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OSCILLOGRAPHER

# THE OSCILLOGRAPH AS A PRODUCTION TOOL

## *Large Volume Production Adjustment of Radio Vibrators by Use of Waveform Interpretation*

In the production of millions of radio vibrators during the past few years, the Oscillograph has become an invaluable aid in the procedure of design development; testing; inspection, and an essential production adjustment tool.

The radio vibrator is basically a high speed reversing switch used to reverse the direction of current flow through an associated transformer winding, thereby producing by conversion, alternating current from a direct current source.

These devices are used extensively in electronic equipment where the most convenient and available source of primary power is low voltage batteries. This type of equipment usually requires high voltage D.C. of 100 to 300 volts to operate the vacuum tube anode circuits. The vibrator, by virtue of its high speed switching facility, converts the low voltage battery power to A.C. after which it can be stepped up to the desired higher voltage, then brought back into the vibrator's synchronous secondary contacts and rectified to high voltage D.C. suitable to operate the electronic equipment such as military field radio and telephone equipment; Walkie Talkie radio; portable and mobile radio used on military motorcycles, scout cars, and police cars, civilian automobiles, trucks, buses; also, the farm radios and "pick me up" type of portable sets, etc.

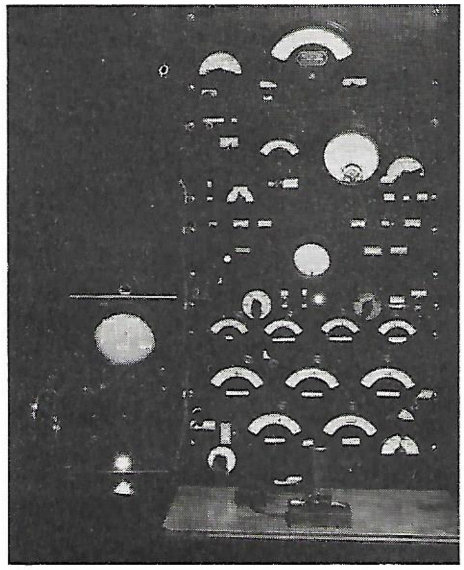
Vibrators are also manufactured with variations in construction for applications requiring A.C. from D.C. sources of from 2 to 120 volts for operation of small synchronous or induction motors; neon sign lighting; ignition power; electric live stock fences; low frequency bell ringing in military field telephones and in aircraft and naval control instruments, coast guard flasher buoys, Etc.

Many of these applications require the vibrator to provide a constant frequency source of very close tolerance comparable with the accuracy of power line frequency. They also require critical adjustments of waveform and other electrical characteristics.

The most comprehensive electrical characteristic of vibrator performance is the alternating current waveform produced across its two pairs of primary contact points while operating with normal load, transformer, buffer condenser, etc.

The electrical waveform may be quite accurately observed by use of the Cathode Ray Oscillograph. This instrument actually traces the pattern of the alternating flow of current caused by the rapid reversal of polarity. The instrument provides very accurate timing and synchronizing facilities, which together with the A.C. voltage produced by the vibrator, guides an electronic pencil which actually writes and retraces the pattern or waveform of the A.C.

From the waveform, at least seven important electrical characteristics of vibrator adjustment may be judged quickly from one composite observation. These details were formerly read from five meters of a test set which required 150% more time and also required more skill. Before the war, these adjustments were made by men technicians, most of whom were soon taken into the armed forces. It was necessary to train girls and women to take their places. This called for a simplified procedure which could be taught to non-technical women. The Oscillograph method proved to be by far the most satisfactory and effective and required only a comparatively short training time.

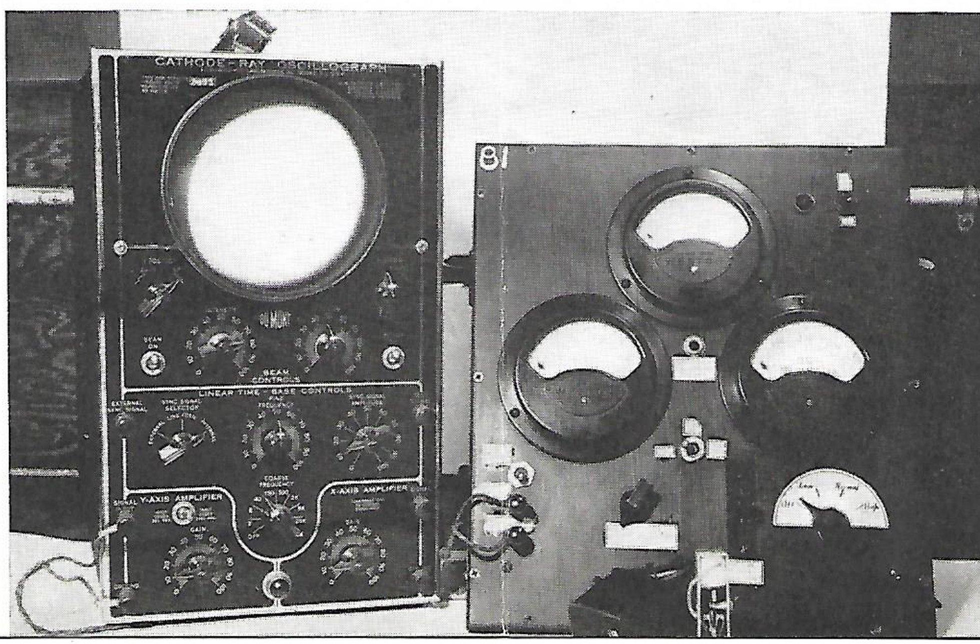


*This is the Master or Laboratory set up for checking vibration. The Oak Company has about 20 DuMont Oscillographs operating continuously on testing vibrators.*

The following diagrams and explanation of vibrator waveform study, are excerpts from a prepared study course given production operators and their supervisors. It is written in elementary form for obvious reasons, yet it helped accomplish the transition from skilled men operators to "Susie the Vibrator Adjuster."

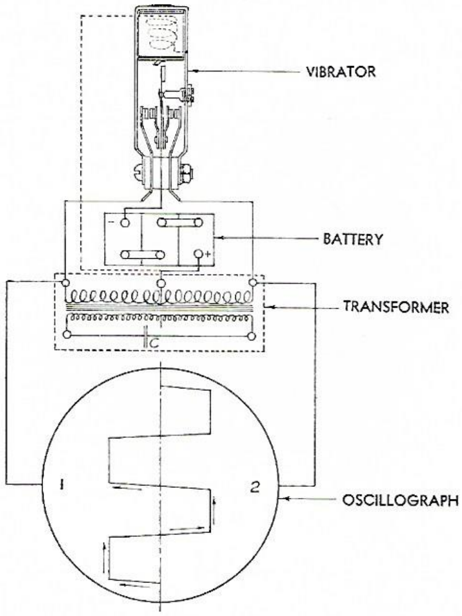
Diagram No. 1 indicates, in simplified form, the way the oscillograph is connected to the A.C. of the vibrator. For the purpose of explanation, we will turn the viewing screen of the oscillograph 90 degrees counter clockwise. This pictures the waveform crosswise to the standard way we use the instrument. In this position we can associate the No. 1 half cycle on the left side (which is normally on the top of the scope) with No. 1 contacts on the vibrator, which are also on the left side. On the second half of the cycle when the reed swings back to the right side and closes

*This is a standard test position for testing vibrators on the line.*



contacts No. 2 producing No. 2 or right hand side of the waveform, we see that the instrument traces electrically the mechanical motion of the vibrating reed.

DIAGRAM NO. 1

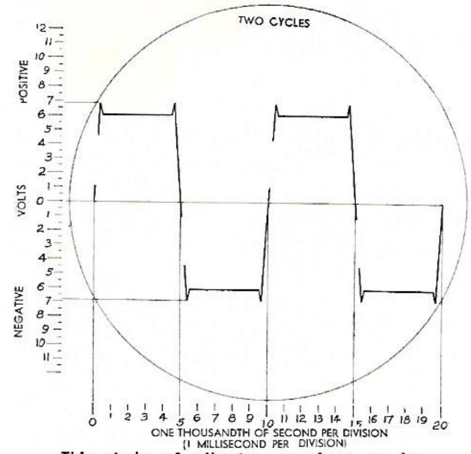



Referring to the oscillograph portion of the above sketch, let us imagine in place of the oscillograph screen a long paper tape such as the player piano roll moving at a steady speed downward, and also imagine in front of that moving paper a vibrator with a small pencil attached to its vibrating armature. Now then, if we permitted the vibrating pencil to write on the moving paper, we would have a trace which is very comparable to the electrical waveform of the vibrator.

The timing mechanism of the oscillograph instrument provides on its fluorescent screen the motion simulated by the player piano roll, and an electronic pencil writes or traces the voltage alternations, which were simulated by the vibrating pencil. Thus we have a simple analogy of how the oscillograph pictures visually the waveform of alternating electricity.

DIAGRAM NO. 2

100 *cycle synchronous vibrator waveform analysis. Contact closure time*: *primary* 43%; *secondary* 40%.




This study of vibrator waveform as indicated by the oscillograph demonstrates the reversal of current flow accomplished by the vibrator.
The oscillograph as applied in this case is essentially a volt meter which indicates both positive and negative voltages vertically on the fluorescent screen, and plots them against time duration horizontally, to produce a replica pattern in graph form of the actual waveform.

Turning the viewing screen back now, to the normal position indicated in diagram No. 2, we consider the instrument as a volt meter, with zero reading in the center and calibrated vertically to read positive and negative reversals of voltage, as the vibrator reed swings from side to side. The instrument also contains a very accurate timing system whereby it plots on the horizontal axis the voltage change during the progress of the cycle. In this manner, we obtain a true visual interpretation of the vibrator's dynamic characteristics.

If we now break down this waveform pattern and study it detail by detail, we learn that it is possible to use it as a means of standardizing vibrator adjustment procedure, and also use it as a basis to establish a standard for specification to guide inspection and testing procedure.

CONTACT ADJUSTMENT AS JUDGED BY WAVEFORM:

Spacing of the vibrator contact points closer provides a higher closure time and less open time during the cycle; contacts spaced wider provide a lower contact closure time. The waveform illustrated on diagram 2 is that of a synchronous vibrator with primary contacts adjusted to 43% contact closure time and with secondary contacts adjusted to 40% closure time.

This fact may be observed from the waveform proportion. The horizontal portion of each half cycle is 40% of the total cycle. This represents the secondary closure time. The horizontal width of the flat top portion of each half cycle inclusive of the peaks at the corners is 43% of the total cycle width. This represents the primary contact closure time. The difference between the two spacings is called the differential or the lag of the secondary contacts. This is represented by the peaks ("dog ears") at the corners of the horizontal lines on the waveform.

Refer to diagram 3. Here we see the waveform of four different vibrator adjustments:

*Sketch "A"* which illustrates comparatively wide spacing of contacts—primary 36%; secondary 30%.

*Sketch "B"* illustrates waveform of contacts adjusted somewhat closer than in sketch "A" —primary 40%; secondary 34%.

*Sketch "C"* illustrates closely spaced contact points — primary 43%; secondary 37%.

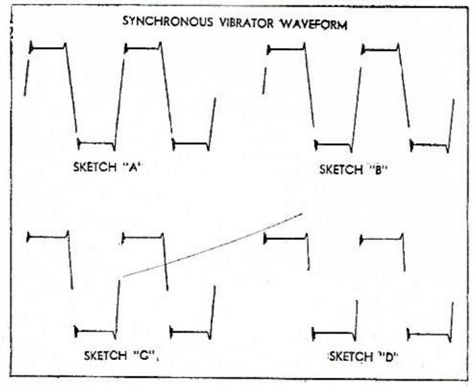
*Sketch "D"* illustrates very close contact spacing — primary 46%; secondary 40%.

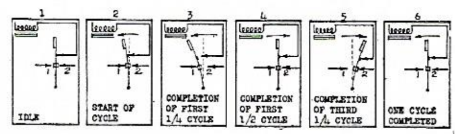
All four sketches indicate a differential or secondary lag of 6%. This is normally the maximum lag necessary. On many applications a differential of only 2% to 5% is adequate.

It should be noted that as the contacts are spaced closer, the vertical lines of the waveform take less angle and become nearly straight up and down on the very close spaced adjustment, while on the wide spaced adjustment the vertical lines slope considerably.

Another useful clue to vibrator adjustment which the waveform provides is the size of the opening in the vertical lines. This characteristic may be reliably used to judge contact spacing for production testing. The size of the opening is inversely proportional to the contact spacing as can be seen from a study of the sketches on Diagram No. 3. However, in any manner that waveform is used to judge vibrator adjustment, con-

DIAGRAM NO. 3




sideration must first be given to the standardization of the test circuit characteristics in which the vibrator is operating. Very careful selection of transformer, buffer condenser and load circuit must be made in order to standardize any specific reference to certain specifications. This standardization has been thoroughly studied and accomplished through the use of uniform and carefully selected test equipment. These test sets which include the components associated with the operation of the vibrator must be maintained accurate and uniform within 1% to 2%.

### VIBRATOR CONTACT CLOSURE TIME:

This important dynamic characteristic of vibrator performance is proportional to the static spacing of the power contacts and the amplitude of reed swing. The "contact closure time," and the frequency of a vibrator are factors that are given serious consideration in the design of the associated transformer and buffer condenser.

Thus, once the most satisfactory contact time is determined and specified for use with a certain group of associated component parts, it is important that this correct value of contact time be maintained to close tolerance. For various applications such as different users of vibrators may apply them, different adjustments of contact closure time will be required.

For a better understanding of just what is meant by "contact closure time," refer to sketches 1 to 6. Here we see the mechanical motion of one complete cycle of vibration. The closure time is that "duration time" which contact points No. 1 are closed or "in contact" during the first half cycle, and likewise that duration of time which contact points No. 2 are "in contact" during the second half of the cycle.

The time required for one complete cycle is equal to 100 per cent time, the "in contact" or closure time of No. 1 points plus the "open contact" time which elapses while the arm or reed of the switch is changing from No. 1 to No. 2 points, plus the closed time of No. 2 points equals 100 per cent.

Now we can see why wider spacing of contact points produces lower contact closure time measurement or reading, — because it allows a greater percentage of the cycle time during the open contact period while the reed is changing from one side to the opposite side.

Example: A certain vibrator for an application where the design requires 86 per cent contact closure time. This means that to divide the closed time equally between the two sets of contacts, we adjust each side to 43%. This leaves 14% open contact time for the reed to change from No. 1 side to No. 2 side.

It is apparent that the power efficiency would be greater when vibrators are adjusted to high percentage closure time. However, there is a limit to this advantage. When the closure time is adjusted extremely high, such as say, 48% per side, this leaves only a very short open contact time for change over of polarity and results in severe strain on the transformer, and sparking at the vibrator points.

The actual time of one cycle is determined by dividing one second by the frequency of the vibrator. (In referring to frequency we mean cycles per second.) Thus,

A 20 cycle vibrator requires 1/20th second or .05 second or 50 milliseconds of time per cycle.

A 60 cycle vibrator requires 1/60th second or .017 second or 17 milliseconds of time per cycle.

A 100 cycle vibrator requires 1/100th second or .01 second or 10 milliseconds of time per cycle.

A 120 cycle vibrator requires 1/120th second or .008 second or 8 milliseconds of time per cycle.

Referring to diagram No. 4 we may learn more about the details of vibrator waveform. This waveform represents a vibrator adjustment of 43% closure time on primary contacts and 37% closure time on secondary contacts. This produces a differential of 6% lag in the spacing of the secondary contacts.

The notations on this diagram very clearly describe and explain every part of the trace. The test equipment is so built that the half cycle produced by No. 1 contacts of the vibrator is always displayed on the upper half of the oscillograph and likewise the half cycle produced by No. 2 contacts is always pictured on the lower half of the screen.

The wave starts always on the left side and progresses to the right. The oscillograph instrument is synchronized so that the first half cycle is always that of No. 1 contact and is always starting from center line upward.

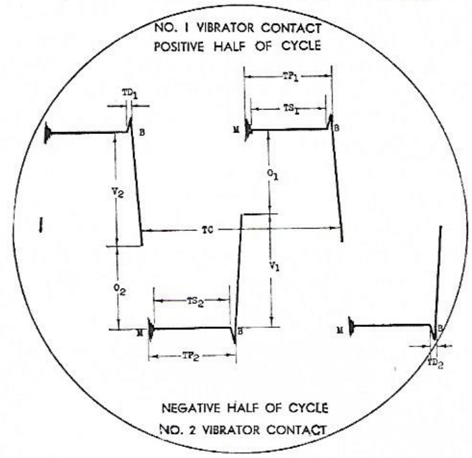
This arrangement definitely establishes the portion of the waveform or the spot at which the vibrator contacts "make" and "break." It shows the duration time which the points hold contact. It shows the duration of the time which all contacts are open while the reed or center arm of the reversing switch is changing over from side to side. This latter time is indicated by the slope or angle of vertical lines.

It will be noticed that on all sketches we have pictured 2 cycles together. This is considered advisable to obtain better focus and less distortion from the oscillograph. Some instruments slightly distort the waveform which appears out near the outer circumference of the fluorescent screen. If we always use a 2 cycle picture and then mentally observe only the center cycle, excluding the half cycle on each side, we will avoid any slight distortion which may be present at outer edges. The center cycle is that indicated between points marked Tc on diagram No. 4.

The openings in the vertical lines are caused by the exceptionally rapid rise in voltage that occurs immediately after the vibrator contacts "make" contact. In this portion of the cycle the voltage change is many times faster than other portions of the cycle. The electronic pencil therefore passes over this portion so rapidly that the fluorescent material on the screen scarcely has time to become aglow and for that reason the trace is very thin and light, hardly visible. There are three factors which contribute to this rapid change in voltage at this particular spot in the waveform. 1st—the reactance of the transformer used in the test circuit. 2nd—the reactance or size of the buffer condenser used in the test circuit. These two factors are reliably fixed at a non-changing value at the time the test sets and specifications are formulated. Therefore, they may be forgotten as far as production adjustment of virbrator waveform is concerned. The 3rd factor governing the size of the openings in the vertical lines is the power contact point spacing. Inasmuch as the first two factors are permanently set, we can depend on the vertical openings to indicate on the oscillograph the dynamic spacing of the contacts. This contact spacing as it exists while the vibrator is actually in normal motion and operation is *the* important electrical characteristic.

DIAGRAM NO. 4

*Synchronous vibrator waveform study.*




THIS WAVEFORM TRACE COVERS TWO COMPLETE CYCLES.

- TC—100% time duration of one cycle.
- $TP_2$—closure time of No. 2 primary contact.
- $TS_2$—closure time of No. 2 secondary contact.
- $TS_1$—closure time of No. 1 secondary contact.
- $TP_1$—closure time of No. 1 primary contact.
- $V_1$—vertical line caused by No. 1 contact spacing.
- $V_2$—vertical line caused by No. 2 contact spacing.
- $O_1$—vertical opening caused by No. 1 contact spacing.
- $O_2$—vertical opening caused by No. 2 contact spacing.
- M—"Make" side of half cycle.
- B—"Break" contact side of half cycle.
- B—Secondary to primary differential peak.
- M—"Hash" corner — caused by voltage peaks due to oscillation in buffer transformer and to contact chatter.
- O—Vertical openings caused by high velocity of voltage rise.—Oscillograph unable to write or trace at that velocity with the given intensity control setting.
- $TD_1$—Differential in closure time between contact No. 1 and its respective secondary contact No. 3.
- $TD_2$—Differential in closure time between contact No. 2 and its respective secondary contact No. 4.

## ADJUSTMENT DEFECTS AS INDICATED BY WAVEFORM:

Referring to diagram No. 5, page 8, we have illustrations of incorrect vibrator adjustments.

Sketch No. 14—*Excessive Differential* between primary and its respective secondary contact spacing.

This means that one or both of the secondary contact spacings are much wider than their respective primary contact spacings, too much lag.

The secondary contacts of a synchronous vibrator should always be spaced slightly wider than the respective primary contacts, but only slightly. If too much lag exists it will appear on the waveform as indicated on diagram No. 5 sketch 14. This results in much lowered efficiency of the vibrator. The differential peak which reliably indicates this condition is located at the right hand end of the horizontal lines of the waveform. This is the "break" contact point of the cycle. Normal differential peaks are shown on the sketches of diagram 3 and also at points "B" on diagram 4.

No. 15—*Insufficient Differential* between primary and respective secondary contact spacing.

This condition is objectionable in that it causes arcing, sparking and burning of contacts. It causes the primary contacts to open the circuit while yet carrying heavy current. When adequate differential is adjusted properly, the secondary contacts remove the electrical load just previous to the opening of the primary contacts. Likewise, the secondary contacts do not apply the electrical load until after the primary contacts have closed on the opposite half cycle.

Insufficient differential or no lag at all also causes bad timing, erratic waveform and transient voltage peaks on waveform. An example of insufficient differential is shown on the No. 1 half of sketch 15 diagram 5. The No. 2 half of same sketch shows no lag or reverse differential where actually the No. 4 secondary contacts are leading the No. 2 primary contacts.

No. 16—*Defective Contacting* as indicated by irregularities on horizontal portion of waveform.

This defect is pictured by sketch 16 on diagram 5 and is caused by an oxide of the contact material, or possibly improper flushing of the contacts. They are not contacting evenly over a sizable portion of the available area, maybe only contacting on a burr or tiny rim. This defect also is sometimes caused by oil or dirt on contacts or occasionally caused by abnormal chatter or bouncing of side contacts. The irregularities illustrated on the horizontal lines of sketch No. 16 are definitely an indication of existing abnormal high resistance at power contacts.

No. 17—*Excessive Unbalance,* one vertical opening longer than the other.

This defect of adjustment means that one side or half of the vibrator is carrying more than its share of the load or that the current is not evenly divided on each half of cycle. The contacts may be spaced statically equal to the eye while not in operation, and yet be considerably unbalanced dynamically when in operation. (This condition exists when the amplitude of reed swing is faulty or provides greater duration of contacting time on one side than on the opposite side.) Correct adjustment of the contact spacing makes allowance for this condition and produces equal contact closure time on each side. This condition is illustrated in sketch 17 on diagram No. 5.

No. 18—*Bad Retrace or Excessive Peaks on Waveform.*

This condition is pictured on sketch 18 diagram No. 5. The upper No. 1 contact half of waveform shows excessive peaks caused by insufficient differential, or imperfect flushing of contacts or too close spacing. The lower No. 2 contact half of sketch 18 shows bad retrace, some times caused by erratic, unsteady swing or reed or varying amplitude of reed swing. This is some times caused by dirty or pitted driving coil contacts, or intermittently shorted driving coil or excessive chatter of side contact plates.

#### NON-SYNCHRONOUS TYPE VIBRATOR:

So far our discussion of waveform has been with reference to the synchronous type vibrator. In general, the same explanation applies fully to the non-synchronous or vacuum tube rectifier type, except that this latter type has no secondary contacts to adjust and therefore no contact differential or lag. This fact changes the waveform only slightly at the ends of the horizontal lines. The differential peaks ("dog ears") which are prominent on synchronous waveform as illustrated on diagram No. 3 are missing on diagram No. 6. Diagram No. 6 shows four different adjustments of non-synchronous vibrator.

*Sketch "E"*

illustrates comparatively wide contact spacing, — approximately 36% contact closure time. This spacing is used on vibrators having high voltage or high power applications. (Note the very small openings in vertical lines.)

*Sketch "F"*

illustrates waveform of contacts adjusted somewhat closer than sketch "E," — approximately 40% closure time. (Note that higher contact closure time of this adjustment produces less slope to vertical lines than on sketch "E.")

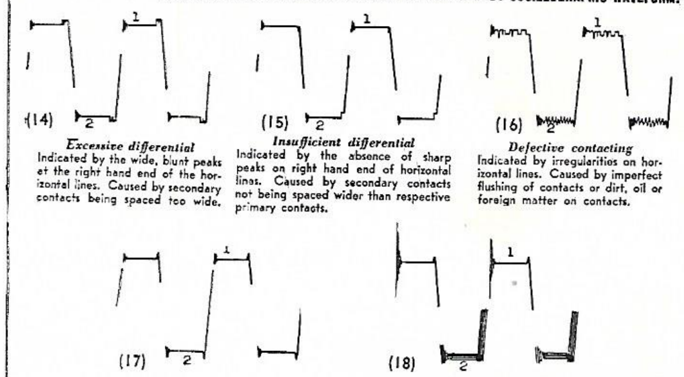
*Sketch "G"*

illustrates closely spaced contact points, — closure time 43%. (Note the larger openings in vertical lines.)

*Sketch "H"*

illustrates very closely contact spacing of 46% closure time. (Note that horizontal lines are longer and vertical lines are nearly straight up and down.)

THESE DIAGRAMS ILLUSTRATE DEFECTIVE VIBRATOR ADJUSTMENT AS INDICATED BY OSCILLOGRAPHIC WAVEFORM.




**(14)** *Excessive differential*
Indicated by the wide, blunt peaks at the right hand end of the horizontal lines. Caused by secondary contacts being spaced too wide.

**(15)** *Insufficient differential*
Indicated by the absence of sharp peaks on right hand end of horizontal lines. Caused by secondary contacts not being spaced wider than respective primary contacts.

**(16)** *Defective contacting*
Indicated by irregularities on horizontal lines. Caused by imperfect flushing of contacts or dirt, oil or foreign matter on contacts.

**(17)** *Excessive unbalance*
Indicated by the size of openings in vertical lines. Caused by one contact being spaced too close and one spaced too wide.

**(18)** *Excessive peaks and bad retrace*
No. 1 contact—upper half of wave indicates excessive voltage peaks, caused by contacts spaced extremely close. No. 2 contact or lower half wave illustrates bad retraces.

DIAGRAM NO. 5

NON-SYNCHRONOUS VIBRATOR WAVEFORM

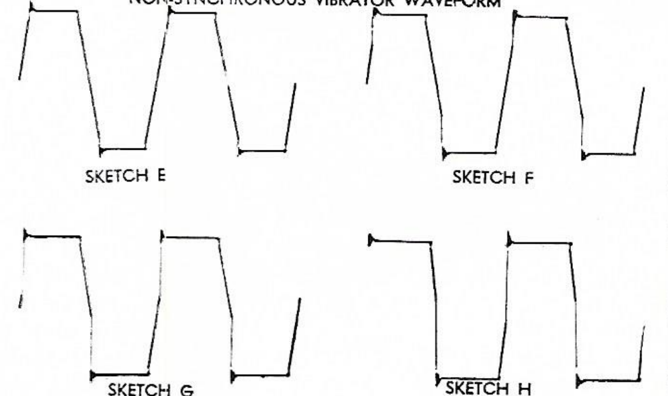
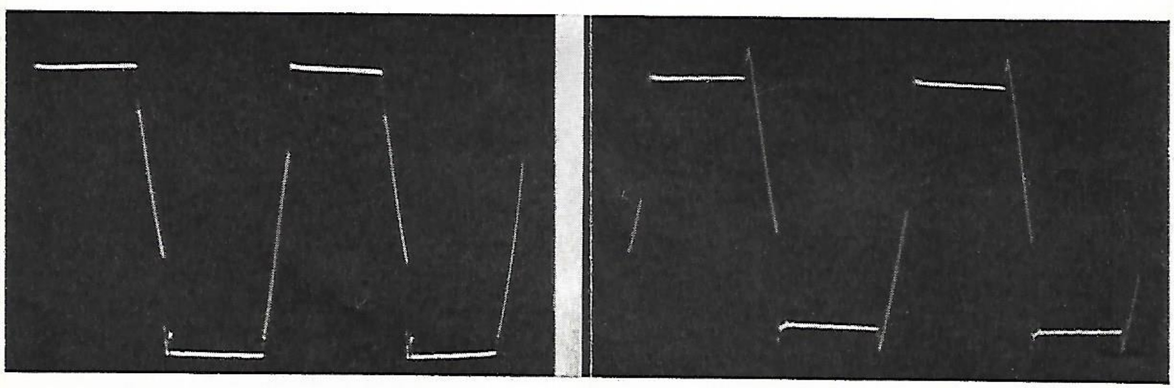



DIAGRAM NO. 6



*Left: Trace obtained with non-synchronous or rectifier type vibrator when operating satisfactorily.*
*Right: Trace obtained with synchronous vibrator when operating under ideal conditions.*

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