MAKING FREQUENCY MEASUREMENTS

WITH

CLASS C-21-HLD PRIMARY-FREQUENCY STANDARD

AND

MEASURING EQUIPMENT

ENGINEERING DEPARTMENT

GENERAL RADIO COMPANY

CAMBRIDGE, MASSACHUSETTS, U. S. A.

FORM 354-E

Type 699
Comparison Oscilloscope

Type 616
Heterodyne-Frequency Meter

Type 617
Interpolation Oscillator

Type 619
Heterodyne Detector

Type 612
Coupling Panel

Type 619-P1
Coil Drawer

Type 614
Selective Amplifier

Type 697
Speaker Assembly

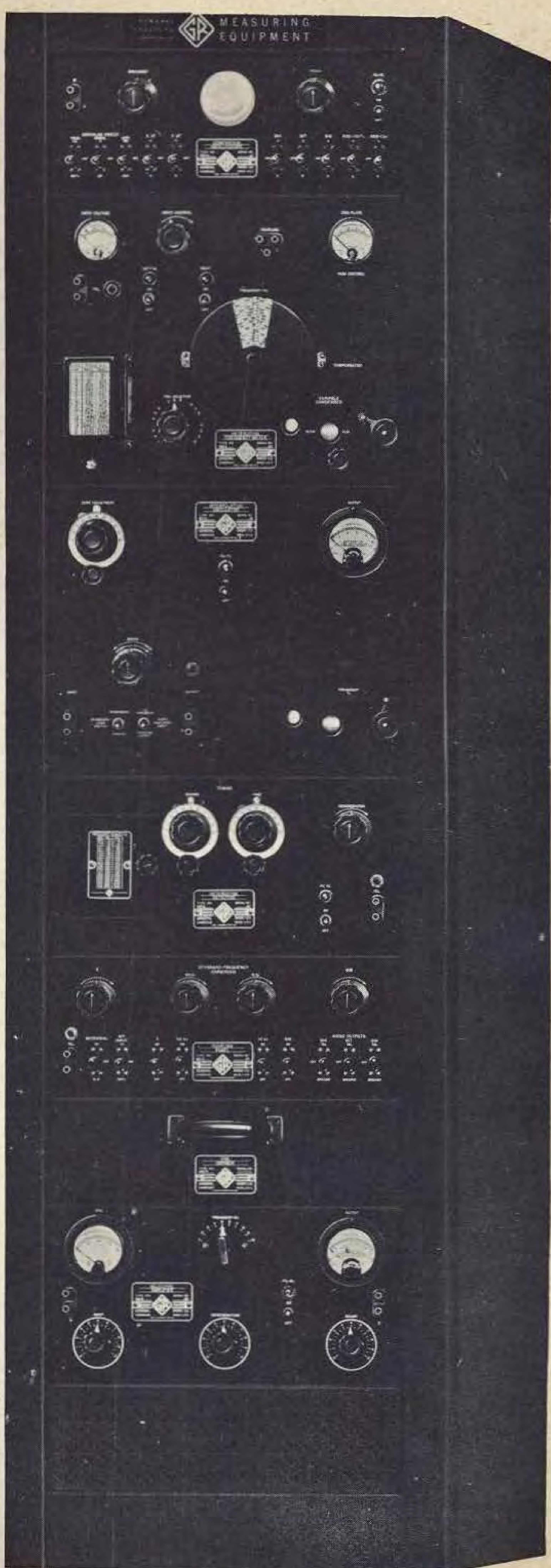

FIGURE 1. Assembly of the frequency measuring equipment for which this book is the instruction manual.

FOREWORD

A General Radio Class C-21-HLD Primary Frequency Standard supplies a multitude of accurately-known standard-frequency reference points distributed at convenient intervals over the audio- and radio-frequency spectrum. The apparatus for measuring the frequency of an unknown signal lying somewhere between these standard reference points is the "Interpolating and Auxiliary Equipment" or, simply, "Measuring Equipment".

The "Measuring Equipment" consists of the following individual pieces of General Radio apparatus:

- Type 699 Comparison Oscilloscope
- Type 616 Heterodyne Frequency Meter
- Type 617 Interpolation Oscillator
- Type 619 Heterodyne Detector
- Type 612 Coupling Panel
- Type 619-P1 Coil Drawer
- Type 614 Selective Amplifier
- Type 697 Speaker Assembly

This book supplies complete and detailed instructions for making frequency measurements with a Class C-21-HLD Primary Frequency Standard and the "Measuring Equipment". Detailed information for setting up and operating the former and the individual instruments of the latter is given in the instruction book accompanying each component. (With the exception of the Type 612 Coupling Panel which, because it is the means for coordinating the operation of the other instruments, is described in this book.)

Every effort has been made to adapt both the equipment and these instructions to every measuring problem within its scope. No difficulties should be experienced once the operator has become familiar with the apparatus and with the technique explained on the following pages. Should troublesome questions arise, the General Radio Company will be glad to do what it can to answer them.

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Any one of these sources may be used, or any combination, as required. Each volume control has a switch which may be used to remove or introduce the corresponding voltage on the heterodyne detector input, without the necessity of turning the volume control back to zero.

The markings of the switches are as follows, the switch positions being numbered from left to right:

		Handle		
Position	Marked	Up	Center	Down
1	Microdial	ON	OFF	SC (short circuit)
2	617 Input	1 KC	619	100 cycles
3	X	ON	-	OFF
4	50 KC	ON	-	OFF
5	10 KC	ON	-	OFF
6	616	ON	-	OFF
7	Audio Output 614	TEL	OFF	SPEAKER
8	Audio Output 617	TEL	OFF	SPEAKER
9	Audio Output 619	TEL	OFF	SPEAKER

The functions of the switches are, briefly, as follows:

Switch No. 1 - MICRODIAL

In comparing the syncronometer reading with time signals, the Type 619 Heterodyne Detector may be used as a receiver. With this switch ON, the microdial is connected across the output circuit of the heterodyne detector.

Switch No. 2 - 617 INPUT

The input circuit of the Type 617 Interpolation Oscillator is connected to any one of three sources, for checking calibration or for matching an unknown beat frequency. These are: UP - 1-Kc standard frequency; CENTER - Output of Type 619 Heterodyne Detector, DOWN - 100-cycle standard frequency.

Switches Nos. 3, 4, 5 and 6

These are the ON-OFF switches associated with the four radio-frequency volume controls. They are, in order, "X", or unknown frequency source; 50-kc harmonic output of frequency standard; 10-kc harmonic output of frequency standard and output of Type 616 Heterodyne Frequency Meter. These switches permit any one of the sources to be cut off from the input of the Type 619 Heterodyne Detector without the necessity of returning the associated volume control to zero.

Switch No. 5, with the 10-kc volume control, also control the output of the 9 or 11 kc output of the Type 698-A Duplex Multivibrator. Selection of the 9, 10 or 11 kc output is made by a switch on the duplex multivibrator.

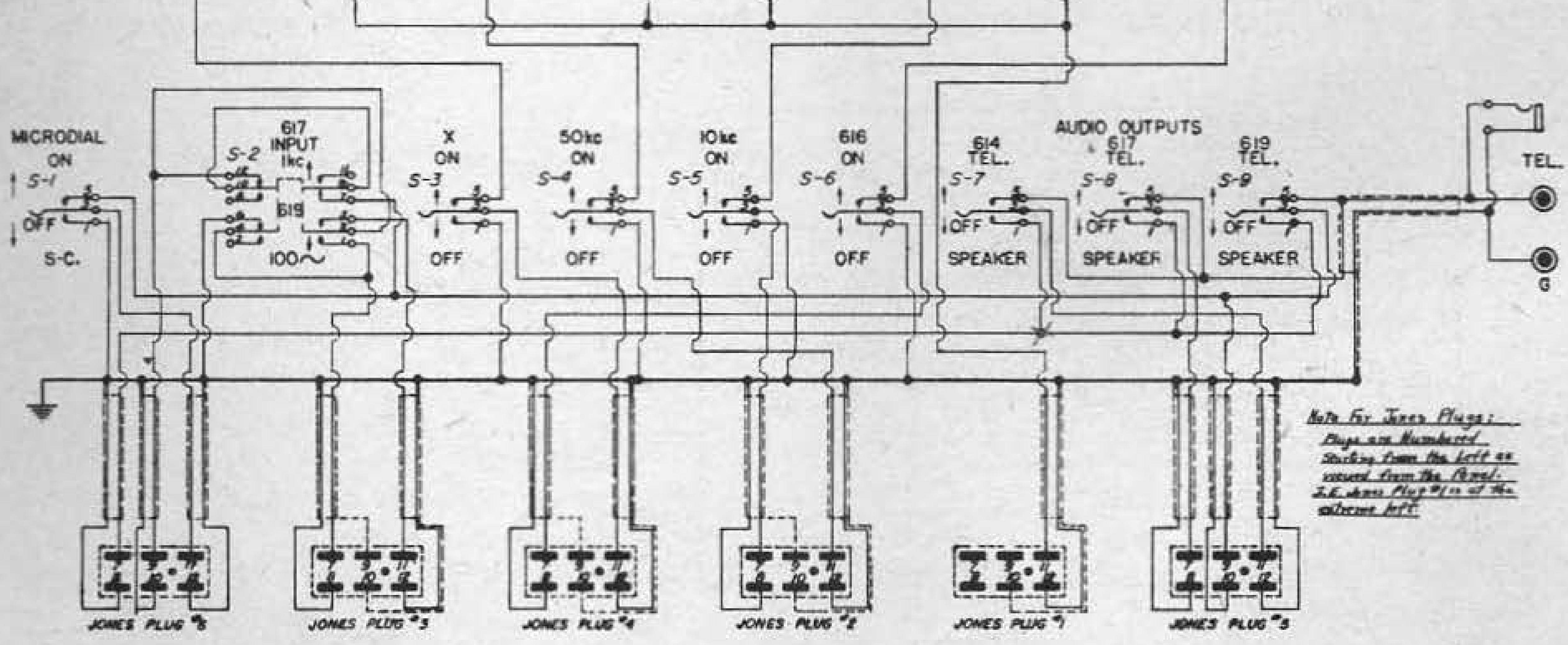


FIGURE 6. Wiring diagram for the Type 612 Coupling Panel

Switches Nos. 7, 8 and 9

This group controls the radio-frequency outputs of three sources, to connect any one or any combination to either telephone receivers or loud speaker. The switches, in order, are for the output of the Type 614 Selective Amplifier, the Type 617 Interpolation Oscillator and the Type 619 Heterodyne Detector.

PART VI
MAKING FREQUENCY MEASUREMENTS

GENERAL STATEMENT The various operations may be traced from the schematic diagram of Figure 7. These are considered in detail in the following section. In general, the successive steps of making a frequency measurement are as follows. In certain cases the procedure may be simplified and in other cases intermediate steps may be required.

STEP 1. Picking up and identifying the signal, the frequency of which is to be measured, for transfer to and comparison with the standard. This step may be very simple in the case of a local oscillator or transmitter; it may be rather complicated in the case of a remote very high frequency transmitter.

STEP 2. Transferring the signal frequency for comparison with the standard. This transfer may be made at the original signal frequency, or, for various reasons, may be at a multiple or sub-multiple of the signal frequency.

STEP 3. Obtaining the audio beat frequency difference between the transferred signal frequency and the nearest standard frequency. This audio frequency must be of a <u>useful</u> value, which may sometimes require a change in transferred signal frequency (Step 2) or a change in standard frequency.

STEP 4. Determination of value of beat frequency obtained in Step 3.

STEP 5. Determination of the sign of the beat frequency difference. This is equivalent to determining whether the unknown is above or below the standard frequency. If the unknown is above the standard, the beat difference is considered positive and the value is added to the standard frequency. If the unknown is below the standard, the beat frequency difference is considered negative, and the value is subtracted from the standard frequency to obtain the value of the unknown frequency.

STEP 6. Determination of the value of the standard frequency used in the measurement. This is equivalent to determining which harmonic of the frequency standard was used, since the fundamental frequency is known in any case.

In special cases, where the frequency transferred to the standard for measurement is not the original signal frequency, either of the two following steps may be necessary.

STEP 7. Identification of the harmonic of the heterodyne frequency meter which was used in the measurement. Generally this is a low number and it

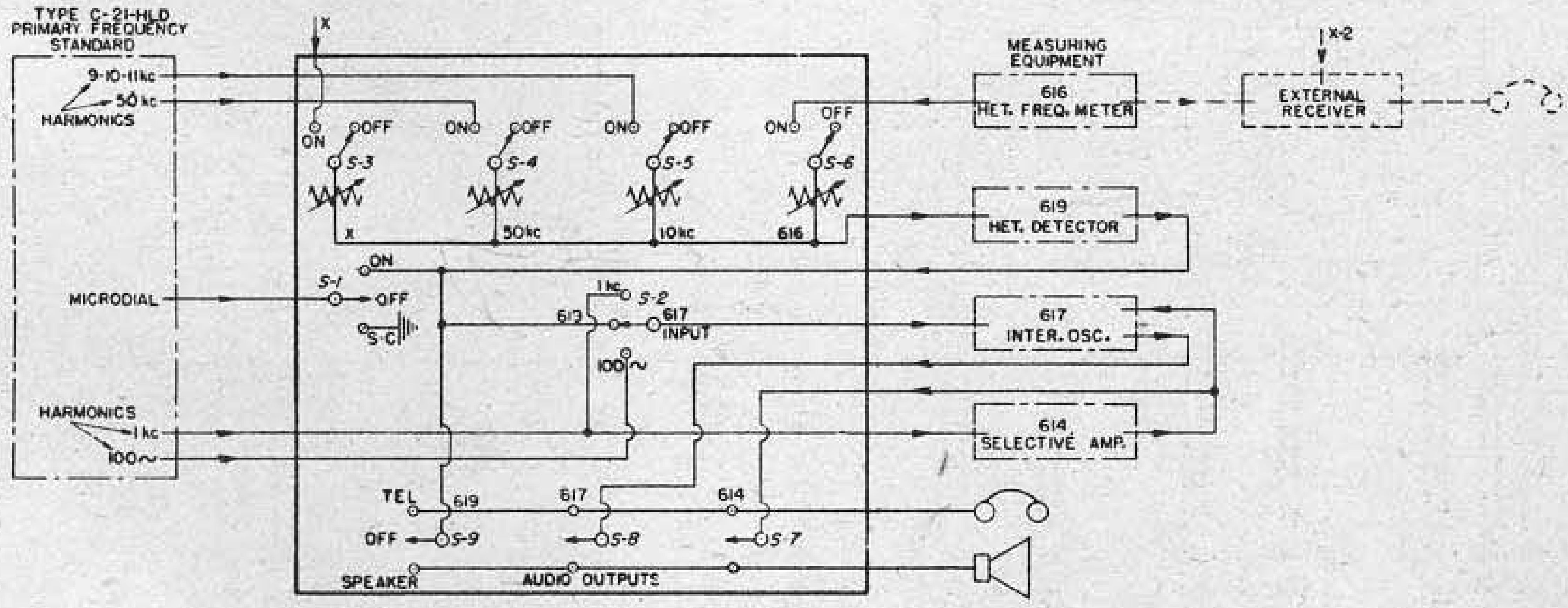


FIGURE 7. Functional schematic diagram of Type 612 Coupling Panel

is often determinable directly from the scale of the frequency meter. This step would be necessary generally only on measurements of high frequencies, say, above 8 or 10 Mc.

STEP 8. Identification of the harmonic of the unknown frequency which was used in the measurement. If not already known from other considerations, it may often be determined directly from the scale of the heterodyne frequency meter. This step would, in general, apply only in the measurement of a low radio frequency, say, below 25 or 50 kc.

In many cases, some of the steps may be eliminated, or they may be taken simultaneously with other steps thereby simplifying the procedure. This is particularly true in cases where routine measurements of a number of stations are made. Since, in such cases, all adjustments are known within close limits in advance, all of the detailed steps above may not be necessary.

PART VII
MAKING MEASUREMENTS: PROCEDURE

A brief summary of the operations involved in carrying out the successive steps of a frequency measurement will be given, followed by some operating suggestions which may prove helpful.

To simplify the diagram, and the details of procedure, the Type 699 Comparison Oscilloscope is considered separately (See Part IX, page 18). In studying the operations given here, all that is necessary is to remember that in addition to the aural and visual (meter) indications described, further visual indications may be obtained for all calibrations, checks and measurements on the Type 699 Comparison Oscilloscope. These are very useful and convenient; so much so that after operators become familiar with handling the measuring equipment, they turn naturally to the comparison oscilloscope in practically all measurements.

In this section the various steps in making frequency measurements are covered with some detail. The actual switching operations are listed in the following table. After becoming familiar with the equipment, the table will give all necessary information.

Refer to Schematic Diagram, Figure 7, page 6, and to Table of Operations, page 10.

STEP 1. Picking up the signal of unknown frequency.

The source of frequency is to be connected to the terminals of line "X" in the upper left of Figure 7. This line is a length of shielded conductor brought out from the rear of the measuring equipment. If a local oscillator is being measured, the "X" line may be connected to a coupling point in the oscillator circuit, to a coupling coil of a few turns, or coupled through a capacitance. If line is connected to an antenna, a coupling transformer or network may or may not be essential, depending on the particular installation.

The normal impedance of the "X" line is 65 ohms. One conductor is "high", one "low"; the "high" side being marked. The "low" side is normally ground. The shield may or may not be grounded at the source, as conditions require.

Throw the X switch to ON and advance the X volume control on the Type 612 Coupling Panel. Plug in the selected coil in the Type 619 Heterodyne Detector. Throw the Type 619 Heterodyne Detector output switch to telephones or speaker as required.

Next adjust the X volume control, the heterodyne detector tuning and regeneration to obtain the required signal, at its fundamental frequency.

Refer to Table, Operation 1.

STEP 2. Transferring signal frequency for comparison with Standard

If the frequency to be measured lies roughly between 25 kc and 8 to 10 Mc, the operations above are all that are necessary for transferring the frequency for comparison with the standard.

If the frequency is lower than 25 kc, either a harmonic should be measured in the range above 25 kc, or the fundamental frequency may be measured in terms of the Type 617 Interpolation Oscillator by means of the Type 699 Comparison Oscilloscope. Both of these operations are described in later sections.

If the frequency is higher than 8 or 10 Mc, it is not easy to obtain the beat difference directly against the standard, first, because the 10-kc standard harmonics are so close together on the frequency scale that great care is necessary in identifying the harmonic used in the measurement, and second, because the very high harmonics become weaker and weaker as the frequency is raised until a point is reached where satisfactory beats are difficult to obtain. The Type 616 Heterodyne Frequency Meter may be used in this case. A harmonic of the heterodyne frequency meter is matched against the frequency to be measured, either in the Type 619 Heterodyne Detector (upper limit 25 Mc) or in an external receiver. The fundamental frequency of the Type 616 Heterodyne Frequency Meter is then measured in the range below 5 Mc, where the measurement may be quickly and easily made.

For frequencies below 25 kc, introduce a harmonic of the frequency being measured at X, Figure 7.

For frequencies 25 kc to 25 Mc introduce the fundamental frequency at X, Figure 7, if no external receiver is to be used.

For frequencies above 8 or 10 Mc, using an external receiver, introduce the frequency to be measured at X-2 and pick-up signal in the external receiver. The output connection from the Type 616 Heterodyne Frequency Meter for use with the external receiver is supplied as a long cable connection from the rear of the measuring equipment.

Refer to Table, Operations 2, 3 and 4.

STEP 3. Obtaining the audio-beat frequency difference between transferred unknown frequency and the standard.

Introduce the standard frequency by throwing the 10-kc harmonic switch and advancing the 10-kc harmonic volume control. With the heterodyne detector in the oscillating state, either the unknown frequency or the standard frequency may be heard on throwing the switches at Positions 3 and 5. Adjust volume controls to give fairly loud signals of about equal intensity from both sources. Next decrease regeneration until the heterodyne detector does not oscillate; retune for maximum beat frequency intensity; readjust volume controls to get desired beat output.

The above covers the general procedure for frequencies from 25 kc to 8 or 10 Mc.

For frequencies below 25 kc, the procedure above is exactly the same if a harmonic of the unknown frequency can be obtained with sufficient intensity to give a good beat output in the heterodyne detector.

For frequencies above 8 or 10 Mc. an intermediate step is necessary. If an external receiver is being used, simply adjust a harmonic of the heterodyne frequency meter to zero beat with the incoming signal. If the heterodyne detector is used, with no external receiver, plug in the proper coil and pick up the unknown signal. Next throw the heterodyne frequency meter switch and adjust the heterodyne frequency meter, using the volume control as necessary, until the harmonic is brought to zero beat with the unknown. (See later section for suggestions on zero beat adjustments.) Leaving the adjustment of the heterodyne frequency meter strictly alone, remove the coil of the Type 619 Heterodyne Detector and substitute the appropriate coil for picking up the fundamental frequency of the heterodyne frequency meter. From this point on, the procedure is exactly the same as that given previously, considering the heterodyne frequency meter fundamental frequency as the unknown, introduced through the 616 switch and volume control.

See Table, Operations 5, 6 and 7.

STEP 4. Determining the value of beat frequency obtained in Step 3.

The beat frequency is measured by connecting the input of the Type 617 Interpolation Oscillator to the output of the Type 619 Heterodyne Detector and transferring the telephones to the interpolation oscillator output.

Throw the STANDARDIZING SWITCH on the Type 617 Interpolation Oscillator panel to "STANDARDIZE" position; AUDIO AMPLIFIER INPUT switch to DETECTOR OUTPUT position; turn MIXER control toward left to obtain maximum input voltage from the Type 619 Heterodyne Detector. The beat frequency output of the Type 619 Heterodyne Detector should then be heard in telephones or speaker.

Next turn the MIXER control toward the right until both the beat frequency output of the Type 619 Heterodyne Detector and the output of the Type 617 Interpolation Oscillator are heard in the telephones or speaker. Adjust the frequency of the Type 617 Interpolation Oscillator to match that of the beat frequency output of the Type 619 Heterodyne Detector.

When nearly matched, a slow waxing and waning in intensity of the tone heard will be observed. If the MIXER control is adjusted to give equal intensities from the two sources, the waxing and waning will extend from practically zero to twice the intensity of either source. This is a desirable adjustment giving the most pronounced deflections of the output meter, and the most pronounced beats in the telephones or speaker.

If the intensity of the Type 619 Heterodyne Detector output greatly exceeds that of the Type 617 Interpolation Oscillator, the MIXER control will have to be turned nearly as far as possible to the right. Under these conditions, the best adjustment for maximum waxing and waning is easier to reach if the output of the Type 619 Heterodyne Detector is reduced by use of the radio-frequency volume controls. (See later sections on checking calibration of Type 617 Interpolation Oscillator.)

Adjust the Type 617 Interpolation Oscillator to obtain a very slow beat on the output meter. Read the value of the beat frequency output of the Type 619 Heterodyne Detector from the scale of the Type 617 Interpolation Oscillator. (See special instructions of Type 617 Interpolation Oscillator, Type 698 Duplex Multivibrator and Type 699 Comparison Oscilloscope for cases where a very low beat is obtained.)

See Table, Operations 8, 9, 23.

STEP 5. Determination of sign of beat frequency difference.

As pointed out previously, this is equivalent to determining whether the frequency under measurement is above or below the standard frequency. There are several methods of doing this; with experience in handling the equipment, this step may be done at the time Step 2 is done instead of in a separate operation.

A. Throw switches, as given in Step 1 above, to pick up the unknown frequency in the Type 619 Heterodyne Detector. With the detector oscillating, adjust for zero audible beat. Throw the X switch to OFF and throw the 10-kc switch to ON. A beat note, of less than 5 kc should be heard. Next observe the direction in which the tuning dial of the Type 619 Heterodyne Detector must be moved in order to approach zero beat against the standard.

If the dial must be moved to lower readings, it indicates that the standard is below the unknown frequency; the sign of the beat frequency is then positive.

If the dial must be moved to higher readings, it indicates that the standard is above the unknown frequency; the sign of the beat frequency is then negative.

The beat frequency should be added to, or subtracted from, the standard frequency according as the sign determined above is positive or negative.

B. If the Type 616 Heterodyne Frequency Meter is used, for the measurement of a high frequency, the sign of the beat frequency can be determined exactly as given above, by considering the unknown to be introduced through the 616 switch and volume control instead of through X.

C. In certain cases, where the beat frequency is very low, perhaps only a cycle or so, use must be made of a change in standard frequency to determine both the value and sign of the beat frequency. By means of the Type 698 Duplex Multivibrator the standard frequency output may be changed from 10 kc to either 9 or 11 kc. For all frequencies except multiples of 990 kc, a change to one or the other will always result in a beat frequency lying near 1 kc or a multiple of 1 kc.

This beat frequency is readily matched on the Type 617 Interpolation Oscillator and the sign and magnitude of the departure from 1 kc (or a multiple thereof) is easily determined from the frequency increment dial. See special instructions for using the Type 617 Interpolation Oscillator.

See Table, Operations 10, 11, 12 and 14.

STEP 6. Determination of the value of the standard frequency used in the measurement.

Over a large part of the frequency range this operation may be combined with Steps 2 and 5 above.

Proceeding as in Step 5, after noting the direction in which the dial of the Type 619 Heterodyne Detector is turned, to move toward zero beat against the standard, adjust to zero beat against the standard. From the calibration of the Type 619 Heterodyne Detector the value of the standard frequency is at once determined, particularly in the low and medium frequency ranges.

For high frequencies, the calibration of the Type 619 Heterodyne Detector may not be sufficiently reliable to discriminate between one 10-kc harmonic and the next. In this case, note the dial reading obtained for the zero beat setting.

Next, cut off the 10-kc standard harmonics by throwing the 10-kc switch to OFF and introduce the 50-kc harmonics by throwing the 50-kc switch to ON.

Move the Type 619 Heterodyne Detector dial above and below the zero beat setting, obtaining zero beat against the nearer 50-kc harmonic. The value of frequency of the nearer is at once determined from the Type 619 Heterodyne Frequency Meter calibration. Set to zero audible beat.

Cut off the 50-kc and introduce the 10-kc harmonics. Carefully readjust the Type 619 Heterodyne Detector tuning toward the original zero beat setting, counting the number of 10-kc harmonics passed over to arrive at this setting. The value of the standard frequency is then known at once as the value of the 50-kc harmonic frequency, plus or minus the number of 10-kc intervals passed over. The sense of the 10-kc intervals is, of course, evident from the direction in which the dial is turned.

Another method is to make use of the direct-reading finder dial of the Type 616 Heterodyne Frequency Meter. After determining the sign of the beat frequency, set the Type 619 Heterodyne Detector to zero beat with the standard harmonic used in the measurement. Throw the Type 616 Heterodyne Frequency Meter switch to ON and adjust the 616 to zero beat. Determine the value of the standard frequency harmonic directly from the dial.

See Table, Operation 22.

STEP 7. Identification of the harmonic of the Heterodyne Frequency Meter used in a measurement.

When the heterodyne frequency meter is used, either with the Type 619 Heterodyne Detector, or with an external receiver, to bring the actual measured frequency into a range below 5 Mc. for convenient measurement against the standard, it is adjusted so that a harmonic is brought to zero beat against the frequency to be measured. To obtain the actual value of the frequency it is necessary to multiply the observed heterodyne fundamental frequency by the number of the harmonics used.

In many cases the approximate value of the signal frequency is known, in which case inspection of the heterodyne frequency meter finder dial (direct-reading) establishes which harmonic is used.

If the approximate value is not known, it may often be estimated with all necessary accuracy from the calibrations of the Type 619 Heterodyne Detector or external receiver.

Finally, if all these fail, it is possible to make a definite test to determine the harmonic number, from two readings of the heterodyne frequency meter. (See detailed instructions for Type 616 Heterodyne Frequency Meter.)

STEP 8. Identification of the harmonic of the unknown frequency which was used in a measurement.

When a harmonic of the unknown frequency is measured, as in measuring low frequencies of, say, less than 50 kc, it is necessary to know which harmonic was used in order to evaluate the unknown fundamental frequency from the observed data.

If the approximate value of the fundamental frequency is known, the harmonic number is generally determined directly from the calibration data of the Type 619 Heterodyne Detector.

If the approximate value is not known, then tune the Type 619 Heterodyne Detector to two successive harmonics, noting the frequency of each as given by the calibration data. The difference of these two frequencies is approximately the fundamental frequency, from which the harmonic number can at once be determined, usually by inspection.

See Table for several operations not considered in detail here, as well as numerous suggestions in procedure.

SUMMARY OF OPERATIONS
TYPE 612 COUPLING PANEL

Operation	Switches	Positions	Remarks
1. Picking up a frequency for measurement in Type 619 Heterodyne Detector. Connect antenna, coupling coil or coupling terminals of source to X cable.	X 619-OUT	UP UP-TEL DOWN-SPKR	Use appropriate coil in 619. Advance X volume control as necessary. Adjust tuning of 619 and regeneration as required. It is generally more satisfactory to use telephones, at least in first picking up distant transmitters.
2. To match a harmonic of 616 Heterodyne Frequency Meter to the frequency to be measured, using 619 Heterodyne Detector. Used, generally, only if frequency being measured is over 8-10 Mc.	X 619-OUT 616	UP UP-TEL UP	Proceed as in 1, to pick up signal. Set receiver to zero beat. Throw 616 switch up, advance 616 volume control and pick up 616 harmonic. Set 616 to zero beat, offset 619 tuning to obtain beat tone of 1-2 kc; reset 616 carefully by three-oscillator method, if exact match is required. Change coil in 619 to coil covering 616 fundamental frequency for measuring against standard.

Operation	Switches	Positions	Remarks
3. To match a harmonic of 616 Heterodyne Frequency Meter to the frequency to be measured, using external receiver. Couple 616 output (cable at rear of measuring equipment) to external receiver.	616	UP	Tune receiver to signal frequency. Set to zero beat. Vary 616 Heterodyne Meter frequency until harmonic is heard in receiver; adjust 616 for zero beat. Offset receiver for tone of 1-2 kc; reset 616 carefully by three-oscillator method.
4. To pick up a harmonic of the unknown frequency (low radio frequencies below, say, 50 kc), introduce signal through X cable. Advance X volume control.	X 619-OUT	UP UP-TEL	Proceed as in 1 above; if signal is strong enough, or if it contains appreciable harmonics, signal will be heard. If not, distortion must be introduced in the coupling system, as by passing through a rectifier.
5. To obtain beat frequency difference between unknown and standard frequency.	X 10 KC 619-OUT	UP UP UP-TEL	With 619 Heterodyne Detector in oscillating condition, pick up signal as in 1 above. Throw X down and 10-kc switch up. A beat will be heard which is approximately the value of the final beat frequency desired. Now with X and 10 kc switches up, decrease regeneration in 619 until non-oscillating state is reached; retune and adjust volume controls until maximum beat amplitude is obtained. On changing 619 tuning only amplitude, <u>not</u> frequency, of beat should change.
6. To obtain beat frequency difference between a harmonic of the unknown frequency (where fundamental of unknown is 50 kc or less) and the standard.	X 10 KC 619-OUT	UP UP UP-TEL	Same as 5 above if harmonic is of sufficient intensity.
7. To obtain beat frequency difference between fundamental of 616 frequency meter and the standard, (harmonic of 616 having been set to match a high frequency signal, above 8 Mc.).	616 10 KC 619-OUT	UP UP UP-TEL	Same as 5 above considering the 616 heterodyne frequency meter as the "X" source and the 616 controls on coupling panel as "X" controls.
8. To measure beat frequency output of 619 Heterodyne Detector.	617-IN 617-OUT	CENTER(619) {UP-TEL DOWN-SPKR	Throw panel switches on 617, STANDARDIZING to STANDARDIZE, AUDIO AMPL. INPUT to DETECTOR OUTPUT (normal positions for most uses in measuring). Turn MIXER control full to LEFT; same tone should be heard as in output of 619. Then advance MIXER to right until voltages from 619 and from 617 are approximately equal. Ad-

Operation	Switches	Positions	Remarks
			just 617 frequency until slow beat is obtained on output meter. (See also instructions for Type 699 Comparison Oscilloscope.)
9. To measure an audio-frequency (less than 5 kc); connect oscillator to INPUT terminals of 617.	617-INPUT	CENTER-619	Throw 617 Panel Switches as in 7 above, and proceed in same way to match. Make certain there is no audio frequency output of 619 Heterodyne Detector.
10. To determine sign of beat frequency difference, of beat between unknown and standard.	X 619-OUT	UP UP-TEL	Pick up unknown as in 1 above. Adjust 619 to zero beat against unknown.
	THEN		
	X 10 KC 619-OUT	DOWN UP UP-TEL	On throwing switches a beat tone should be heard, less than 5 kc. Retune 619 toward zero beat and note direction in which dial is turned. See page 9.
11. To determine sign of beat frequency difference, of beat between 616 Heterodyne Frequency Meter and Standard.	616 619-OUT	UP UP-TEL	Pick up 616 as in 5 above. Set 619 to zero beat with 616.
	THEN		
	616 10 KC 619-OUT	DOWN UP UP-TEL	On throwing switches a beat tone should be heard, less than 5 kc. Retune 619 toward zero beat and note direction in which dial is turned. See page 9.
12. To obtain a useful beat frequency output when difference of unknown and a 10-kc standard harmonic is very small.	X 10 KC 619-OUT	UP UP UP-TEL	As in 5 above. Resulting beat frequency is too low to use readily. Then throw 9-10-11 kc switch on 698 Duplex Multivibrator in standard to either 9 or 11 kc, whichever gives the best beat tone. See page 9.
13. To check calibration of 617 Interpolation Oscillator.	617-INPUT 617-OUT	{UP-1 KC / DOWN 100~} {UP-TEL / DOWN-SPKR}	Throw 617 Panel switches, as in 7 above. Proceed as in matching a beat tone, where in this case a match can be made at each 100 cycles when checking against the 100-cycle standard or each 1000 cycles when checking against the 1-kc standard. Many other check points may also be obtained. See Type 699 Oscilloscope instructions.
14. Use of Incremental Frequency Dial on Type 617 Interpolation Oscillator.	X 10 KC 619-OUT	UP UP UP-TEL	Obtain beat as in 5; if beat frequency is very low, then change 9-10-11 kc on Type 698 Duplex Multivibrator to either 9 or 11 kc, whichever gives best beat.

Operation	Switches	Positions	Remarks
	THEN		
	617-IN 617-OUT 619-OUT	UP UP-TEL CENTER	Throw switches and check 617 against 1 kc, or 1 kc multiples, at which beat was obtained above. Set incremental dial to zero. Then set main dial carefully for zero beat against the 1-kc harmonic.
	THEN		
	617-IN 617-OUT	CENTER 619 UP	Readjust incremental frequency dial on 617 for zero beat. Read frequency increment from dial.
15. To use output meter of 617 Interpolation Oscillator to show a slow beat between unknown and standard frequencies.	X 10 KC 619-OUT	UP UP {UP-TEL / DOWN-SPKR	Operate 619 in oscillating condition, with tuning offset for beat of 1 or 2 kc. Slow beat appears as slow waxing and waning of beat amplitude.
	THEN		
	617-OUT	UP or DOWN	Throw 617 output switch to same side as 619 output just above (places 617 output circuit in parallel with 619 output). Throw 617 Panel Switches,- AUDIO AMPL. INPUT to 1 KC HARMONICS position. (If 614 Selective Amplifier is operating, turn it off.) The slow beat will then appear on 617 output meter.
16. To adjust a radio frequency to an integral number of kilocycles, directly against the standard.	X 10 KC 619-OUT	UP UP UP-TEL	Pick up beat between X and standard, as in 5 above. Set 614 Selective Amplifier to proper multiple of 1 kc.
	THEN		
	617-IN	CENTER-619	Set 617 Panel Switches, STANDARDIZING SWITCH to STANDARDIZE; AUDIO AMPLIFIER INPUT to 1 KC HARMONICS. Adjust MIXER for maximum swing on output meter. See also page 22, (2).
17. To adjust one radio frequency source to zero beat against another by the three-oscillator method.	616 10-KC 619-OUT	UP UP UP-TEL	Set 619 Heterodyne Detector(oscillating) to zero audible beat with the 10-kc harmonic to which it is desired to adjust the Type 616 Heterodyne Frequency Meter. Adjust 616 also to zero audible beat. Offset tuning of 619 to obtain an audible note of 1 or 2 kc. This note will carry a low frequency "flutter". Carefully adjust tuning of 616 to bring the "flutter" down to a very slow waxing and waning of the amplitude of the output of 619. Check to make certain that the right pair of oscillators is in

Operation	Switches	Positions	Remarks
			zero beat by shifting tuning of 619. If tone changes, but rate of waxing and waning does not, the 616 has been set to zero beat against a selected 10-kc multiple. Procedure is the same for any pair of radio frequency sources fed into 619 or into external receiver.
18. To use microdial in checking frequency standard against time signals.	X 619-OUT THEN MICRODIAL	UP UP-TEL UP	Tune in time signal on 619 Heterodyne Detector, connecting X cable to suitable antenna. Then throw microdial switch up; turn microdial, by key provided, toward lower dial readings until just the nose of the time dot is left. Fractions of a second are then read from microdial, each division being 0.01 second. (See instructions for Primary Frequency Standard.)
19. To use microdial in external circuits.	MICRODIAL	CENTER-OFF	Connect microdial into external circuit by means of shielded plug connection on terminal strip of Primary Frequency Standard.
20. To use outputs of Primary Frequency Standard in External Circuits: 50 KC 10 KC 1 KC 100 ~	 50 KC 10 KC 617 617	 CENTER CENTER CENTER DOWN	Connect to desired output by means of shielded plug connection on terminal strip of standard. CAUTION: Remember that such external circuits are in parallel with circuits to the measuring equipment; some loss in high frequency harmonics, or loss in total output may result unless guarded against.
21. Use of 616 Heterodyne Frequency Meter output in external circuits.	616	CENTER	Connect 616 output cable (at rear of assembly), to external circuit. CAUTION: (above) applies here only to output of 616 frequency meter.
22. Use of 616 Heterodyne Frequency Meter direct-reading finder dial in checking which standard frequency harmonic is used in a measurement.	X 10 KC 619-OUT THEN X 10 KC THEN X 10 KC 616	UP UP UP-TEL DOWN UP DOWN DOWN UP	as in (5) above. Set 619 Heterodyne Detector to zero audible beat against the harmonic of the standard used in the measurement. Adjust 616 Heterodyne Frequency Meter to obtain zero audible beat against 619. The harmonic of the standard can then be identified at once from finder dial.

Operation	Switches	Positions	Remarks
23. To match a very low beat frequency output of Type 619 Heterodyne Detector with Type 617 Interpolation Oscillator.	X 10 KC 619-OUT	UP UP UP-TEL	as in (5) above. If beat frequency is very low, revert to three-oscillator method, obtaining an audio tone with the low beat frequency as a "flutter".
	THEN		
	619-OUT 617-IN 617-OUT	CENTER-OFF CENTER-619 UP-TEL	Set 617 to low frequencies and adjust carefully. A match can be obtained against the "flutter" even in the presence of the "carrier" tone. (See also use of comparison oscilloscope in this case, under "modulated waves.")

PART VIII
GENERAL NOTES AND SPECIAL INSTRUCTIONS

This section covers special instructions and suggestions for the use of certain items of measuring equipment. These instructions would appear in the individual instruction books for the instruments but it is felt that repeating pertinent data here will be more convenient.

I Checking Calibration of Type 617 Interpolation Oscillator

The Type 617 Interpolation Oscillator is direct reading, within plus or minus two cycles over the range from zero to 5000 cycles. The calibration should be checked periodically, to determine the magnitude of any errors, to correct alignment or to make measurements. Since the accuracy of measurements can be maintained at a much higher value, if the instrument is checked during frequency measurements, the checking operation has been made very simple.

The instrument may be checked against either 100 cycles or 1000 cycles from the frequency standard, by throwing the 617 switch on the Type 612 Coupling Panel to the lower or upper positions, respectively.

For checking alignment, it is recommended that 1 kilocycle be used, with readings taken every 500 cycles over the entire range. (See instruction book of Type 617 Interpolation Oscillator for adjustments to correct alignment.)

To check calibration, either the 1-kc or 100-cycle standard frequency may be used. The first gives a large number of check points at multiples of 1000, 500, 333.3, 250, 200 --- cycles. The second may be used easily at multiples of 100 and 50 cycles. (See instructions for use of Type 699 Comparison Oscilloscope for more easily obtaining a very large number of check points.)

In making a measurement, it is recommended that the calibration be corrected at a point near the frequency being measured. For example, if a frequency of 1237 cycles is being measured, adjust the Type 617 Interpolation Oscillator to 1200 divisions on the dial and throw the 617 switch to 1 kc (Position 2, Figure 7). A slow beat may be heard in the 617 output; bring this to zero by adjustment of the "zero set" dial. The calibration is then correct at 1200 cycles, and may be used with confidence above and below 1200 cycles. If the next frequency is quite different, it is wise to repeat this check adjustment at the new portion of the scale.

See Table, Operation 13.

II Using Frequency Increment Dial on Type 617 Interpolation Oscillator

When this dial is used, a beat frequency of very nearly 1 kc, or a multiple of 1 kc is to be matched (see Steps 4 and 5, Section VII), but the essential point is the small departure from an exact multiple of 1 kc.

To obtain this departure, set the frequency increment dial to zero (center-scale). Next set the main dial to 1 kc, or the multiple of 1 kc, as required. Then check the Type 617 Interpolation Oscillator against the 1-kc standard, by throwing the 617 INPUT switch to upper position. Adjust the main dial carefully to obtain the best possible adjustment against the standard.

Throw the 617 INPUT switch to the center position (619 output)thereby introducing the beat frequency to be matched. A slow beat will be heard which is the departure, from 1 kc or a multiple of 1 kc, which is to be determined.

Now adjust the frequency increment dial only (leaving main dial entirely alone) until zero beat is obtained. The magnitude and sign of the departure may then be determined from the frequency increment dial. Positive increments indicate that the beat frequency is above 1 kc. (or a multiple of 1 kc) by the amount of the frequency increment dial reading. The sign of the increment with respect to the radio frequency being measured must be determined in each case by knowledge of whether the 9- or 11-kc harmonic used in the measurement is above or below the frequency being measured. (See details in Type 698 instruction book.)

See Table, Operation 14.

III To Use Output of Type 617 Interpolation Oscillator in External Circuits

Throw STANDARDIZING SWITCH on panel of Type 617 Interpolation Oscillator to OPERATE position. Throw AUDIO AMPLIFIER INPUT switch to DETECTOR OUTPUT. Connect external circuit to panel terminals marked OUTPUT. Adjust output voltage by MIXER control. Output voltage at OUTPUT terminals is indicated by output voltmeter on panel.

IV To Use Output Meter of Type 617 Interpolation Oscillator as a Beat Indicator, Without Using the Oscillator Itself

If a slow beat is obtained between X and the standard, it may be indicated on the 617 output meter by operating the 619 heterodyne detector on the "three oscillator method" (see below) and following this procedure:

Obtain the waxing and waning tone from the Type 619 Heterodyne Detector on telephones or speaker, by throwing the Type 619 output switch to the desired position.

Throw the 617 output switch to the same side as the one above.

Throw the AUDIO AMPLIFIER INPUT switch on the panel of the 617 oscillator to 1 KC HARMONICS position. (If Type 614 Selective Amplifier is operating,it should be turned off.)

Adjust radio-frequency inputs, or regeneration of Type 619 Heterodyne Detector to obtain desired output meter reading.

The slow beat-frequency difference is then indicated on the meter.

This arrangement is convenient, if the X source is to be adjusted into exact agreement with a harmonic of the standard; that is, to zero beat with integral multiples of 9, 10, 11 or 50 kc.

See Table, Operation 15.

V To Adjust a Source to an Exact Frequency, which is an Integral Number of Kilocycles, Directly Against the Standard

In this case the X and standard frequencies are introduced into the Type 619 Heterodyne Detector and the resulting beat frequency output is to be made exactly 1 kc or a multiple thereof. (Heterodyne detector not oscillating). The X frequency must be adjusted until this condition is obtained.

Turn on the Type 614 Selective Amplifier and adjust it for the desired multiple of 1 kc.

Throw 617 input switch to 619 output. Throw STANDARDIZING SWITCH on panel of Type 617 Interpolation Oscillator to STANDARDIZE; throw AUDIO AMPLIFIER INPUT switch to 1 KC HARMONICS. Adjust MIXER for maximum swing on output meter.

If the voltages from either the Type 619 Heterodyne Detector or Type 614 Selective Amplifier outputs are abnormally large, better adjustment on the MIXER will be obtained if the larger is reduced.

Adjust the Type 614 Selective Amplifier input, or regeneration, to adjust the 1-kc harmonic output; adjust the radio-frequency controls on X or standard, or regeneration of Type 619 Heterodyne Detector to control the magnitude of the beat-frequency signal.

If the operator has a reasonably good sense of pitch, this comparison may also be made by throwing the Type 614 output switch to speaker and throwing the Type 619 output switch to telephones. Wearing the telephones, a beat will be heard between the tone in the telephones and the tone from the speaker. If the operator's sense of pitch is not good, an adjustment of the beat-frequency output of the Type 619 Heterodyne Detector to one-half or twice the 1-kc harmonic may be made in the belief that these two frequencies are matched.

See Table, Operation 16.

VI Three-Oscillator Method of Obtaining Zero-Beat Adjustment

If two radio frequencies are fed into a detector the difference, when in the audible range, will be heard in telephones connected to the detector output. If now we wish to adjust one of the frequencies to exactly equal the other,we find on listening that the apparent range of equality is broad, and a definite zero beat, or exact match, indication is not obtainable.

The width of the apparent zero beat zone depends on the strength of the signals and the audio characteristics of detector, amplifier, telephones and ear.

In practice it is found that if noise or hum is present, zero beat can be detected as a slow rising and falling in the intensity of the noise or hum.

If a third radio frequency is introduced, each of the two nearly equal radio frequencies produces a beat frequency; the combination of the two beat frequencies gives an audio tone which waxes and wanes in <u>intensity</u> at a rate equal to the difference in the two radio frequencies.

A simple and easy way to introduce the third frequency is by making the detector oscillate. If the following procedure is followed, there is no question of which pair (of the three frequencies) is adjusted for zero beat.

Pick up the fixed radio frequency in the detector, with the detector oscillating. Adjust detector for zero audible beat. Introduce the adjustable radio frequency and adjust it for zero audible beat, leaving the detector as it was before. Now change the detector tuning sufficiently to give a beat output of one or two kilocycles. A "flutter" will be heard on this beat tone; slowly change the adjustable frequency oscillator until this flutter becomes very slow.

As a check in this method, having obtained a slow waxing and waning of the audio output of the heterodyne detector, change the detector tuning to vary the beat output. The <u>pitch</u> of the tone heard should change, but <u>not</u> the <u>rate</u> of waxing and waning. If the rate changes, it indicates a wrong pair of oscillators have been set to zero beat.

See Table, Operation 17.

VII Use of Microdial to Check Frequency Standard Against Time

Pick up the time signals in the Type 619 Heterodyne Detector. These should be of the type having pulses at integral seconds (not the "rhythmic" type). An antenna may be connected at X; the detector output to telephones or speaker. Throw microdial switch to ON. Insert the key in the right-hand opening in the panel of the Type 693 Syncronometer. Rotate the microdial mechanism toward <u>lower</u> readings until the time pulses are heard. Continue to move the microdial toward lower readings until the time dots become shorter and shorter, until a just recognizable pulse is left. The fraction of a second difference between the syncronometer reading and the time signal is then read off the microdial. Each division of this scale is 0.01 second. Settings may be made to 0.005 seconds or better.

The fraction of a second thus read must be taken as a positive reading; thus, if the clock face indicated 11:59:59 and the microdial 0.37, the time reading of the syncronometer is 11 hours: 59 minutes: 59.37 seconds.

See Table, Operation 18.

VIII Using Microdial in External Circuits

Connect the external circuit to the microdial by means of the plug on the terminal strip of the frequency standard. Throw the microdial switch on the coupling panel to OFF (Position 1, Figure 7). The contactor provides a closed circuit for approximately 0.90 second and an open circuit for approximately 0.10 second. The occurrence of the pulse may be phased to occur at any instant during the second by rotating the microdial mechanism in the Type 693 Syncronometer.

See Table, Operation 19.

IX Use of Outputs of Frequency Standard in External Circuits

Connections to the standard frequency outputs may be made at the terminal strip by means of the plugs provided. Terminal 1 is the "high" connection; terminal 2 is the "low" connection; terminal 3 is shield.

It should be borne in mind, however, that where the standard is used with the frequency measuring equipment, any external connections to the frequency standard are in parallel with the connections to the measuring equipment. Unless guarded against, such parallel circuits may cause a loss in amplitude or loss of higher harmonics from the standard as used at the measuring equipment.

X Use of Type 616 Heterodyne Frequency Meter in External Circuits

An output connection for the Type 616 Heterodyne Frequency Meter is provided at the rear of the frequency measuring equipment. (X-2 in Figure 7). This is a low-impedance (65-ohm) cable. The circuit is in parallel with the output to the Type 612 Coupling Panel, consequently undue loading of this circuit should be avoided to prevent loss of output to the measuring equipment, particularly at very high frequencies.

PART IX
TYPE 699 COMPARISON OSCILLOSCOPE

This section deals entirely with the Type 699 Comparison Oscilloscope and its use.

The panel of the instrument is shown in Figure 8. At the left are binding posts for introducing a frequency from an external source for comparison with the frequency standard, or for measurement with the measuring equipment. The three-inch cathode-ray oscilloscope is in the center, with a brilliancy control to the left and a focusing control to the right. The power supply switch, with bull's-eye is at the right end of the panel. Along the lower edge of the panel are ten key switches, for controlling all circuits and making all frequency comparisons.

All connections to the frequency standard and frequency measuring equipment are made through shielded cables supplied with the measuring equipment.

A schematic wiring diagram is given in Figure 9b, from which the operations listed below may be readily traced. In the diagram, to avoid confusion, the engraving of the switches is shown adjacent to the switches with the upper, center and lower positions listed from top to bottom below the switch designation. To abbreviate descriptions of the operations, the switches are given numbers, corresponding to their location on the panel, progressing from left to right on the instrument.

Provision is made, as far as possible, for all operations which may be useful in comparing frequencies, including checking, calibrating or measuring the frequency of an external source; matching the frequencies of any two sources in the measuring equipment and calibrating the component units of the measuring equipment. While the largest number of uses naturally falls in the audio frequency range, comparisons up through low radio frequencies are feasible.

The following brief summary of the types of patterns obtained in the various cases will be helpful.

1. <u>Lissajous Figures.</u> These patterns are well known. The only comment necessary here is to note that one of the objections to use of this type of comparison is that the appearance of the pattern changes with phase, an objection overcome by using a circular sweep. In Figure 10, representative patterns are shown in different phases, and the method of determining the ratios of the frequencies is indicated.

If the frequency ratio is given by larger numbers, for example 7:5, the pattern appears almost as a network covering the area and unless the pattern is extremely steady it is very difficult to count the tangent points. With higher numbers the figures become too complicated for counting. This limits the usefulness of this type of pattern to frequency ratios represented by the ratios of comparatively small numbers.

2. <u>Modulated Wave Figures.</u> These patterns are familiar for checking the percentage of modulation of a wave, as in a radio transmitter, and for indicating

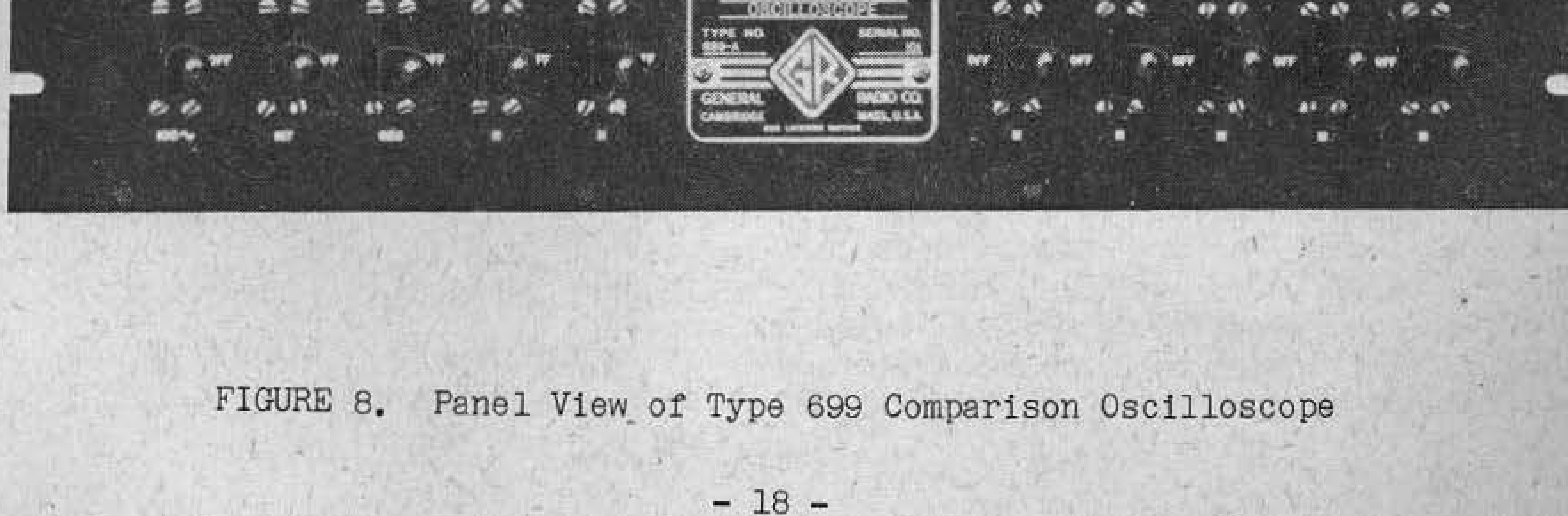


FIGURE 8. Panel View of Type 699 Comparison Oscilloscope

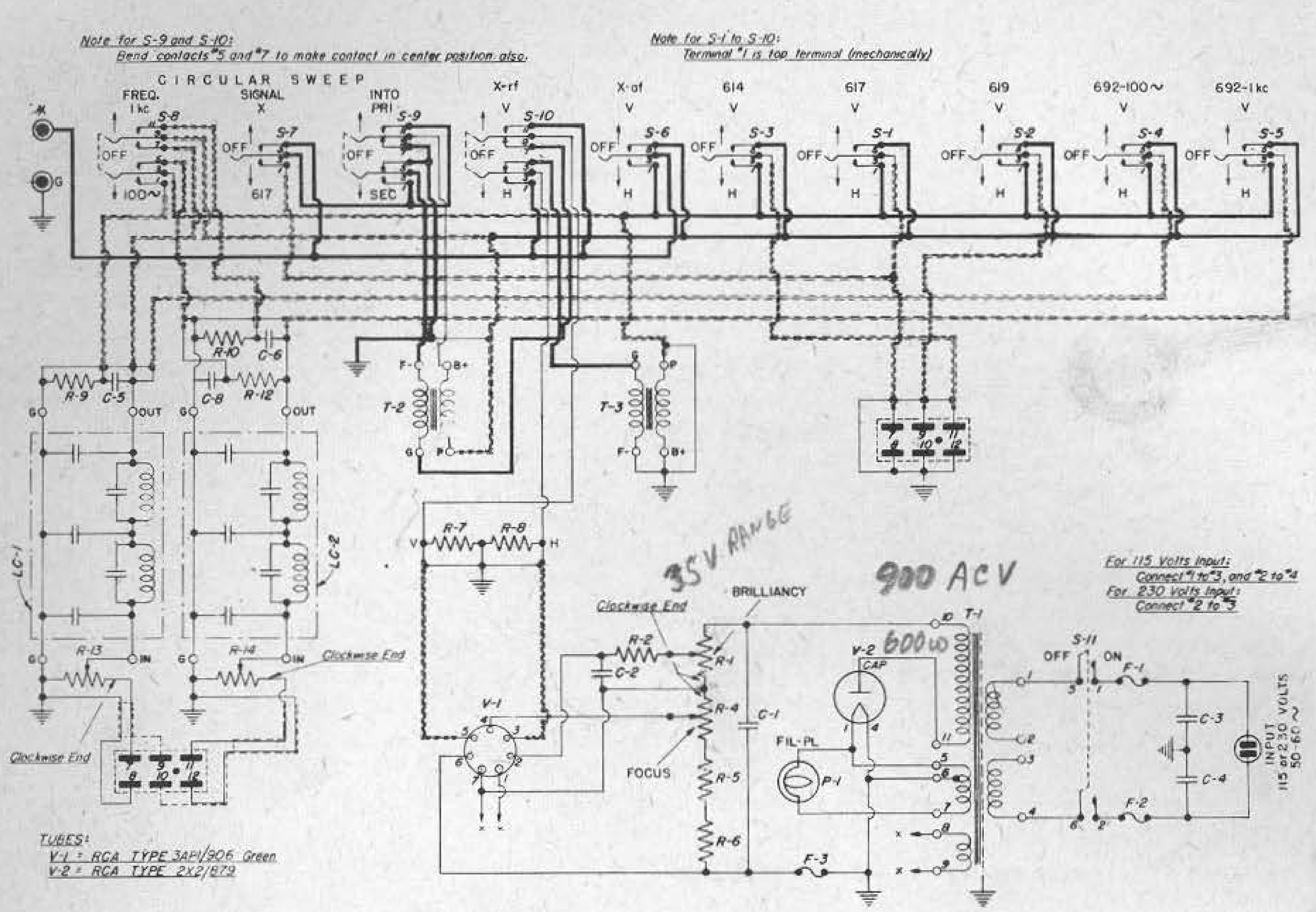


FIGURE 9a. Wiring Diagram of Type 699 Comparison Oscilloscope

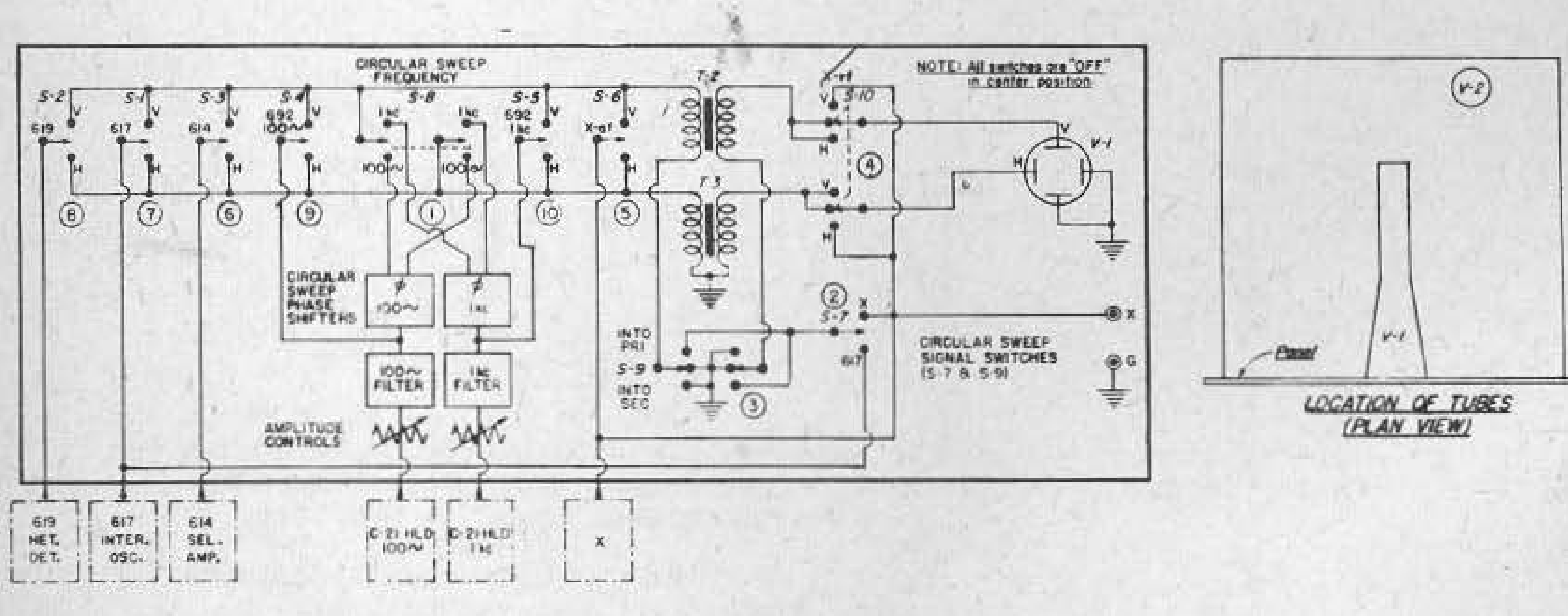
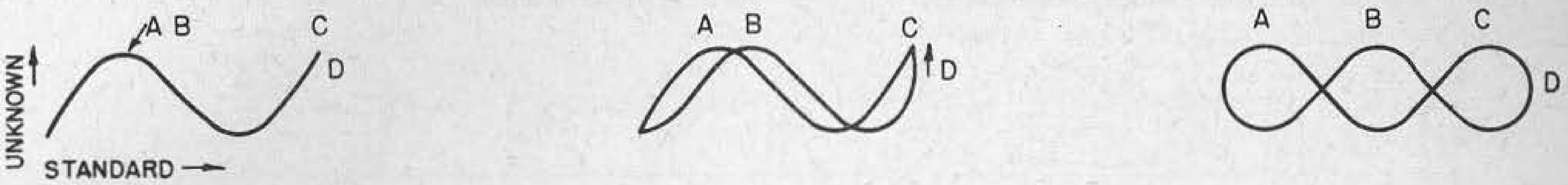


FIGURE 9b. Schematic Diagram of Type 699 Comparison Oscilloscope

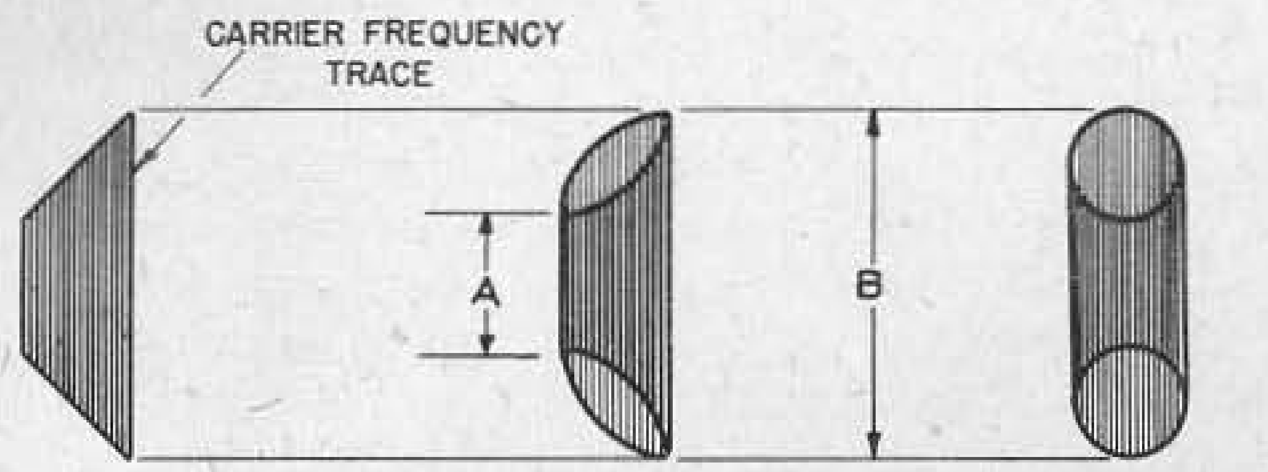


In phase

Slightly out of phase

In quadrature

FIGURE 10. Lissajous Figures. Count horizontal tangent points, A, B, C; count verticall tangent points D; then frequency ratio is 3:1. If unknown is on vertical plates, then unknown is three times the standard frequency.



In phase

Slightly out of phase

In quadrature

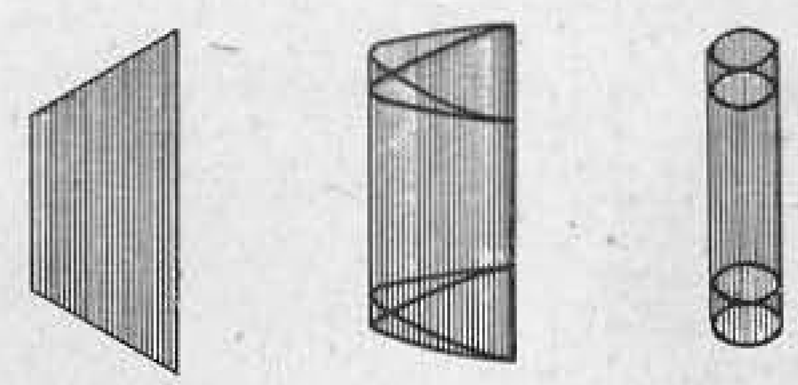
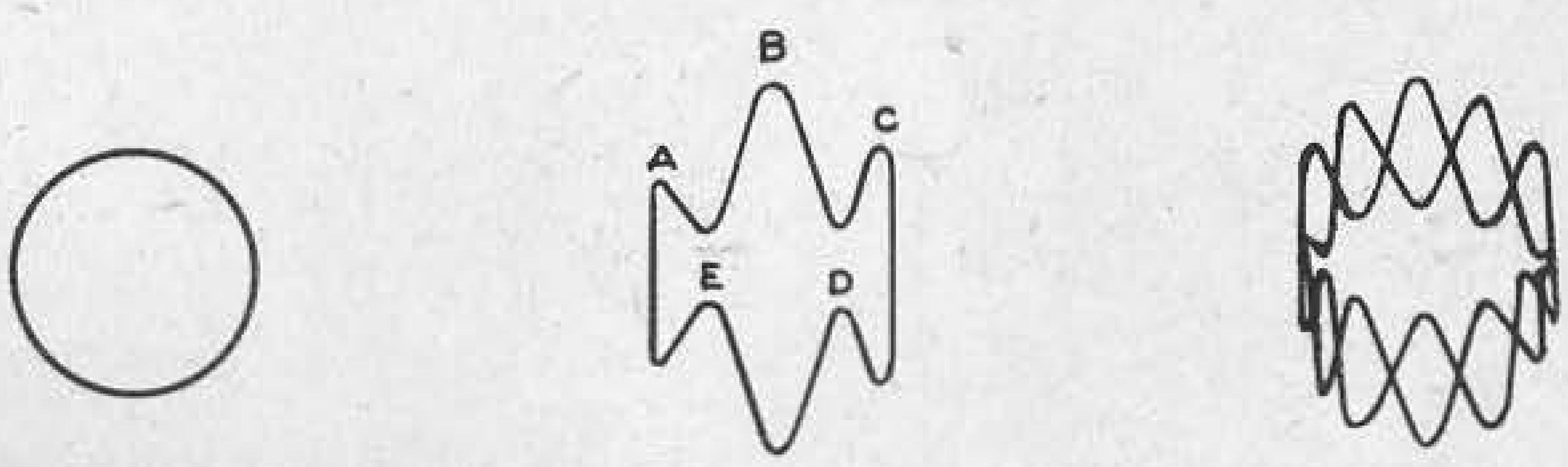


FIGURE 11a. Modulated Wave. The figures above show this type of pattern for a modulation of approximately 50 percent, A/B = 0.5. If the matching frequency is not exactly equal to the modulation frequency, the pattern slowly rotates through the sequence shown and back again. The illusion of a three-dimensional figure is strong; the pattern appears like a tube, with the ends cut at an angle.

FIGURE 11b. Modulated Wave. If the matching frequency is a multiple of the modulation frequency, the pattern appears to consist of parallel tubes, one for each multiple. Above are shown the successive phases of the pattern when the matching frequency is twice the modulation frequency.



Standard Frequency Circular Sweep

Circular pattern with superimposed frequency equal to five times the standard.
Superimposed frequency on vertical plates.
SINGLE LINE PATTERN

Circular pattern with superimposed frequency equal to 9/2 times the standard.
Superimposed frequency on vertical plates.
DOUBLE LINE PATTERN

FIGURE 12. Circular Sweep

roughly the quality of modulation. They do not appear to have been much used in frequency measurements; they offer several advantages particularly in the checking of low beat frequencies.

For example, if a radio frequency being measured differs from the standard frequency by 10 cycles, the beat frequency output of the Heterodyne Detector (non-oscillating) would be 10 cycles. If this output is fed to the Interpolation Oscillator for matching, difficulty is encountered in sensing the matching by ear because of the low frequency and by eye on the output meter because of possible distorted waveform.

If the detector is made to oscillate (three-oscillator method) the audio output would consist of a tone (the frequency of which can be varied by varying the detector tuning) modulated by 10 cycles. This is equivalent to an audio-frequency carrier with 10-cycle modulation.

If this output is fed to the vertical deflecting plates and the output of the Interpolation Oscillator is fed to the horizontal plates, patterns of the form shown in Figure 11a will be obtained. The number of lines composing the body of the pattern depends on the audio carrier frequency; the higher the frequency the more closely is the body of the pattern filled. The ends of the pattern are determined by the matching of the Interpolation Oscillator frequency to the modulation frequency. If an exact match is obtained the pattern will stand still. If the match is not exact, the pattern will rotate through the phases shown and back again.

An advantage of this method is that the Interpolation Oscillator can be set to a multiple of the low modulation frequency, with improved accuracy of reading. The form of the pattern is shown in Figure 11b. The number of loops at the ends tells at once which multiple of the modulation frequency is the one to which the matching oscillator has been adjusted.

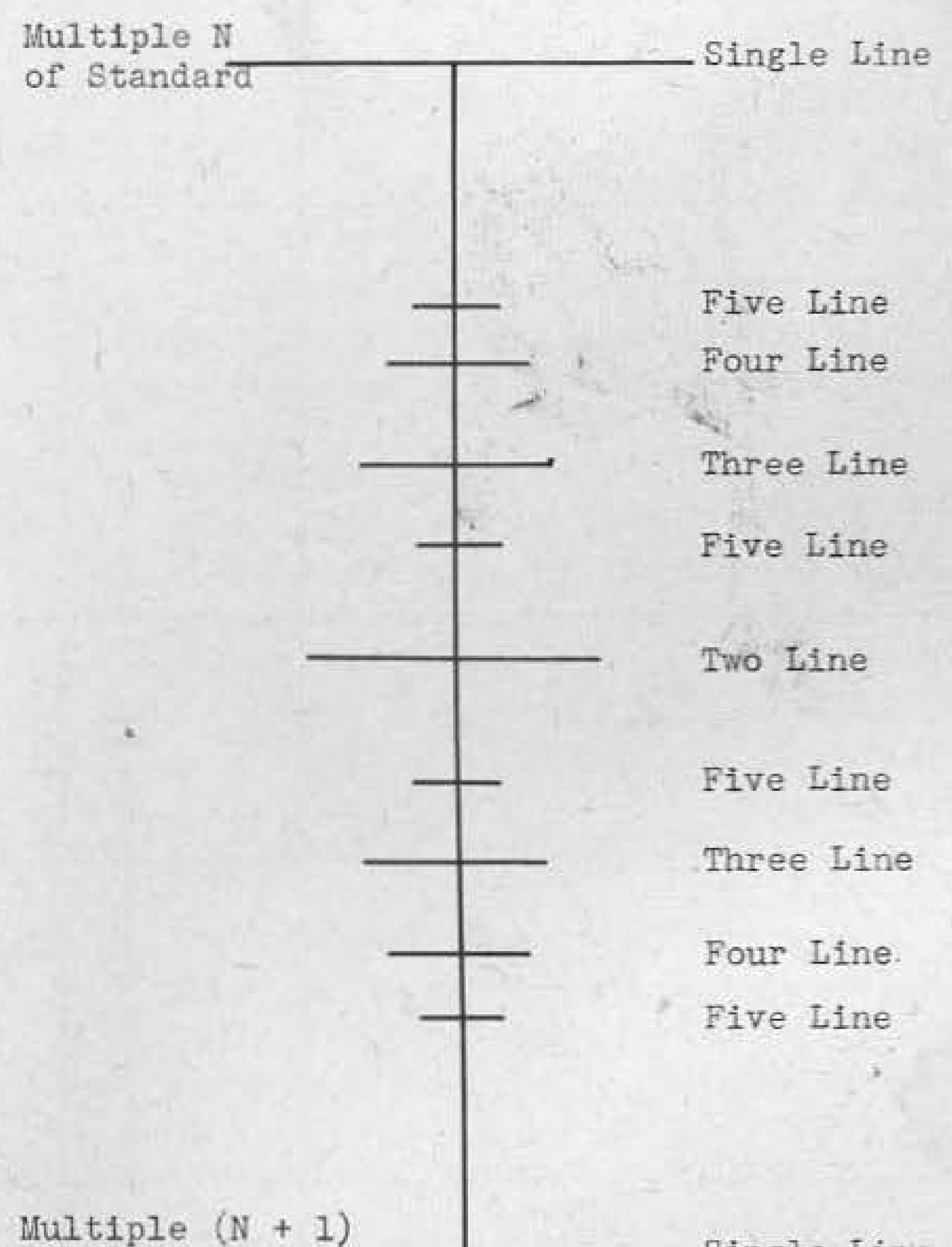
3. <u>Circular Sweep Patterns.</u> A very useful and convenient pattern is obtained with a circular sweep; the form of the pattern is indicated in Figure 12. If the standard frequency is placed on the circular sweep and the frequency of an oscillator, to be calibrated or checked, on the vertical plates, then a pattern like that shown in the center figure will be obtained. If the tops of the waves, such as ABCDE are counted, the frequency ratio is determined, in this case 5:1 with the oscillator frequency five times the standard frequency. (If the oscillator frequency is 1/5 the standard, the pattern consists of five almost concentric circles.)

In many applications, the oscillator calibration is fairly well known and it is desired to check this calibration. The beauty of the circular sweep method in such cases is that the number of points need not be counted. All that need be noted is that each time a "single line" pattern is obtained, the oscillator frequency is an integral multiple of the standard frequency; the number of the multiple being known from the calibration.

When two standard frequencies are available, as in this case, a preliminary calibration may be made at multiples of 1 kc; these points would be readily identified in the audio-frequency range. Changing to 100-cycle standard frequency would then permit "filling in" many points with no doubt as to the values of frequency.

A further advantage is that simple forms of "double line", "three line", etc. patterns are obtainable. In each case, a double line pattern indicates a multiple of one-half the standard frequency; the "three line" pattern a multiple of one-third the standard frequency and so on. With but little care patterns up to and including "five line" may frequently be used.

Put in another way, the following table indicates points which may be easily filled in in each interval between one multiple of the standard frequency and the next.



For a 100-cycle circular sweep this means that in <u>each</u> 100-cycle interval between two successive harmonics, points at 20, 25, 33.3, 40, 50, 60, 66.7 and 80 cycles may be readily filled in. For a 1000-cycle circular sweep multiply these by 10.

In the following list of settings of switches for obtaining various comparisons, all switches not otherwise designated are assumed to be in the OFF position. In general, it is convenient to place the standard frequency on the horizontal deflection plates, the unknown, or frequency being matched, on the vertical deflection plates.

TABLE OF OPERATIONS FOR TYPE 699 COMPARISON OSCILLOSCOPE

(Refer also to schematic diagram, Figure 9b)

I. Lissajous Figures

Operation	Switches	Positions	Remarks
1. Match 619 beat output with 617.	8 7	UP DOWN	The 617 ordinarily would be set to match at fundamental; pattern would be circular or elliptical. Type 617 may be set to a multiple of beat frequency just as readily, which is sometimes useful if 619 beat output is of a low frequency.
2. Set 619 beat output to a multiple of 1 kc against 614.	8 6	UP DOWN	If frequency being measured is to be adjusted to an exact multiple of 1 kc, select this multiple on 614, then adjust X frequency to obtain stationary circle or ellipse. For each 1-kc multiple selected by 614 several other frequencies at fractions of 1 kc may be obtained by multiple patterns for multiple or submultiple adjustments of 619 beat output.
3. Check 617 against multiples of 1 kc selected by 614.	7 6	UP DOWN	For each 1-kc multiple selected by the 614, numerous check points are obtainable by using multiple and submultiple patterns. (Useful for demonstration;more convenient routine checks can be made by circular sweep.)
4. Check 617 against 100-cycle standard frequency.	7 9	DOWN UP	Useful at times in low-frequency range of 617.
5. Check 617 against 1-kc standard frequency.	7 10	DOWN UP	Useful for a quick check in realigning 617. Points every 500 cycles are easily and quickly identified throughout range. Circular sweep may also be used. (Refer to 16)
6. Match an audio frequency introduced at X terminals of 699 with 617.	5 7	UP DOWN	The frequency of an external audio oscillator is to be measured by comparison with 617.

Operation	Switches	Positions	Remarks
7. Check or adjust an audio frequency introduced at X terminals of 699 against multiples of 1 kc selected in 614	5 6	UP DOWN	If the external source is to be adjusted to a multiple of 1 kc, this adjustment is complete on obtaining a stationary circular or elliptical pattern. By using multiple patterns exact adjustments at many different frequencies are obtainable against the standard frequency.
8. Check or adjust an audio-frequency introduced at X terminals of 699 against 100-cycle standard.	5 9	UP DOWN	The external oscillator frequency may be accurately adjusted at many different frequencies above and below 100 cycles by using multiple figures.
9. Check or adjust an audio frequency introduced at X terminals of 699 against 1-kc standard.	5 10	UP DOWN	The external oscillator frequency may be accurately adjusted at many different frequencies above and below 1 kc by using multiple figures.
10. Measure a low radio frequency introduced at X terminals of 699 against 617.	4 7	UP DOWN	The X frequency is applied directly to vertical deflection plates; sufficient voltage is necessary to obtain a deflection. Frequencies up to about 50 kc are readily measured in terms of 617 Interpolation Oscillator by using multiple patterns.
11. Check or adjust a low radio frequency introduced at X terminals of 699 against 1-kc multiples selected by 614.	4 6	UP DOWN	The X frequency is applied directly to vertical deflection plates; sufficient voltage is necessary to obtain a deflection. Frequencies up to 100 kc or so are easily checked using simple multiple patterns.
12. Check or adjust a low radio frequency introduced at X terminals of 699 against 1-kc standard.	4 10	UP DOWN	The X frequency is applied directly to vertical deflection plates; sufficient voltage is necessary to obtain a deflection. Frequencies in the upper audio and very low radio frequency ranges are easily checked at numerous points using multiple patterns.
13. Check 100-cycle standard output against 1-kc standard output.	9 10	DOWN UP	A stationary 10:1 figure should be obtained. Adjustment of the 692 100-cycle multivibrator of the standard, for both frequency and control, is easily made.

II Modulated Wave Figures

Operation	Switches	Positions	Remarks
14. Measuring a low beat-frequency output of 619 by means of 617.	8 7	UP DOWN	Use 619 in oscillating condition; tone corresponds to "carrier", low beat frequency corresponds to modulation. Type 617 may be set to a multiple of the modulation frequency by using multiple pattern.

III Circular Sweep Patterns

Operation	Switches	Positions	Remarks
15. Check 617 calibration against 100-cycle standard.	1 2 3	DOWN DOWN UP	The amplitude of the waves superimposed on the circle is controlled by adjusting the output of the Type 617 Interpolation Oscillator. For quick checks at 100-cycle intervals, look for "single line" patterns and make them stand still. Using not over "two line" patterns checks may be made every 50 cycles. For best accuracy in measurements made with 617, correct the calibration to zero error at a point near the frequency to be measured.Use zero set dial for correcting.
16. Check 617 calibration against 1-kc standard.	1 2 3	UP DOWN UP	The amplitude of the waves superimposed on the circle is controlled by adjusting the output of the 617 oscillator. For checking realignment of 617, alternate one- and two-line patterns are obtained at 500-cycle intervals throughout the range. (See 617 instructions concerning realignment adjustments.)
17. Checking or calibrating an external audio oscillator against 100-cycle standard. Connect oscillator to X terminals on panel of 699 Oscilloscope.	1 2 3	DOWN UP UP	Amplitude of waves superimposed on circle may be controlled by adjusting external oscillator output. If amplitude is too great, throw Switch 3 DOWN, eliminating audio transformer. Single line patterns occur for each 100-cycle multiple; other frequencies are obtainable with multiple line patterns. See description.
18. Checking or calibrating an external audio oscillator against 1-kc standard. Connect oscillator to X terminals on panel of 699 Oscilloscope.	1 2 3	UP UP UP	See 17 above. Single line patterns are obtained for each multiple of 1 kc; other frequencies are obtainable with multiple line patterns. If amplitude is too great throw Switch 3 DOWN.

Operation	Switches	Positions	Remarks
19. Checking or calibrating an external oscillator of high audio or low radio frequency against 1-kc standard. Connect oscillator to X terminals of 699 Oscilloscope.	1 2 3	UP UP DOWN	See 18 above. With Switch 3 down, oscillator is connected directly to vertical deflection plates. Sufficient voltage must be applied to obtain a deflection.
20. Checking 100-cycle 692 Multivibrator against 1-kc standard.	1 10	DOWN UP or DOWN	A 10:1 stationary pattern should be obtained. Check adjustment of 692 100-cycle Multivibrator to obtain stationary 10:1 pattern with small control voltage; then operate with control voltage advanced well beyond this point.
21. Set 619 beat output to a multiple or submultiple of 100 cycles or 1 kc.	1 2 3	{DOWN 100~ {UP 1 kc UP UP	Connect output of Type 619 Heterodyne Detector to X terminals of 699 Oscilloscope. By use of single and multiple line patterns, the oscillator being adjusted can be set in steps of only a few cycles directly against the standard. (See 2 above). This present method is only needed (a) for very small steps in frequency or (b) to attain a specific desired frequency.

VACUUM-TUBE DATA

Voltages are measured between terminals shown with meter of 20,000 ohms per volt (d-c); 1,000 ohms per volt (a-c).

Currents are measured in series with terminal shown.

INSTRUMENT	SOCKET TERMINAL NOS.		V-1	V-2	V-3	V-4	V-5	V-6	NOTES
616-D			6J7G	6J5G	6J5G	6X5G	VR-105-30	4A1	A, B
	2-7	v ac	6.5	5.8	5.8	5.8	—	—	
	8-Gnd	v dc	0	0	7	—	—	—	
	8-5	v dc	—	0	7	—	—	—	
	3-8	v dc	10	60	162	—	—	—	
	3	ma dc	2.1	3.1	3.1	—	—	—	
	4-8	v dc	58	—	—	—	—	—	
	4	ma dc	.9	—	—	—	—	—	
	5-Gnd	v ac	—	—	—	157	—	—	
	3-Gnd	v ac	—	—	—	157	—	—	
	8-Gnd	v dc	—	—	—	177	—	—	
	3	ma dc	—	—	—	9	—	—	
	5	ma dc	—	—	—	10	9.0	—	
	5-2	v dc	—	—	—	—	102	—	
	1-4	v ac	—	—	—	—	—	3.3	

VACUUM-TUBE DATA

INSTRUMENT	SOCKET TERMINAL NOS.	RIGHT → V-1	V-2	V-3	V-4	V-5	→ LEFT V-6	NOTES
617-C		6J7G	6J7G	6J5G	6J5G	6X5G	VR-105-30	A,C
	2-7 v ac	5.8	5.8	5.8	5.8	5.8	—	
	8-Gnd v dc	0	0	5	2	—	—	
	8-5 v dc	0	0	5	2	—	—	
	3-8 v dc	5	5	83	80	—	—	
	3-3 ma dc	1.1	1.1	.2	3.4	—	—	
	4-8 v dc	30	30	—	—	—	—	
	4 ma dc	.5	.5	—	—	—	—	
	5-Gnd v ac	—	—	—	—	160	—	
	3-Gnd v ac	—	—	—	—	160	—	
	8-Gnd v dc	—	—	—	—	187	—	
	3-3 ma dc	—	—	—	—	8.9	—	
	5 ma dc	—	—	—	—	6.9	12 (0-50)	
	5-2 v dc	—	—	—	—	—	103	
619-E		6J7G	6J5G	6J5G	6X5G	VR-105-30		A,D
	2-7 v ac	5.6	5.6	5.6	5.6	—		
	8-Gnd v dc	0	25	5	—	—		
	8-5 v dc	—	10	5	—	—		
	3-8 v dc	140	42	150	—	—		
	3-3 ma dc	.03	1.9	4.5	—	—		
	4-8 v dc	3	—	—	—	—		
	5-Gnd v ac	—	—	—	153	—		
	3-Gnd v ac	—	—	—	153	—		
	8-Gnd v dc	—	—	—	158	—		
	3 ma dc	—	—	—	11.4	—		
	5 ma dc	—	—	—	8.1	15		
	5-2 v dc	—	—	—	—	104		
614-C		6J5G	6J5G	6J5G	6X5G			A,E
	2-7 v ac	6.2	6.2	6.2	6.2			
	3-8 v dc	155	205	190	—			
	8-Gnd v dc	6.0	7.2	10.0	—			
	3-3 ma dc	3.0	6.0	1.1	—			
	5-Gnd v ac	—	—	—	175			
	3-Gnd v ac	—	—	—	175			
	8-Gnd v dc	—	—	—	225			

NOTES

A. Remove signal cable plug when taking readings.

B. Put coil selector switch on blank position to take readings. V-5 may be either VR-105-30 or VR-90. For VR-90, 5 = 7.5, 5-2 = 90.

C. Remove grid lead from tube, taking care clip does not touch circuits. Ground cap of tube when taking readings on V-1, V-2. When measuring one tube, leave the other in normal circuit. V-6 may be either VR-105-30 or VR-90. For VR-90, 5 = 10, 5-2 = 90.

D. Use Coil 1-L; set regeneration control just below oscillation point. V-6 may be either VR-105-30 or VR-90. For VR-90, 5 = 12, 5-2 = 90.

E. Set input and regeneration controls at zero.

PATENT NOTICE

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

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Patent No. 1,542,995
Patent No. 1,931,530
Patent No. 1,943,302
Patent No. 1,955,739
Patent No. 1,713,146
Patent No. 1,744,675
Patent No. 1,967,184