)
954 in crystal oscillator socket } (on top of sub-shelf)
84 in rectifier socket (on main shelf)

Note: In mounting the 954 crystal oscillator tube, be certain that the plate terminal enters the connector in the block below the tube socket.

POWER SUPPLY For a-c operation connect the instrument to the 115-volt 50-60 cycle mains by means of the attachment cord provided. To turn instrument on, throw POWER switch to "A-C".

For battery operation, connect battery leads to multipoint connector (at the right, seen from the front of the instrument). Connect 6-volt filament battery to terminals 7 and 8 (polarity is not important); connect 150-volt plate battery, positive to terminal 11, negative to terminal 12 (which is also grounded).

COUPLING Coupling connections are provided on the front panel and also through the left-hand (seen from front) multipoint connector on the rear of the instrument. For most work a short wire connected to the ungrounded terminal and led in the vicinity of an oscillator will provide adequate coupling. In cases where permanent wiring is desired, the connection at the rear may be utilized to advantage.

On operating the equipment, particularly in the immediate vicinity of transmitters, excessive coupling or stray pickup is indicated by the plate current dropping to low values when the transmitter is turned on. The coupling should be reduced, or a change in location of the instrument should be made, if the change in plate current is more than a few tenths of a milliampere.

If excessive pickup at the fundamental frequency is obtained and a change in location is not feasible, measurements may still be satisfactorily made by using harmonics instead of the fundamental.

TELEPHONES Telephone receivers may be plugged in at the front panel, either at the telephone jack or using a GR plug on the jack-top binding posts. For permanent wiring the connections at the rear multipoint connector may be used (terminals 10-11 of left-hand plug, seen from front of instrument).

PART 3
FREQUENCY MEASUREMENTS

CHECKING CALIBRATION When it is desired to check the heterodyne frequency meter calibration on any range, simply throw the CAL switch to "ON". The crystal oscillator plate current is indicated by the meter when the switch below the meter is thrown to the CAL position. If the crystal does not oscillate, the plate current meter will read about 7 milliamperes; when the crystal oscillates, the reading is about 1.5 milliamperes.

At each end of the condenser range a loud beat against the calibrator will be heard, corresponding to a heterodyne frequency of an integral number of megacycles. For example, on Coil 17, such loud points are found at 0 and 1.0 on the dial corresponding to 17.0 and 18.0 megacycles.

Intermediate points, where the beats are not as loud as the principal beats mentioned above, occur at several points along the scale. These intermediate points occur where a harmonic of the heterodyne beats with a crystal harmonic. For example, the second harmonic gives a zero beat setting at 1/2 scale, or 0.5 Mc; the third harmonic gives zero beat points at 1/3 and 2/3 scale, corresponding to 0.33 and 0.66 Mc; the fourth harmonic gives points at 0.25, 0.50 and 0.75 Mc and so on. Figure 3 shows where these harmonic points are obtained, the number of the harmonic and the exact frequency, for harmonics up to the 10th.

It should be noted here that the <u>dial readings for these harmonic points are the same on all coil ranges</u>, which makes it very convenient in checking or in interpolating.

The difference in reading between the heterodyne and the crystal calibrator frequency at any point where zero beat may be obtained is the error of the heterodyne. While instructions are given below for realigning the heterodyne frequency meter, it will be found more convenient to simply correct the reading of the heterodyne to compensate for the error, unless the error is unusually large.

MEASURING AN UNKNOWN FREQUENCY For example suppose zero beat against an unknown frequency is obtained giving an <u>indicated</u> frequency of 16.613 Mc. The calibrator is then turned on, and the heterodyne checked at the nearest convenient harmonic point, say at 16.500 Mc. Let the check reading turn out to be 16.482 Mc, showing that the heterodyne reading is <u>low</u> by 16.500 - 16.482 = 0.018 Mc. Consequently, the <u>indicated</u> frequency of the unknown is <u>low</u> by 0.018 Mc, so the <u>true frequency is 16.613 + 0.018 = 16.631 Mc.</u>

Similarly, if the heterodyne reading were <u>high</u>, the true frequency would be the indicated frequency <u>minus</u> the heterodyne correction.

SETTING HETERODYNE TO A DESIRED FREQUENCY In the case where it is desired to set a local oscillator to a specific frequency, the heterodyne may be set to this frequency in advance. The oscillator may then be varied until zero beat is obtained. For example, suppose it is desired to set an oscillator to 16.631 Mc. The heterodyne is checked against the calibrator at the nearest convenient harmonic, say 16.500 Mc. Let the check reading be 16.482 Mc, showing that the heterodyne reading is <u>low</u> by 16.500 - 16.482 = 0.018 Mc. Consequently, the heterodyne must be set <u>low</u> by this amount from the desired frequency, or at 16.831 - 0.018 = 16.813 Mc to obtain the desired frequency.

Similarly, if the heterodyne reading were high, the heterodyne must be set high from the desired frequency by the amount of the correction.

USE OF HARMONICS The principal use for harmonic methods lies in extending the range of the heterodyne frequency meter to higher or lower frequencies. In this equipment every effort has been made to make this harmonic extension as simple and reliable as possible.

EXTENSION TO HIGHER FREQUENCIES In Figure 4 are shown, on a logarithmic scale, the frequency ranges covered by each harmonic of the heterodyne frequency meter from 1 to 20. Each range is shown as a horizontal line, the lengths of the lines being constant, since the percentage frequency coverage of each range is the same.

On each line are marked 10 intervals corresponding to the 10 coil ranges of the instrument. The interpretation of these coil range marks will agree with the engraving of the coil switch if the first is called 10, the second 11, and so on up to 19. The last mark is then 20, which represents the highest frequency which can be reached on Coil 19.

For any frequency, simply move upward to the point where the desired frequency line crosses the harmonic range line. At the intersection read off the number of the harmonic (which is the number of the line), the coil range and an approximate indication of the condenser scale reading. For example, let the desired frequency be 25 Mc. Entering at 25 on the frequency scale move upward meeting line 2 at Coil 12, condenser approximately 1/2. The desired frequency is then obtained when the heterodyne is set to Coil 12, with the condenser at about half-scale, using the second harmonic. The harmonic number being known (in this case 2), the exact setting of the heterodyne is 25/2 = 12.50 Mc.

In extending the range to higher frequencies, it should be noted from Figure 4 that the gain toward higher frequencies is obtained only at the high frequency ends of the harmonic ranges. Consequently, to use the lowest harmonic in a given high frequency measurement, always use as high a fundamental frequency as possible. In searching for an unknown high frequency always start with the heterodyne set on Coil 19 with the condenser at 1.0 (20 Mc) and progress toward lower frequencies until zero beat with the unknown frequency is picked up. For example, suppose a frequency near 60 Mc is to be measured. Entering Figure 4 at 60 on the frequency scale, an intersection on line 3, Coil 19, condenser maximum is found. Progressing further upward, an intersection on line 4, Coil 15, condenser zero is obtained. Similarly, line 5, Coil 12, condenser zero, line 6, Coil 10, condenser 0. Any one of these settings gives a harmonic at 60 Mc, being, respectively, the 3rd, 4th, 5th and 6th.

The lowest harmonic would in this case be the third. The unknown frequency is then 3 times the frequency of the heterodyne. (In this case 3 x (19+1.0) = 60.) If the harmonic beat against the unknown fell at 19.78 Mc (instead of just 20 Mc) the harmonic frequency would be 3 x 19.78 = 59.34 Mc.

If no idea is had of the value of an unknown frequency, the procedure is to start at the high frequency end of the heterodyne range and note the successive settings of harmonic beats as the frequency of the heterodyne is progressively reduced. Then with the coil and condenser settings of the highest frequency point, enter a harmonic line, and search for the next lower settings on the line immediately above the one entered. If agreement is obtained, the proper line was entered; if not, move up or down a line and try again. If more than two settings of the heterodyne were obtained, agreement should be obtained for every line crossed. This is simply another way of stating that the successive fundamental frequencies of the heterodyne, each multiplied by the correct harmonic number must give the same answer for the unknown frequency. A quick test on the figure will generally fix the correct harmonic numbers much more quickly than numerical trials.

EXTENSION TO LOWER FREQUENCIES When measuring frequencies below the fundamental range of the heterodyne frequency meter, the actual measurement is made at a harmonic of the unknown frequency. If a sufficiently strong signal of the unknown frequency is applied to the COUPLING terminals, harmonics will be generated in the detector itself. With weak signals, however, an external means of harmonic generation must be provided. In Figure 5 are shown the sub-harmonic frequency ranges of the heterodyne frequency meter. The general description of the chart follows that already given for Figure 4 From this chart the appropriate submultiple number (subharmonic number), the coil switch setting and approximate condenser setting may be found for frequencies below the range of the heterodyne frequency meter. For example, suppose the settings of the heterodyne are desired for a frequency of 4800 kc. Entering at 4800 kc on the frequency scale, move downward meeting the 3rd subharmonic line at Coil 14, condenser 1/3, and, next below, line 4 at Coil 19, condenser 1/4. The actual settings would be 4800 x 3 = 14,400 kc or 14.40 Mc and 4800 x 4 = 19,200 kc or 19.20 Mc.

In measuring an unknown frequency lying below the range of the heterodyne, always start with the heterodyne set at the lowest frequency (10.00 Mc) and progress toward higher frequencies until zero beat with the unknown is obtained, to make use of the lowest subharmonic number in a given measurement.

If no idea of the value of an unknown frequency is had, the procedure is to start at the low frequency end of the heterodyne range and note the successive points at which zero beat can be obtained against the unknown, as the heterodyne frequency is progressively increased. Then with the coil and condenser settings of the lowest frequency point, enter on a subharmonic line and search for the next higher settings on the line immediately below the one entered. If agreement is obtained the proper line was entered; if not, move up or down a line and try again. If more than two settings of the heterodyne were obtained, agreement should be obtained for every line crossed. This is simply another way of stating that the successive fundamental frequencies of the heterodyne, each divided by the correct subharmonic number must give the same value for the unknown frequency. A quick test on the figure will generally give the correct subharmonic numbers much more quickly than numerical trials.

PROCEDURE FOR VERY LOW FREQUENCIES

For frequencies below 1 Mc it will be found that more than one zero beat point will be found on a given coil range. If the readings at two successive points, corrected for any frequency meter errors, be noted, then the difference between them is approximately the unknown fundamental frequency. With this approximate value of the unknown frequency, it is easy to determine the number of the harmonic for any of the zero beat points which may be heard on the given coil or any other coil.

When the unknown frequency is very low, several zero beat points will be found in one coil range. In this case, taking the difference between two successive zero-beat settings can only give an approximate value for the unknown frequency. It is sufficiently good, however, to permit the harmonic numbers to be determined without ambiguity. Knowing the numbers of the harmonics corresponding to any zero beat point, it is possible to improve the accuracy of measurement by taking the difference in frequency of two zero beat points which are separated by several harmonics, then dividing this difference by the number of harmonic intervals between the two observed zero beat points (or the difference in the harmonic numbers of the two zero beat points).

For example, a low frequency is being measured and on Coil 10 zero beat points are observed at 0.127, 0.374, 0.621 and 0.868 on the condenser scale. The difference between successive harmonics is 0.247 Mc (247 kc) which is the approximate value of the unknown frequency. The frequency of the first zero beat point is 10.127 Mc which, divided by 0.247 Mc, the approximate fundamental, gives 10.127/0.247 = 41 for the harmonic number of this point. Then the harmonic numbers of the other points are, by inspection, 42, 43 and 44, respectively.

The fundamental frequency may then be determined by dividing the frequency of any zero beat point by its harmonic number, 10.127/41, 10.374/42, 10.621/43, 10.868/44 etc. giving 0.247 Mc or 247 kc for the unknown frequency; or the unknown frequency may be found from the difference in frequency of any two zero beat points, thus:

$$\frac{10.868 - 10.127}{44 \quad\quad 41} = \frac{0.741}{3} = 0.247 \text{ Mc } (247\text{kc}).$$

INSTRUCTIONS FOR ALIGNING HETERODYNE

Factory adjustments of the values of inductance, fixed capacity and variable capacity are made to make the calibration agree with the dial readings. Ordinarily the error of the heterodyne will be small enough that for use over long periods of time no readjustment should be required. If it becomes necessary to realign the heterodyne, the following procedure should be used.

If the calibration shifts upward on the dial, while the span remains essentially constant (that is, if the calibration reads, say, 2 divisions high at 0 and also 2 divisions high at 1.0 on the dial) adjust the zero capacity for the particular range involved, increasing the capacity to bring the calibration into agreement with the dial. (If the calibration is low, decrease the capacity.) As a precaution, after making this adjustment, check the span to see that calibration agrees with dial reading.

If the span is not correct, even though the calibration may agree with the dial readings at one end or the other of the dial, proceed as follows: If the span is too small (that is, one megacycle occupies a larger portion of the dial than the space between 0 and 1.0) decrease the inductance for the particular range involved, by turning the hex-head adjusting screw at the rear of the coil. If the core is plain metal, turn slightly to the right to decrease inductance. If the core is powdered iron, turn slightly to the left to decrease inductance. After adjusting inductance, check the calibration, and adjust capacity, if necessary, as instructed in preceding paragraph.

If the span is too large (that is, one megacycle occupies a smaller portion of the dial than the space between 0 and 1.0) increase the inductance for the particular range involved, by turning the hex-head adjusting screw at the rear of the coil. If the core is plain metal, turn slightly to the left to increase inductance. If the core is powdered iron, turn slightly to the right to increase inductance. After adjusting inductance, check the calibration, and adjust capacity, if necessary, as instructed above.

The positions of the coils and condensers for adjustment of the various ranges are shown in Figure 6.

APPLICATIONS The Type 620-A Heterodyne Frequency Meter and Calibrator has such a wide field of usefulness that no complete instructions for application of the instrument in any given problem can be given. The following suggestions may prove helpful, in those cases which are similar to the ones outlined, and may suggest suitable procedures in other problems.

For measuring high frequency transmitters, where the heterodyne is located in the transmitting room, or at least in the immediate vicinity of the transmitter, generally no special coupling means is necessary. A short wire connected to the upper "coupling" post on the panel of the heterodyne will increase the pickup considerably.

For low frequency transmitters, particularly where harmonic suppressor circuits are employed, or where the transmitter is very well shielded, it may be necessary to extend the coupling wire inside of the transmitter shield to obtain sufficient pickup, particularly if a high harmonic must be used in the measurement. Another method of obtaining a signal strong enough to be measured is to use an auxiliary oscillator whose fundamental is set to a harmonic of the transmitter frequency, and to measure a harmonic of this oscillator.

In measuring ultra-high frequency transmitters located at some distance from the heterodyne, an exposed coupling wire or small antenna has made it possible to measure the frequency of a transmitter at a distance of nearly one-half mile. The distance which may be covered in such measurements will depend greatly upon the particular locality, the frequency and the power of transmitter.

In checking automobile transmitters and receivers, it has been found convenient to put up a coupling grid or zig-zag over the space in which the cars may be parked during test. The coupling grid is connected to the upper coupling post of the heterodyne, which may be located in an adjoining room or building. For convenience, a long cord connected to the telephone binding posts may be led back into the area where the cars are parked and terminated in a loud speaker or telephones. The operator adjusting the transmitters then simply adjusts for zero beat.

For checking oscillators of low harmonic content as well as relatively low output voltage, such as signal generators (which also normally have a very low output impedance) best results are obtained by coupling the "high" side of the output to the upper coupling post. The attenuator setting should be for maximum voltage and maximum impedance. Shielded cables, or other high-capacity devices should not be used. In those cases where a coupling rod antenna is provided in the signal generator, connected to a point of comparatively high voltage, the coupling wire of the heterodyne may be brought near or wrapped around the rod. In some cases, particularly at low frequencies, it is necessary to use an auxiliary oscillator or oscillating receiver set to the signal generator as a source in order to obtain sufficient harmonic output or sufficient output voltage.

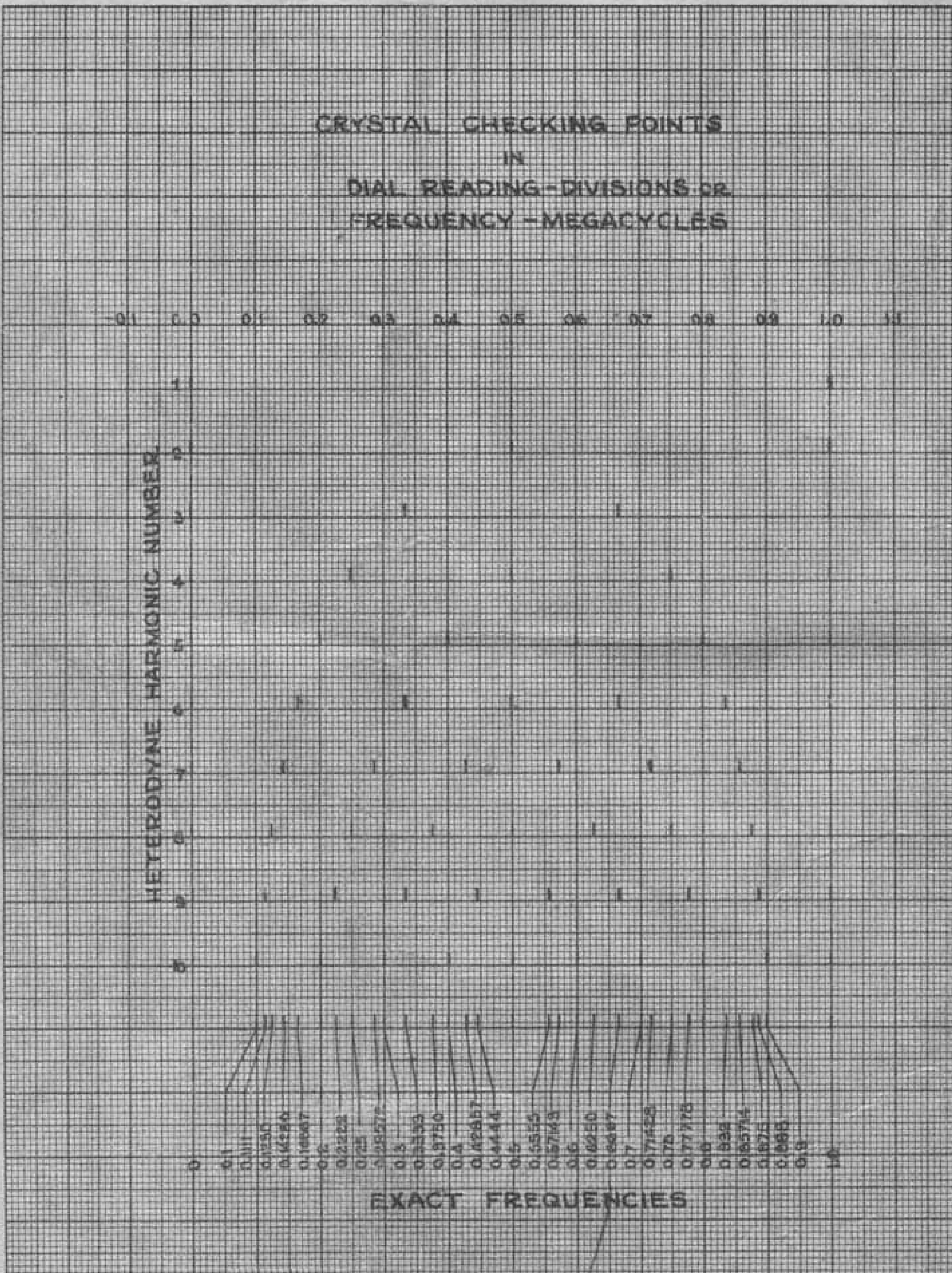
CRYSTAL CHECKING POINTS
IN
DIAL READING - DIVISIONS OR
FREQUENCY - MEGACYCLES
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
HETERODYNE HARMONIC NUMBER
1
2
3
4
5
6
7
8
9
0
0
0.1
0.111
0.1250
0.14286
0.16667
0.2
0.2222
0.25
0.28571
0.3
0.3333
0.3750
0.4
0.42857
0.4444
0.5
0.5555
0.57143
0.6
0.6250
0.6667
0.7
0.71428
0.75
0.77778
0.8
0.833
0.85714
0.875
0.888
0.9
1.0
EXACT FREQUENCIES

FIGURE 3

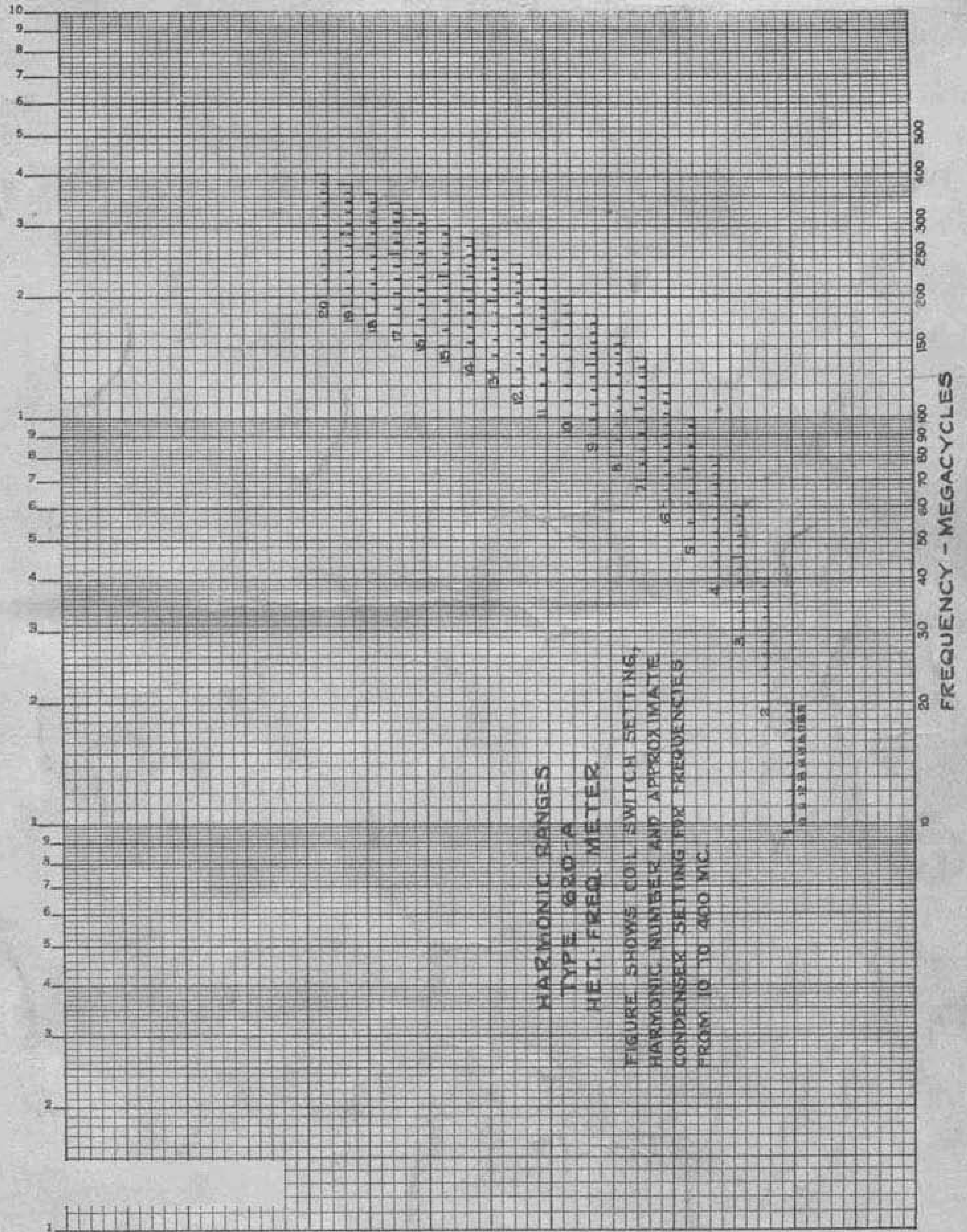
HARMONIC RANGES
TYPE 620-A
HET. FREQ. METER
FIGURE SHOWS COIL SWITCH SETTING,
HARMONIC NUMBER AND APPROXIMATE
CONDENSER SETTING FOR FREQUENCIES
FROM 10 TO 400 MC.
FREQUENCY - MEGACYCLES

FIGURE 4.

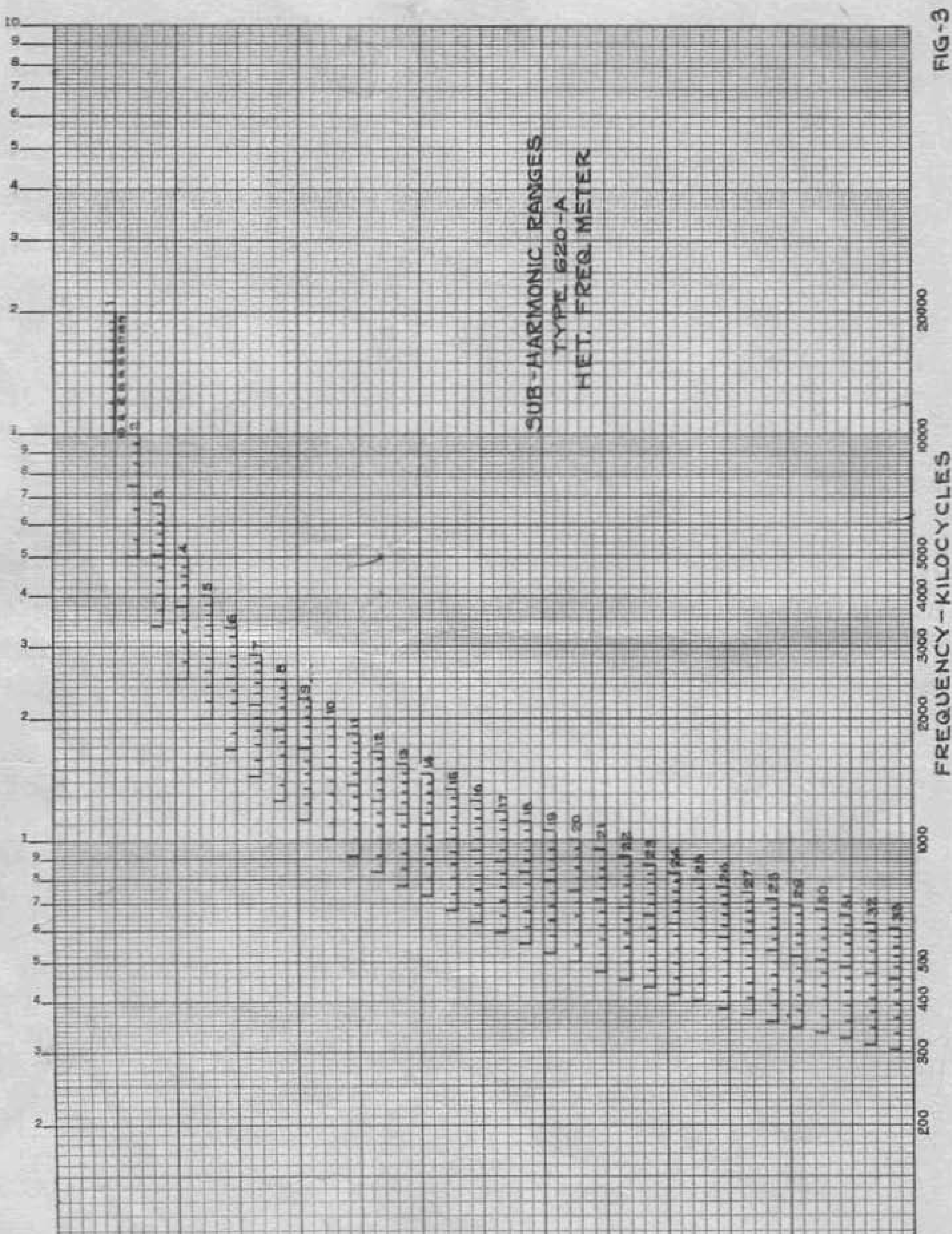
SUB-HARMONIC RANGES
TYPE 620-A
HET. FREQ. METER
FIG-3
FREQUENCY - KILOCYCLES

FIGURE 5.

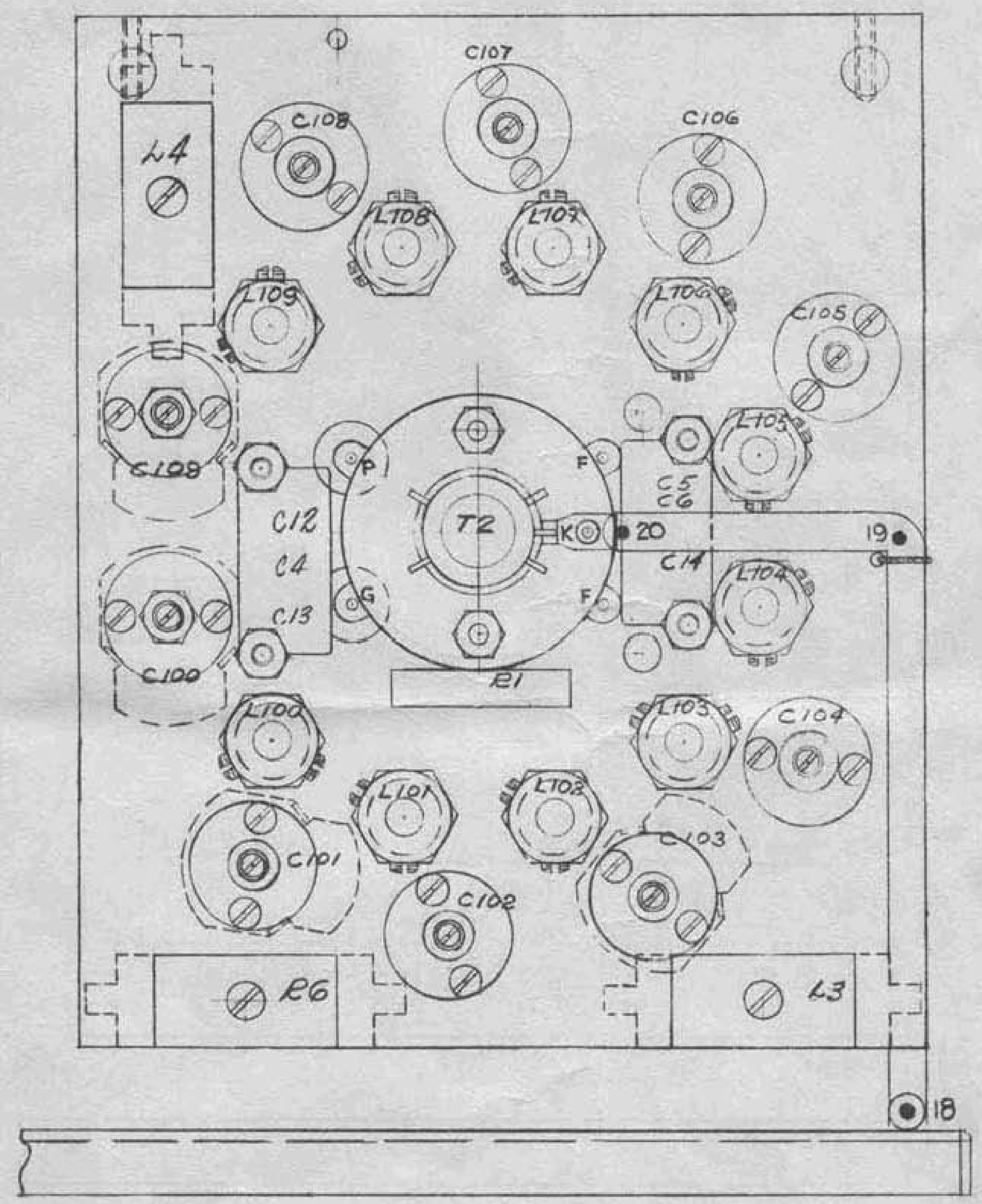

FIGURE 6. Location of Coils and Condensers

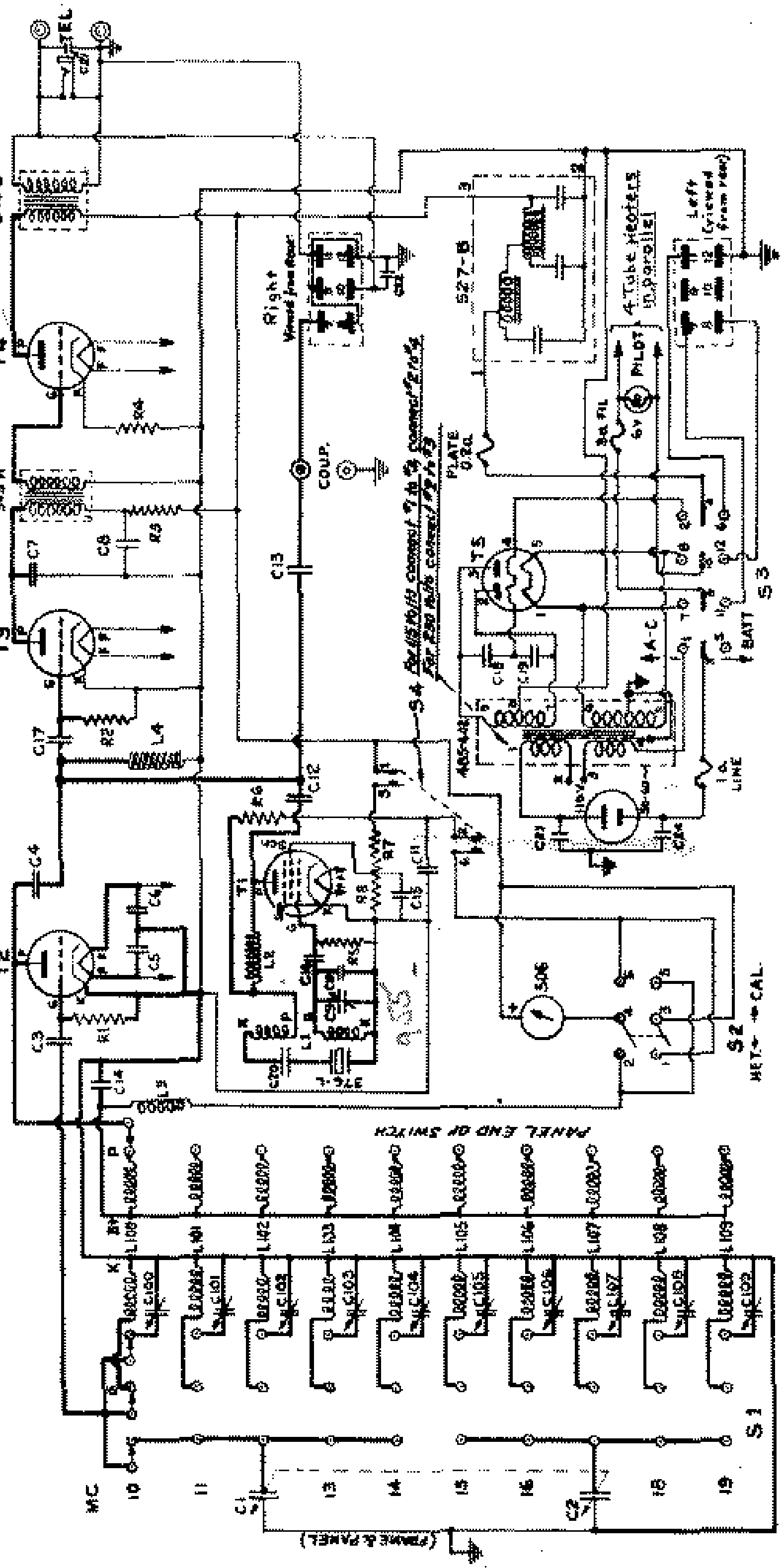

FIGURE 7. Wiring Diagram for Type 620-A Heterodyne Frequency Meter and Crystal Calibrator

PARTS LIST

CONDENSERS

C-1 = } 620-350
C-2 = }
C-3 = 20 uuf
C-4 = 5 uuf
C-5 = 0.0002 uf
C-6 = 0.0002 uf
C-7 = 0.0002 uf
C-8 = 1.0 uf
C-9 = } 420 uuf
C-10 = }
C-11 = 0.01 uf
C-12 = 5 uuf
C-13 = 5 uuf
C-14 = 200 uuf
C-15 = 0.01 uf
C-16 = 250 uuf
C-17 = 10 uuf ± 20%
C-18 = 0.0001 uf
C-19 = 0.0001 uf
C-20 = 0.01 uf
C-21 = 0.001 uf
C-22 = 0.001 uf
C-23 = 0.01 uf
C-24 = 0.01 uf
C-100 = 75 uuf
C-101 = 75 uuf
C-102 = 75 uuf
C-103 = 100 uuf
C-104 = 100 uuf
C-105 = 50 uuf
C-106 = 50 uuf
C-107 = 50 uuf
C-108 = 50 uuf
C-109 = 50 uuf

RESISTORS

R-1 = 0.5 MΩ
R-2 = 3 MΩ
R-3 = 50,000 Ω
R-4 = 1000 Ω
R-5 = 4 MΩ
R-6 = 4000 Ω
R-7 = 7000 Ω
R-8 = 16,000 Ω

INDUCTORS

L-1 = Type 620-36
L-2 = Nat'l 100 Choke
L-3 = Nat'l 100 Choke
L-4 = Nat'l 100 Choke
L-100 = Type 620-310
L-101 = Type 620-311
L-102 = Type 620-312
L-103 = Type 620-313
L-104 = Type 620-314
L-105 = Type 620-315
L-106 = Type 620-316
L-107 = Type 620-317
L-108 = Type 620-318
L-109 = Type 620-319

SWITCHES

S-1 = Type 510-450
S-2 = Type 139-335
S-3 = Type 339A
S-4 = Type 139-333

TUBES

T-1 = Type 954
T-2 = Type 955
T-3 = Type 955
T-4 = Type 955
T-5 = Type 84

PATENT NOTICE

This instrument is manufactured under the following U. S. Patents and license agreements:

Patents of the American Telephone and Telegraph Company, solely for utilization in research, investigation, measurement, testing, instruction and development work in pure and applied science.

Patents and patent applications of Dr. G. W. Pierce pertaining to piezo-electric crystals and their associated circuits.

Patent 1,542,995.
Patent 2,012,497.

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