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DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
WASHINGTON

Letter
Circular
183

(October 12, 1925)

DIRECTIONS FOR USE OF THE PIEZO OSCILLATOR AND AUXILIARY GENERATOR FOR CALIBRATION OF A RADIO FREQUENCY METER.

1. General

The piezo oscillator when used in connection with the continuously variable radio frequency generator gives a method of checking or completely calibrating a radio frequency meter (wavemeter). The piezo oscillator will produce any one of three frequencies, fixed by the dimensions of the quartz plate used. The electron tube circuit in which it is connected gives numerous harmonics for each fundamental frequency. The auxiliary generator which is continuously variable can be adjusted to any frequency and will likewise give a series of harmonics for each fundamental frequency to which it is adjusted.

The interaction of a frequency from the piezo oscillator with a corresponding frequency produced by the auxiliary generator gives a beat note which may be heard in a pair of head phones in either circuit. The auxiliary generator may then be adjusted to zero beat, i.e. to the exact frequency of the piezo oscillator. This frequency can then be transferred to the frequency meter. The harmonics present in the piezo oscillator circuit and auxiliary generator make it possible to obtain a large number of points. Any frequency present in the piezo oscillator can beat with a corresponding frequency present in the generator and so give a frequency point which is directly related to one of the fundamental frequencies of the piezo oscillator.

2. Operation of the Auxiliary Generator.

The connections of the batteries, coils, and phones are indicated on the panel of the auxiliary generator, the electron tube being turned on by means of the rheostat knob. The milliammeter indicates the current flowing in the grid circuit of the electron tube and shows whether or not the filament is lighted. The seven coils and the condenser cover the frequency range, 18 to 12,000 kilocycles, the approximate frequencies for the various settings of the condenser dial being indicated on the curve supplied with each coil. To produce a given frequency the connections are made as indicated, the proper coil selected as shown on the curve sheets and plugged in to the sockets marked "coil." When the filament is turned on the circuit will generate a frequency corresponding to the condenser setting. The frequency

can then be varied within the limits of the coil by changing the position of the condenser. When the auxiliary generator is producing the higher frequencies it will be found that bringing the hand near the condenser dial will change the frequency. This can be avoided by using the extension handle provided.

3. Transfer of a Frequency from the Auxiliary Generator to the Frequency Meter.

To transfer a frequency from the auxiliary generator to the frequency meter (wavemeter) the coils of the two circuits should be coupled rather closely. The frequency meter condenser should then be varied slowly while watching the grid current milliammeter on the auxiliary generator panel. When the frequency meter is adjusted near resonance to the generator the reading of the grid current milliammeter will start to decrease, reaching a minimum deflection at exact resonance. The coupling between the frequency meter and auxiliary generator should then be reduced so that the decrease of the grid current is only a few divisions. The setting of the frequency meter condenser for the exact point of minimum deflection now corresponds to the fundamental frequency produced by the auxiliary generator. If the auxiliary generator is adjusted to zero beat with the piezo oscillator or other source of radio frequency, the beat note should be observed during the adjustment of the frequency meter and the coupling kept loose enough not to change the beat note during the adjustment.

The current flowing in the frequency meter circuit when tuned to resonance will not usually be sufficient to operate the resonance indicator of the instrument. Since in some cases this adjustment of the indicating circuit may change the calibration of the frequency meter the setup of the frequency meter and indicating instrument must be the same during calibration as when in use.

4. Operation of the Piezo Oscillator.

The connections are made as indicated on the panel, the electron tube being turned on by means of the rheostat knob. The milliammeter indicates the plate current flowing. Three fundamental frequencies can be produced (approximately, high 450 kc, medium 105 kc, and low 75 kc) the exact frequencies being given in the certificate which accompanies the quartz plate and piezo oscillator. To produce the 450 kc frequency, the coil with the smaller number of turns is plugged in the socket marked "coil," the quartz plate holder plugged into the sockets marked "quartz plate," the switch set on F, and the filament rheostat turned on. The condenser dial is then turned slowly, starting from zero, until the plate current suddenly decreases, shown by a sudden decrease in the reading of the milliammeter. The circuit is now producing the highest frequency of the quartz plate (approximately 450 kc) and its

harmonics. It can be used as described below. The condenser setting for the highest frequency is given on the certificate accompanying the quartz plate.

To produce the two low frequencies the coil is changed to the one having the greater number of turns. Starting with the condenser dial at zero and the switch on F, the plate current will be found to be smaller than normal. If the dial is turned slowly there is a further decrease in the plate current, indicating that the circuit is producing the medium fundamental frequency (approximately 105 kc) and its harmonics. If the dial is slowly turned further, the plate current is still further reduced until at a certain dial setting the plate current suddenly returns to normal but may be instantly reduced again without turning the dial further. This indicates that instead of the 105 kc fundamental, the quartz plate is supplying the low fundamental frequency (approximately 75 kc). If the dial is turned so as to increase the dial reading, the plate current will be reduced further until suddenly the plate current goes back to normal, when the piezo oscillator is no longer supplying a radio frequency. The dial settings for the medium and low frequencies are also given in the certificate accompanying the quartz plate. These dial settings are important in distinguishing which fundamental frequency is being supplied by the quartz plate.

It will be observed that the dial setting for the medium fundamental (105 kc) is somewhat critical in that if the dial is turned too far, the low frequency fundamental will be brought in. Typical condenser settings for the three fundamentals are 450 kc, 55 with small coil; 105 kc, 17 with large coil; 75 kc, 75 with large coil. The lowest frequency may also be obtained at a setting of 20, with the large coil; hence care must be taken not to confuse the two lower frequencies. Changes in condenser setting will not change the frequency of the quartz plate unless the dial is near one of the critical points of the scale, but the plate current may be changed considerably which may alter the strength of the beat note produced between the piezo oscillator and the auxiliary generator. It may be necessary to tap or shake the quartz plate slightly in order to start oscillations.

5. Method of Calibration of a Frequency Meter (Wavemeter)

The arrangement of the apparatus for the calibration of a frequency meter is as shown in Fig. 1, attached, which likewise gives the schematic diagrams of the circuits used. If only one pair of phones is available they may be transferred as required from the piezo oscillator to the auxiliary generator. The binding posts marked "phones" must either have phones connected or be connected together by a piece of wire.

The piezo oscillator is adjusted to give its low fundamental frequency (with the larger coil in and the condenser adjusted to

give the decrease in plate current for the highest condenser setting). The coil which includes 75 kc is plugged into the auxiliary generator and the condenser set to give approximately 75 kc. The piezo oscillator and auxiliary generator coils are placed so that the coils are a few inches apart. While listening with the head phones connected in the piezo oscillator circuit the condenser of the auxiliary generator is varied slowly back and forth until a beat note is heard. Beat notes may be heard at several settings of the auxiliary generator condenser, but no difficulty will be found in determining the setting for the frequency of 75 kc when the approximate calibration of the auxiliary generator is used. The beat note produced by this frequency of the auxiliary generator will be much louder than the beat note produced by any other frequency. The generator condenser is now adjusted to the point of zero beat. As this condenser is turned continuously the pitch decreases, disappears and reappears again as an increasing pitch. The point at which the pitch disappears is the region of zero beat. The auxiliary generator is then producing exactly the same frequency as the piezo oscillator. This frequency should be transferred to the frequency meter as described in section 3 above, and gives the first point in the calibration.

The next point to obtain is the second harmonic of the piezo oscillator (approximately 150 kc). The piezo oscillator is left adjusted as before and the coil including 150 kc plugged into the auxiliary generator. The condenser is set to a frequency corresponding to 150 kc and as before, adjusted to zero beat. This frequency which is two times the exact frequency of the low fundamental frequency of the piezo oscillator quartz plate as given in the certificates, is transferred to the frequency meter as before. The third, fourth, etc. harmonics of the piezo oscillator are similarly selected. The piezo oscillator is then adjusted to its medium fundamental frequency and the procedure repeated. It is again repeated with the high fundamental frequency. When adjusting the auxiliary generator to zero beat, at the higher radio frequencies, if the beat note changes when the hand is removed from the auxiliary generator condenser dial, the extension handle should be used when making the adjustment.

To obtain points on the frequency meter of a lower frequency than the fundamentals of the piezo oscillator the phones are transferred to the auxiliary generator circuit and the piezo oscillator adjusted to give its high fundamental frequency (450 kc). The auxiliary generator is then set approximately to one-half the frequency (225 kc) and adjusted to zero beat. The frequency of the auxiliary generator which is now exactly one-half the high fundamental frequency of the piezo oscillator is transferred to the frequency meter. This is repeated for 1/3, 1/4, 1/5, etc. The process is then repeated for the other two fundamental frequencies of the piezo oscillator.

From the points already obtained it should be possible to draw calibration curves for the frequency meter. It may be

found, however, that there are several regions of uncertainty, i.e., where calibration points are widely separated. The use of so-called "fractional" harmonics will give points in any region of the curves. This consists of using the beats between harmonics of the piezo oscillator and harmonics of the auxiliary generator. If f is the fundamental frequency of the piezo oscillator which is being used and F the fundamental frequency of the auxiliary generator which gives zero beat, then

$$af = bF$$

where a and b are integers (1, 2, 3, 4, etc.)

For example, to obtain one of these points, adjust the piezo oscillator to give the low fundamental frequency, 75 kc. Set the auxiliary generator to give 50 kc and adjust to zero beat. The second harmonic of the low fundamental of the piezo oscillator (2 x 75 = 150) is beating with the third harmonic of the fundamental of the auxiliary generator (3 x 50 = 150). Then

$$2f = 3F$$

$$F = 2/3f$$

The fundamental frequency of the auxiliary generator is transferred to the frequency meter and is exactly 2/3 the low fundamental frequency of the piezo oscillator. This can be repeated for any combination of harmonics using any one of the three fundamentals of the piezo oscillator. The phones should be in the circuit which is producing the higher harmonic. In some cases there may be some uncertainty what harmonics are producing the beat note. However, with the approximate calibration of the auxiliary generator available it will be usually possible to identify them. In case an error is made it will be obvious when the point is plotted with the others on coordinate paper. It will probably only be necessary to use fractional harmonics for the lower frequency range of the frequency meter. Such values as 3/4f, 2/3f, 2/5f, 5/4f, 4/3f, 3/2f, 5/3f, 7/4f, etc., may be useful.

General information on piezo electric oscillators is contained in the following references:

Piezoelectric crystal resonators and crystal oscillators applied to the precision calibration of wavemeters. By G.W. Pierce. Proc. American Academy Arts & Sciences, 59, pp.81-106, Oct., 1923.

New methods for maintaining constant frequency in high frequency circuits (abstract). By W.G.Cady. Radio News, 3, p.392, Nov., 1921.

A piezoelectric method for generating electric oscillations of constant frequency (brief abstract). By W.G.Cady. Physical Review, 19, pp.381-382, April, 1922.

The quartz crystal oscillator (explanation of theory and application of dependable frequency control). By D.B.McGown. Radio (San Francisco), 7, pp.29-31, July, 1925.

Oscillating crystals. By H.S.Shaw. QST, 7, pp.30-33, July, 1924.

Oscillating crystals for wavemeter calibration. By R.G. Harris. Radio News, 5, p.1418, April, 1924.

The piezoelectric oscillograph. By C.B.Bazzoni. Radio News, 7, pp.142-143, August, 1925.

The quartz oscillator. By E.Mallet and V.J.Terry. Wireless World and Radio Review, 16, pp.630-636, June 24, 1925.

The piezoelectric effect in composite Rochelle salt crystals. By A. McL. Nicolson. Proc.A.I.E.E., 38, pp.1315-1333, Nov., 1919.

Attached: Figure 1.

Department of Commerce,
Washington, D.C.

Summary of "Directions for Use of the Piezo Oscillator and Auxiliary Generator for Calibration of a Radio Frequency Meter."

Fundamentals of piezo oscillator are approximately: low, 75 kc; medium, 105 kc; high, 450 kc. (The actual fundamental frequencies are given in the certificate which accompanies the quartz plate).

1. Obtaining points of higher frequencies than fundamentals.

(Phones in piezo oscillator circuit). The specific values hofckilocycles here given are approximate and illustrative.

a. Adjust piezo oscillator for low (±75 kc) fundamental. Set auxiliary generator for 75 kc and adjust to zero beat. Transfer frequency from auxiliary generator to frequency meter. Point on frequency meter = low fundamental of piezo oscillator.

b. Leave piezo oscillator at low fundamental. Set auxiliary generator for 150 kc and adjust to zero beat. Transfer frequency from auxiliary generator to frequency meter. Point on frequency meter = two times low fundamental of piezo oscillator.

c. Leave piezo oscillator at low fundamental. Set auxiliary generator to 3 x 75 (= 225); 4 x 75 (= 300); etc. Transfer frequencies from auxiliary generator to frequency meter. Points on frequency meter = three times low fundamental, four times low fundamental, etc.

d. Adjust piezo oscillator for medium (105 kc) fundamental. Repeat a, b and c.

e. Adjust piezo oscillator for high (450 kc) fundamental. Repeat a, b and c.

2. Obtaining points of lower frequencies than fundamentals.

(Phones in auxiliary generator circuit).

a. Adjust piezo oscillator for high (450 kc) fundamental. Set auxiliary generator to 225 kc and adjust to zero beat. Transfer frequency from auxiliary generator to frequency meter. Point on frequency meter = 1/3 high fundamental of piezo oscillator.

b. Leave piezo oscillator at high fundamental. Set generator to 450/3, 450/4, etc. and adjust to zero beat. Transfer frequency from auxiliary generator to frequency meter. Point on frequency meter = 1/3, 1/4, etc. high fundamental of piezo oscillator.

c. Adjust piezo oscillator for medium fundamental frequency. Repeat a and b of this section.

d. Adjust piezo oscillator for low fundamental frequency. Repeat a and b of this section.

3. Obtaining intermediate points ("fractional harmonics") (See note

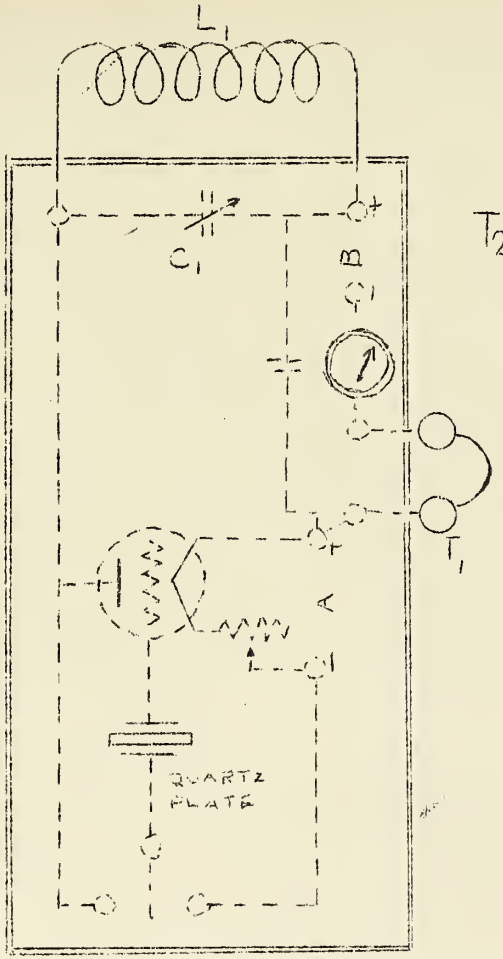
(Phones in circuit giving higher harmonic).

a. Adjust piezo oscillator to low fundamental frequency. Set auxiliary generator to 50 kc and adjust to zero beat. Second harmonic of piezo oscillator beating with third harmonic of auxiliary generator. Transfer frequency from auxiliary generator to frequency meter. Point on frequency meter = 2/3 low fundamental frequency of piezo oscillator.

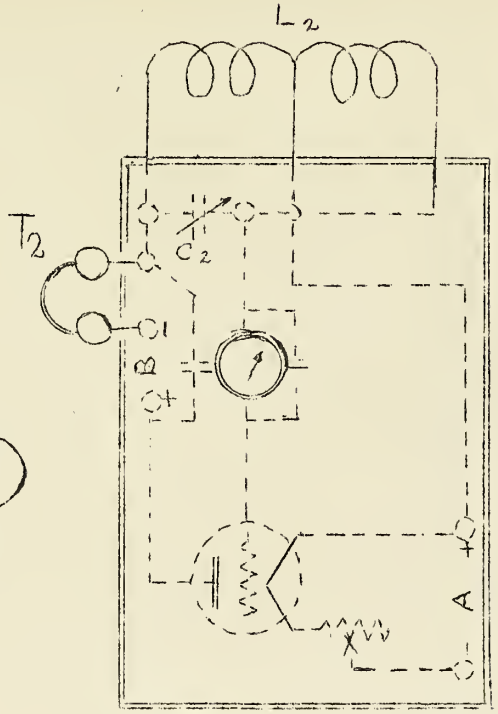
Repeat for other combinations of harmonics for this and the other two fundamental frequencies.

Note:- Paragraphs 1 and 2 will probably give a sufficient number of points for satisfactory calibration curves. Paragraph 3 gives a method of filling in doubtful regions of the curves.

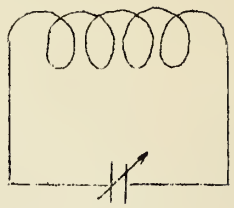
FIGURE 1



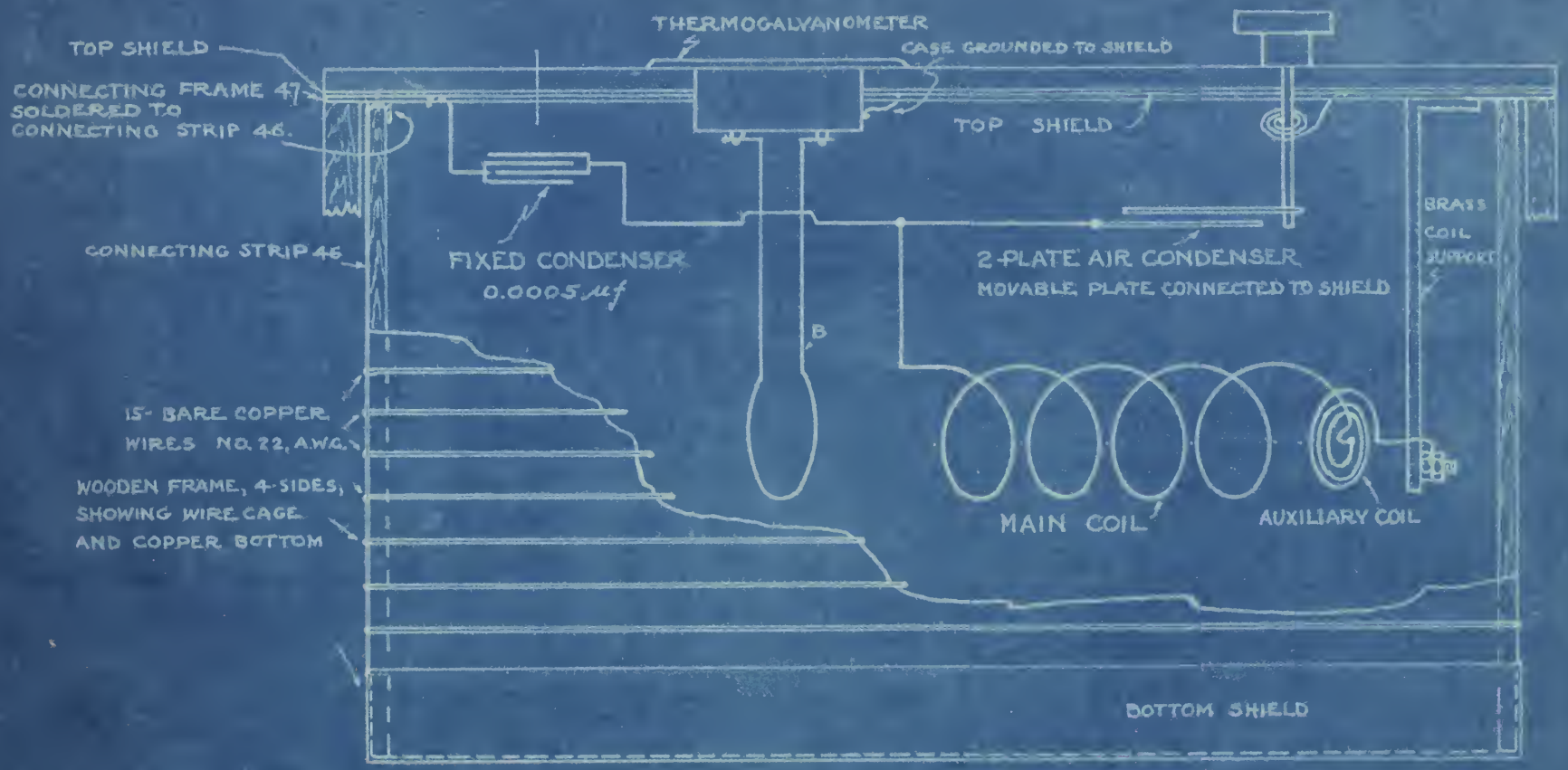
PIEZO OSCILLATOR



AUXILIARY GENERATOR



FREQUENCY METER
TO BE CALIBRATED



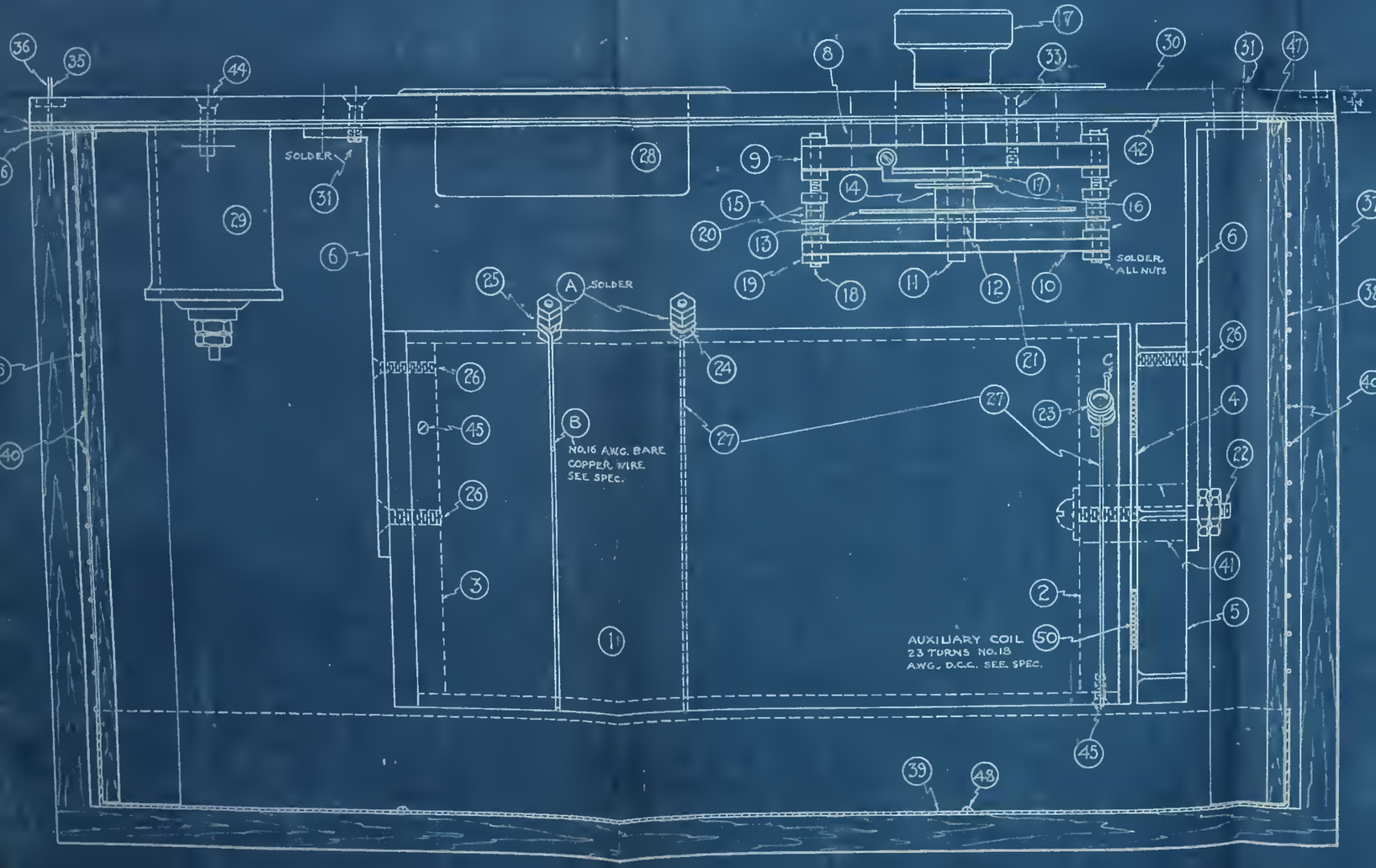
RADIO FREQUENCY INDICATOR TYPE B

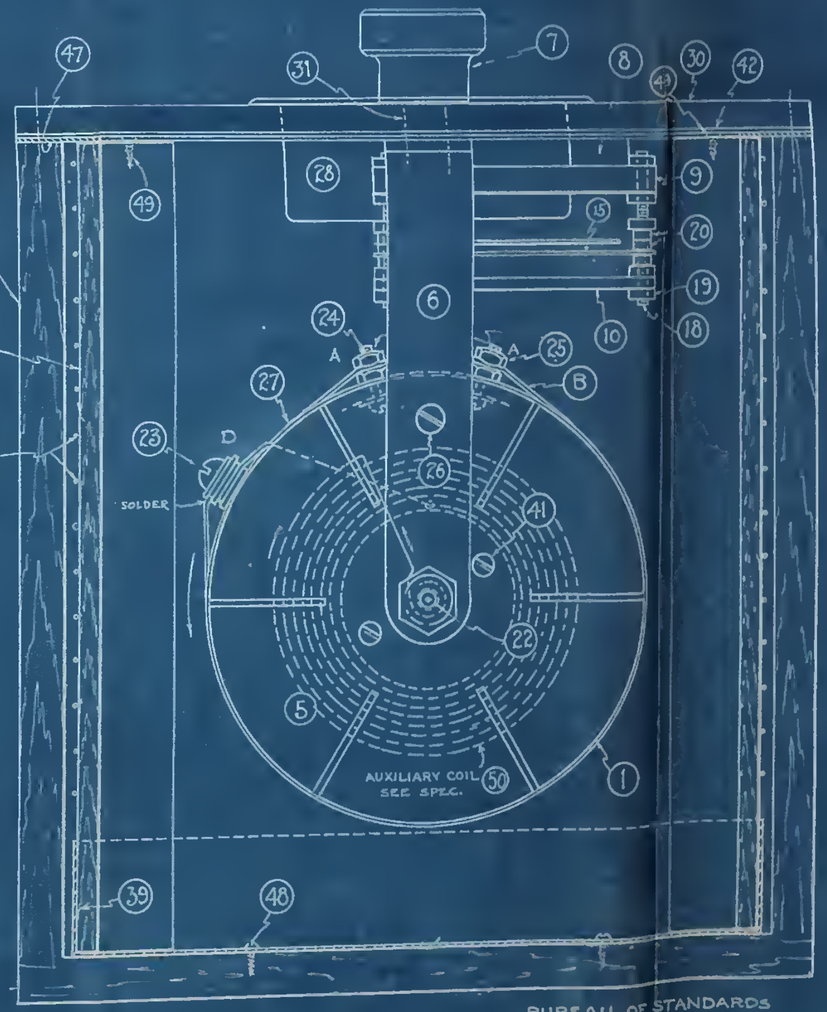
CIRCUIT DIAGRAM.

Bureau of Standards
Radio Section
Radio No 970 D
Drawn By JPB. Date May 26, 24

BUREAU OF STANDARDS RADIO FREQUENCY INDICATOR TYPE B.

SYM	NO REQD.	DESCRIPTION	MATERIAL	REMARKS
1	1	Tube	Insulation	
2	1	Right end disc	"	
3	1	Left end disc	"	
4	1	Separator disc	"	
5	1	Disc	"	
6	2	Legs	Brass	
7	1	Knob & pointer	Ins. & Brass	
8	4	Blocks	Insulation	
9	1	Top Condenser panel	"	
10	1	Lower " "	"	
11	1	Shaft	Steel	
12	1	Separator	Brass	
13	1	Movable plate	Aluminum	
14	1	Separator	Brass	
15	1	Fixed Condenser plate	Aluminum	
16	1	Disc	"	
17	1	Washer & Terminal	Brass	
18	3	Screw Rods. 8-32 Thrd.	"	
19	18	Nuts. 8-32 Thrd.	"	Solder all nuts.
20	9	Separators	Aluminum	
21	1	Stop pin	Steel	
22	1	Screw .12-24 x 1 5/8" Nothreads	Brass	2 Washers
23	1	" 8-32 x 1"	" "	3 Washers
24	1	" 8-32 x 9/16"	" "	Nut & Washer (3 units)
25	2	" 8-32 x 9/16"	"	" " (6 ")
26	3	" 10-32 x 9/16"	"	" " (9 ")
27	1	Main coil	Copper wire	See Spec. (No. 16 AWG. BARE COPPER WIRE)
28	1	Thermogalvanometer		" "
29	1	Fixed Condenser		" "
30	1	Top panel	Insulation	10" x 7" x 1/2"
31	4	Screws 8-32 Thrd.	Brass	Dull Nickle Finish
32	2	Letters	Engrave	
33	4	Screws 8-32 x 1 1/16"	Brass	" "
34	3	Screws	"	" "
35	2	" No. 4 x 7/16"	"	" "
36	10	" No. 6 x 5/8"	"	" "
37	1	Box	Oak	DARK STAIN
38	1	Frame	Wood (dry)	
39	1	Bottom Shield	Copper	Part of Spec. No. 31
40	15	Wires	Bare copper	No. 22. B & S. 50 feet required.
41	2	Screws 10-32 x 1"	Brass	
42	1	Top Shield	Copper	No. 18. B & S.
43	1	Letters	Engrave	
44	2	Screws		Dull Nickle Finish
45	5	" 6-32 x 1/4	Brass	
46	1	Connecting strip	Copper	
47	1	" Frame	"	
48	8	Screws No. 2 x 1/4"	Brass	
49	4	" 40. 2 x 1/4	"	
50	1	Auxiliary coil	Copper	23 Turns No. 18 A.W.G. D.C.C. see spec.





BUREAU OF STANDARDS
RADIO FREQUENCY INDICATOR, TYPE B
RADIO NO. 875-A
DRAWN BY J.G.S.
CHECKED BY
DATE May 24, '24
APP.:

Sheet No. 2

3-DRILL No. 27

12 THREADS = 1.0 1/32 x 1/32"

NUMBER OF THREADS EQUAL NUMBER OF TURNS OF WIRE REQUIRED. LOCATE 3-HOLES "A" TO SUIT SUCH REQUIREMENT. ANNULAR GROOVE "B" SHOULD BE PLACED 1 3/16" OUT FROM LAST TURN OF WIRE.

SEE NOTE

7"

TUBE - INSULATING MATERIAL.

DRILL No. 48

DRILL No. 18

2 - DRILL No. 27

1/16" SLOT - TO PASS WIRE THROUGH: IDENTIFING HOLE "C", SYM. 1.

8-32 x 1/4" TAP

10-32 TAP (2)

12-24 TAP

6-32 x 1/4"

INSULATING MATERIAL

RIGHT END DISC.

10-32 TAP

3-6-32 x 1/4"

INSULATING MATERIAL

END DISC.

2-DRILL No. 9

DRILL No. 1

INSULATING MATERIAL

ROUND CORNERS OF SLOTS

10-32 TAP

DRILL No. 9-CS.

DRILL No. 1

INSULATING MATERIAL

PRESS FIT, 3/16" SHAFT

SOLDER

2-TAP 8-32 THRDS.

NO. 9 DRILL-CS.

NO. 1 DRILL-CS.

(FOR LEFT LEG, DRILL, No 9-CS.)

2 - BRASS LEGS

BRASS STOP-PIN 1/16 x 1/8

INSULATING MATERIAL

1/16 x 3/16 STEEL PIN

3 - 3-48 x 1/8 SCREWS

6-32

BRASS END PIN.

STEEL SHAFT

PRILL No. 18

INSULATING MATERIAL 4 WANTED

BRASS SPACER

BRASS SPACER

3-DRILL No. 18

FIXED PLATE ALUMINUM 1/32" THICK

MOVABLE PLATE ALUMINUM 1/32" THICK.

8-32 THREAD 3-WANTED - BRASS.

ALUMINUM WASHER 1/32 THICK x 7/8" ø

8-32 THD.

BRASS NUTS 18 WANTED

3-DRILL No. 18 (3)

PRESS FIT, 1/16 STOP PIN

INSULATING MATERIAL CONDENSER TOP

3-DRILL No. 18

4-8-32

TAP 3-48

PRESS FIT 1/16 STOP PIN

DRILL No. 18 ALUMINUM 3-WANTED

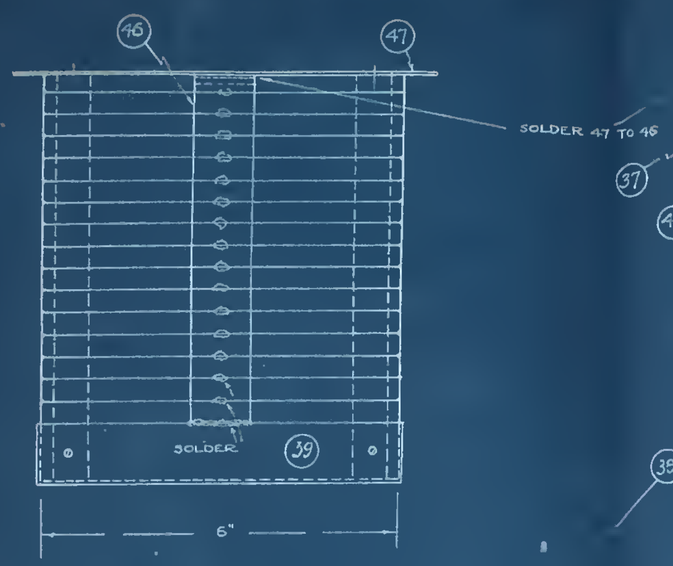
BUREAU OF STANDARDS

RADIO FREQUENCY INDICATOR TYPE B.

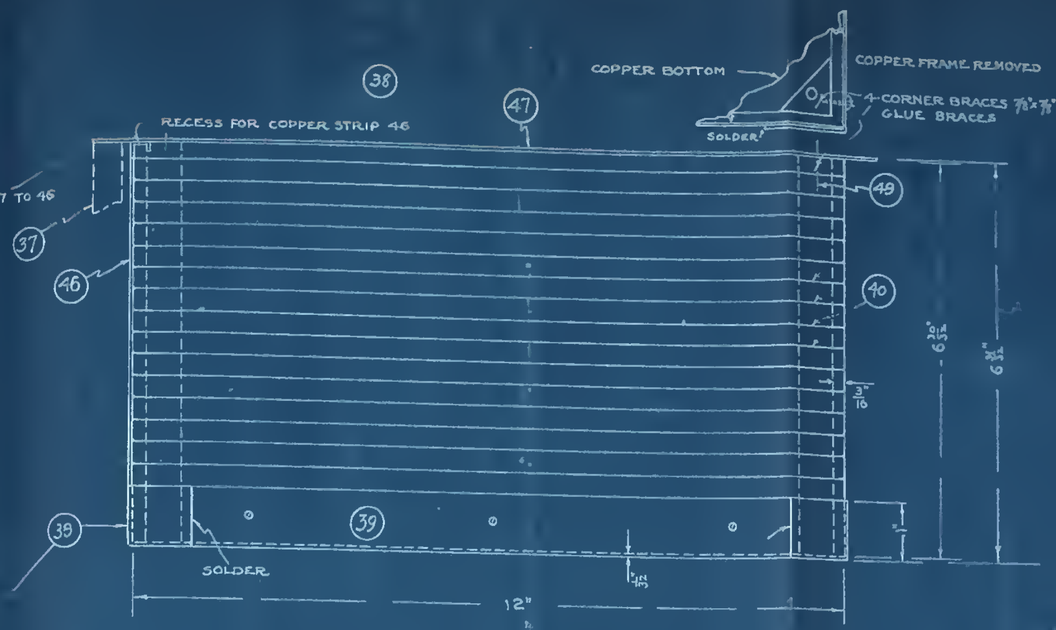
RADIO NO. 970-B : MAY 23 '24

DRAWN B JJQ.

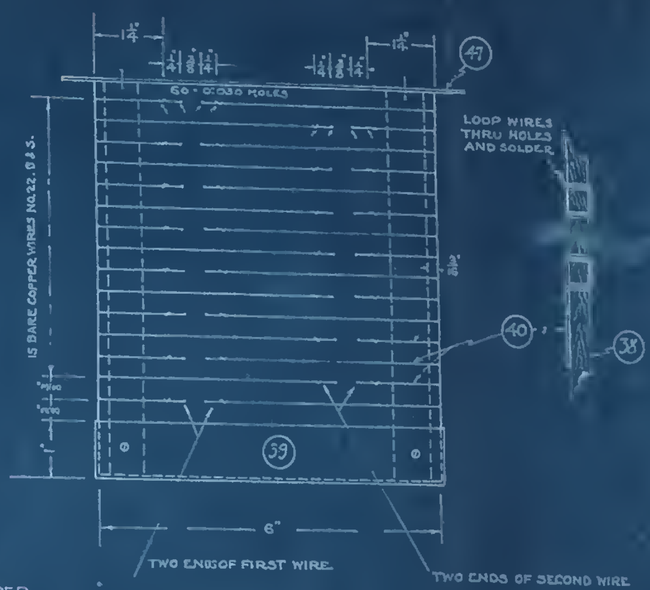
CHECKED BY APP :



LEFT END ELEVATION
SHOWING WIRES SOLDERED TO COPPER STRIP

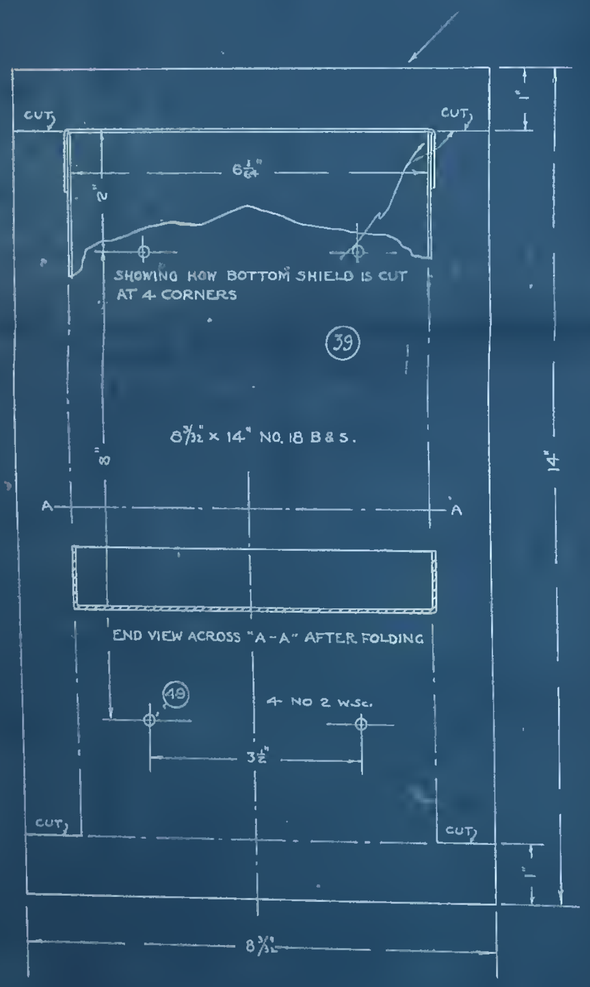


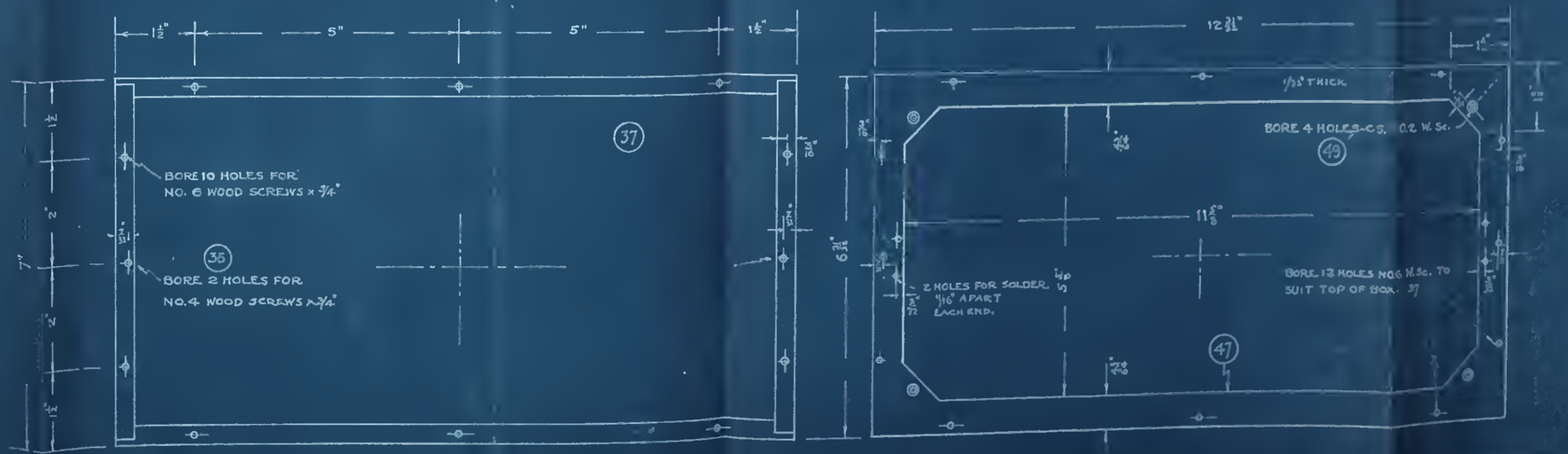
SIDE ELEVATION



RIGHT END ELEVATION
SHOWING ENDS OF WIRE SEWED IN WOOD WITH SOLDERED ENDS

3/16" WHITE PINE FRAME - 4 SIDES, COPPER BOTTOM, BRACED AT CORNERS AS SHOWN.





BUREAU OF STANDARDS
RADIO FREQUENCY INDICATOR
TYPE B.
RADIO NO. 970-C
DRAWN BY C.J. CHECKED BY
DATE May 24-24 APP: