THE General Radio EXPERIMENTER

VOLUME XIV NO. 11 APRIL, 1940

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

## Also IN THIS ISSUE



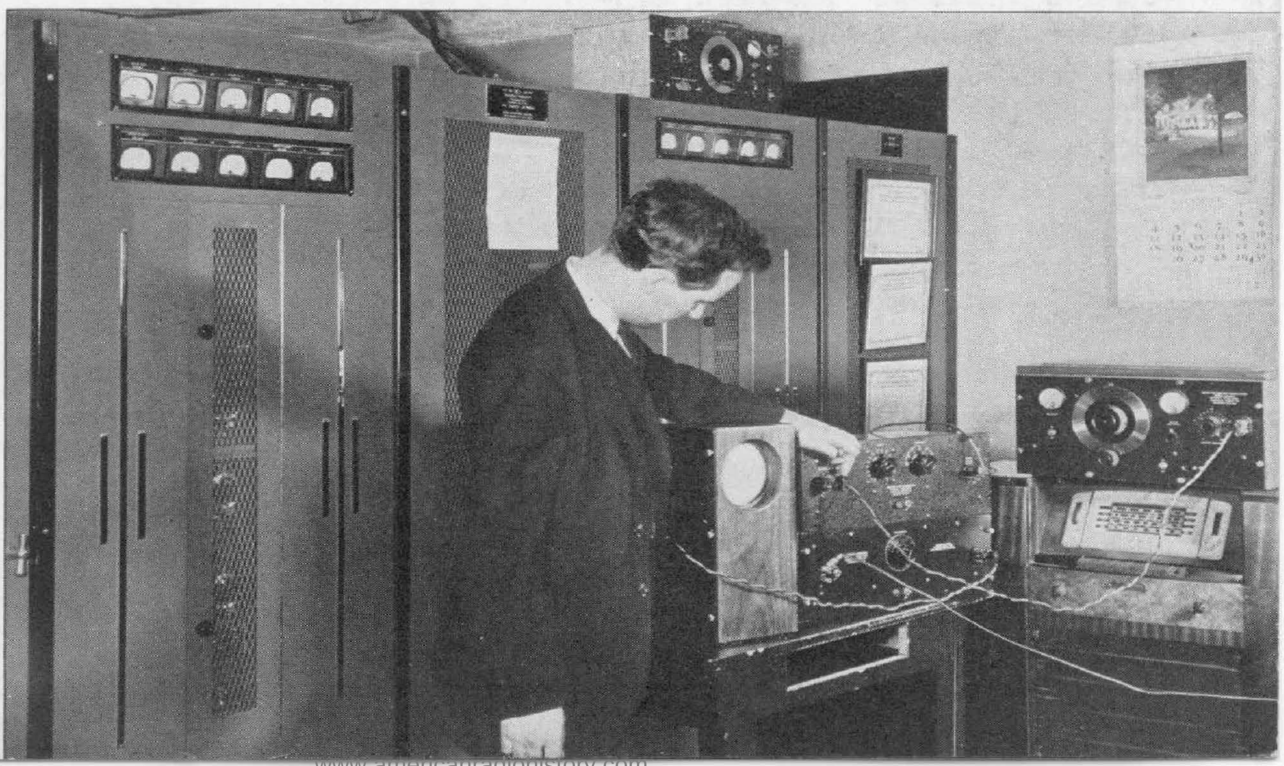
# TRANSIENT RESPONSE OF A BROADCAST SYSTEM

● AS STATED IN A PREVIOUS ARTICLE,* a knowledge of the response of a linear network to a suddenly applied voltage is sufficient to determine the behavior of the network when any other voltage is applied and, similarly, tests of the operation of a linear amplifier with square waves applied are sufficient to determine its response to the complex waveforms of speech or music.

The advantages of square-wave testing on audio-frequency amplifiers suggest the desirability of extending the test method to radio broadcasting systems. Although broadcast transmitters and receivers operate

*L. B. Arguimbau, "Network Testing with Square Waves," General Radio *Experimenter*, December, 1939.

FIGURE 1. The author with the equipment used for making the tests. In the background is the frequency-modulated relay transmitter of the Yankee Network.



www.americanradiohistory.com

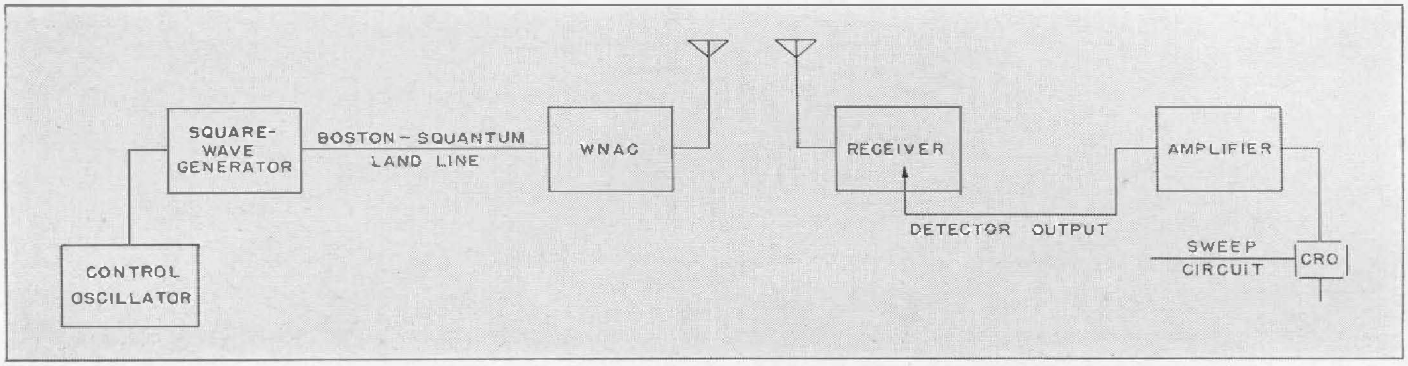


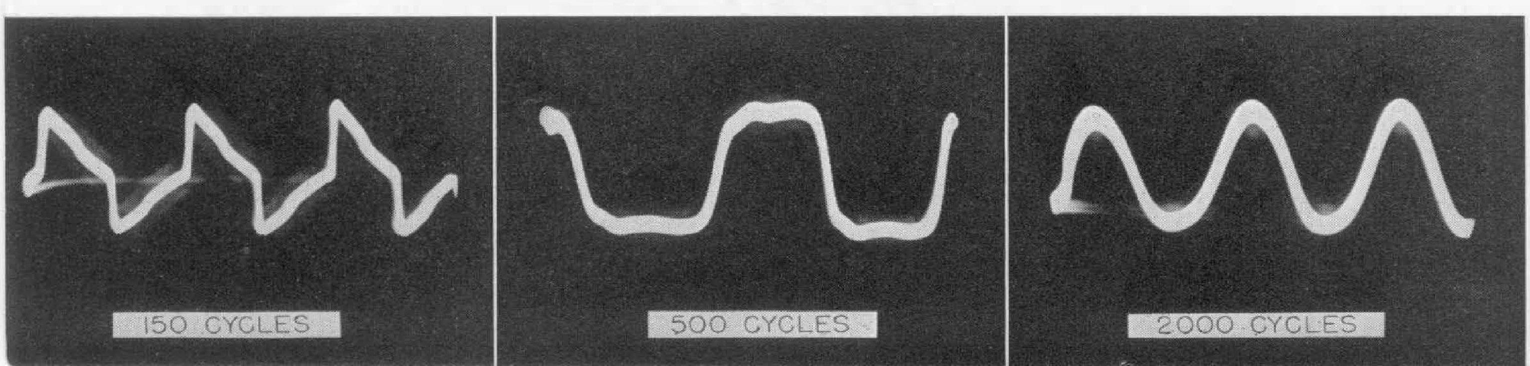

FIGURE 2. Diagram of the test method used for the amplitude-modulated system.

by virtue of non-linear elements, the carrier envelope in an amplitude-modulated transmitter output varies in a linear fashion with the audio-frequency input, and the audio output of a diode detector varies linearly with the carrier envelope. The envelope can be treated as a simple signal except when high percentage of modulation and unsymmetrical side-band clipping are present simultaneously. Under normal conditions, therefore, the same test methods that are used on linear networks should be valid for the broadcast system.

Through the courtesy of Mr. Paul de Mars of the Yankee Network, we were able to make a series of tests on the over-all transient response of two typical broadcast systems, one using an amplitude-modulated transmitter (WNAC of Boston), the second using an Armstrong frequency-modulated transmitter. It should be emphasized that in these tests no attempt has been made to localize the elements limiting the frequency range. As will be seen from Figure 2, the amplitude-modulated system included the program line and a receiver in addition to the transmitter. It is likely that the receiver was more important than the transmitter in limiting the fidelity. This arrangement was intentional as the tests were made to determine whether or not square-wave methods were applicable to such a complicated system and not for the purpose of making a technical investigation of the details of the system. As a matter of fact, this arrangement made it possible to get a direct comparison of the fidelity of an amplitude system as used at present under favorable conditions with the fidelity of the Armstrong system. The results of the tests on WNAC are shown in Figure 3. Several points may be noticed. With a 150-cycle square wave, the response has a very sharp slope, indicating phase shifts at the low frequencies.

The response to a 500-cycle square wave is somewhat similar to the high-frequency response of a single-stage

FIGURE 3. Oscillograms showing the shape of square waves after passing through the complete amplitude-modulation system.




www.americanradiohistory.com

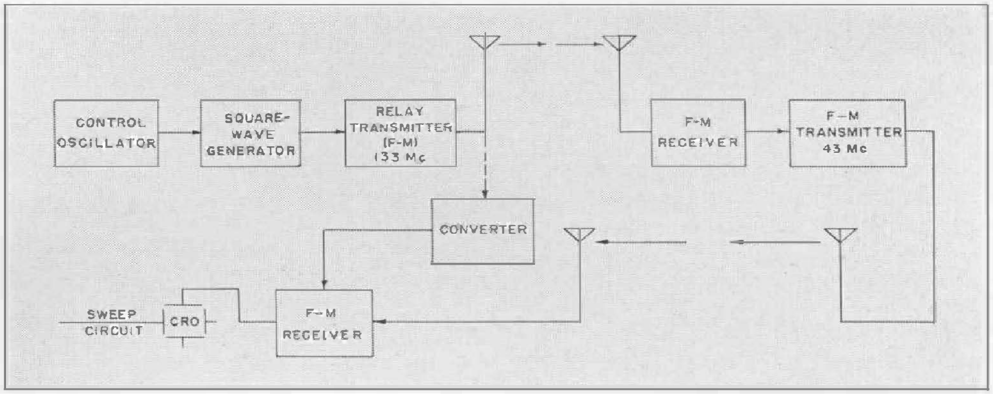



FIGURE 4. Diagram of the arrangement used for testing the frequency-modulation system.

amplifier and indicates appreciable attenuation at frequencies as low as 1500 cycles.

As is well known, a square wave contains only odd harmonics of its fundamental period. Thus, a square wave having a repetition frequency of 2000 cycles will have a 2000-cycle component and no other components below 6000 cycles. The fact that the response to a 2000-cycle square wave is essentially sinusoidal indicates that the system does not pass 6000 cycles or higher frequencies.

Figure 4 shows the arrangement used in testing the frequency modulation system. Two connections were tested. In one case the relay transmitter in Boston was modulated by a square wave and received in Paxton, Massachusetts, about 40 miles distant. The receiver output was then used to modulate the Paxton transmitter, which was then received in Boston. This chain of two transmitters and receivers is the arrangement normally used by the Yankee Network in Boston. In a second test, the output of the relay transmitter was passed through a converter and received directly.

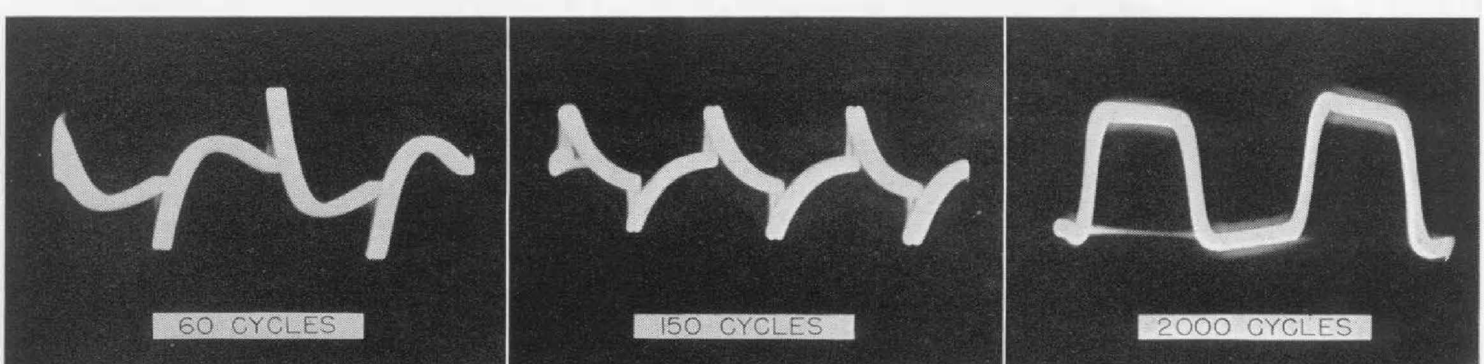
The response for the complete two-link system is shown in Figure 5. The 60-cycle response bears a close resemblance to that of a multi-stage resistance-capacitance-coupled amplifier.* In spite of the severe phase shift shown by this curve, a careful analysis of it indicates that the attenuation at 60 cycles is less than 2 db.

At 150 cycles the phase shift is obviously less. There is no measurable attenuation at this frequency. The high-frequency response as indicated by the 2000-cycle square-wave pattern is excellent.

Corresponding patterns for the relay transmitter are shown in Figure 6. The 150-cycle pattern is similar to that for the amplitude-modulated system. The difference in appearance of the vertical trace is caused by the limited high-

*A method for computing such curves is given in an article by H. M. Lane, "Resistance-Coupled Amplifier in Television," *Proc. I. R. E.*, April, 1932.

FIGURE 5. Square-wave patterns obtained for the complete frequency-modulation system. The oscillograms at the center and the right compare respectively with those at the left and right in Figure 3.




www.americanradiohistory.com

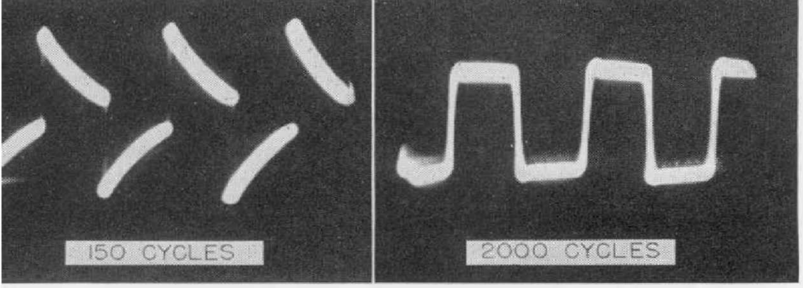



FIGURE 6. Oscillograms for the f-m relay transmitter and receiver only. Compare these with the results for the same frequencies on the amplitude modulation system (Figure 4).

frequency response of the amplitude-modulated system. The 2000-cycle pattern indicates that the cut-off frequency is around 30 kilocycles.

The writer is not in a position to comment upon the theoretical questions concerning the fidelity of frequency-modulation systems, but can say without hesitation that the experimental results indicate a very high fidelity.

These square-wave tests do not include the microphone and loudspeaker. While it is impossible to test these elements by purely electrical methods, the combination of speaker and microphone can be so tested by applying square waves to the speaker, picking up the sound wave with the microphone, and observing its waveform on a cathode-ray oscillograph. Tests were made in this way on a variety of loudspeakers and microphones. With none of these combinations was it possible to get recognizable square-wave patterns on the oscillograph.

This is not true of a phonograph recording and reproducer. In recent work done at M. I. T. by Mr. L. P. Reitz, a square-wave generator was applied to a record cutter and the pickup was later connected to an amplifier and cathode-ray tube. The results were by no means as good as those shown for the broadcast systems but the patterns were definitely recognizable as due to simple flaws such as insufficient low-frequency response and high-frequency resonance. The effect of equalizers on the high-frequency resonance could be followed clearly.

There has been much discussion about the applicability of square-wave technique to acoustics, about whether or not phase is of importance and, if so, under what circumstances. Comments of a large number of people would indicate that there is a considerable difference of opinion on the point. In any case, we can say that the response of a high-fidelity radio system is almost perfect in comparison to that of any available acoustic systems. The difference between these two is so glaring that it would seem that much more emphasis should be put on acoustic work.

The results show that square waves are useful in testing electrical networks and mechanical reproducers, but are not applicable to any of the acoustic systems tested. At least the results indicate that the method has considerable promise in design and maintenance work on electrical networks.

— L. B. ARGUIMBAU

# TYPE 50 VARIACS FOR MULTIPLE AND 3-PHASE OPERATION

● **THE NEW TYPE 50 VARIAC***, because of its ability to handle comparatively large amounts of power, has a considerably greater field of application than the smaller types. Ganged assemblies for use in 3-phase circuits and for parallel operation extend this field still further.

*S. A. Buckingham, "New Models of the Variac," General Radio *Experimenter*, Volume XIV, No. 2, July, 1939.



www.americanradiohistory.com

## THREE-PHASE OPERATION

As pointed out in a previous article,† the maximum amount of power which can be handled by an assembly of Variacs in a three-phase system is

$$(E_{in})\ (I_{max})\ (\sqrt{3})$$

where

$E_{in}$ = input line voltage

$I_{max}$ = maximum allowable output current.

This holds regardless of the type of circuit used, i.e., whether the Variacs are connected in a wye, a closed delta, or an open delta. This power can be handled in the vicinity of line voltage. When the over-voltage feature is used, rated current instead of maximum current must be used in calculating the output rating. It should also be noted that, when the power rating, so calculated, exceeds the combined ratings of the individual Variacs in the assembly, a greater-than-normal temperature rise may be expected because of greater losses produced by the higher flux density in the core. For a 50° Centigrade rise, the maximum power drawn should not exceed the sum of the individual ratings.

The connections most commonly used in three-phase Variac assemblies are the wye and the open delta. The closed delta, while sometimes useful for specialized applications, does not give the type of voltage variation usually desired. Circuits for the wye and open delta connections are given in Figures 1 to 4. Corresponding ratings are listed in Table I, page 6. Only circuits operating at 230 volts and higher are listed because there are comparatively few applications for lower-voltage three-phase systems.

†L. E. Packard, "Three-Phase Voltage Control with the Variac," General Radio *Experimenter*, Volume XI, No. 10, March, 1937.

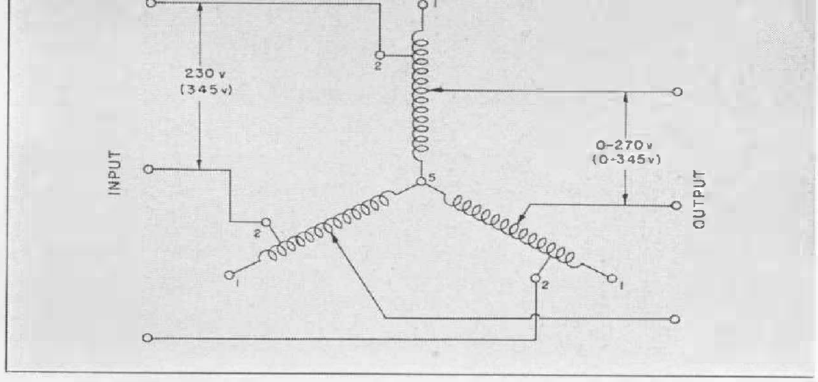



FIGURE 1. Three TYPE 50-A Variacs, wye-connected as shown here, can be used on a 230-volt circuit to give a maximum output voltage of 270 volts. If the over-voltage connection is not used, i.e., if the line input is connected to terminal 1 instead of terminal 2, a maximum of 345 volts can be handled.

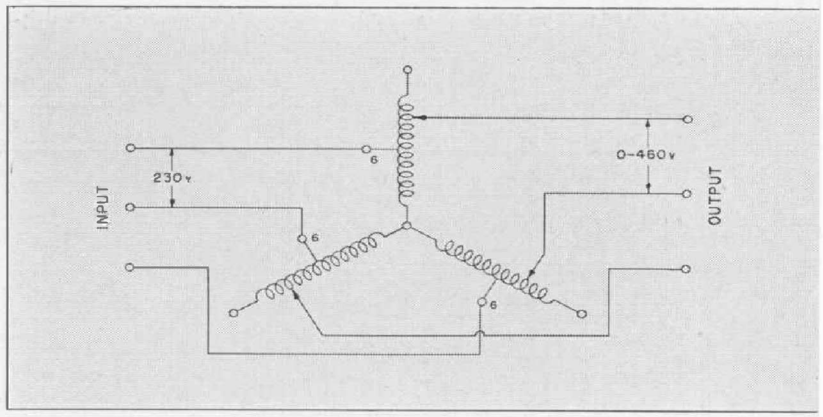



FIGURE 2. TYPE 50-B Variacs, wye-connected on a 230-volt circuit, will give a maximum output voltage of 460, open circuit. Regulation, however, is poor.

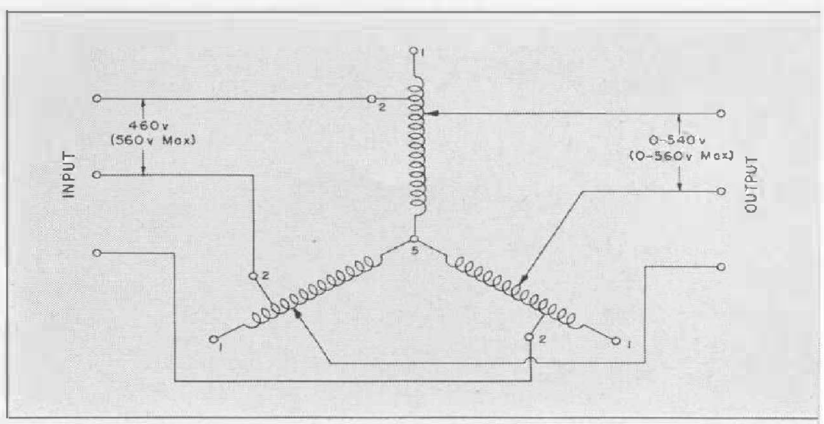



FIGURE 3. TYPE 50-B Variacs in a wye connection can be used on a 460-volt circuit to give a maximum output voltage of 540. If the input line is connected to terminal 1 instead of terminal 2, the maximum input and output voltage can be 560.

## PARALLEL OPERATION

When Variacs are operated in parallel a current equalizing choke must be used



www.americanradiohistory.com

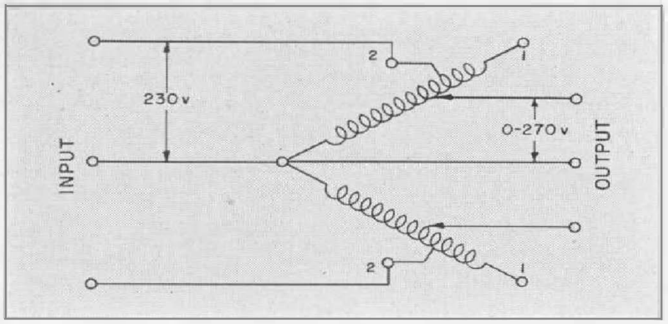



FIGURE 4. The open-delta connection uses one less Variac than the wye. This diagram shows two TYPE 50-B Variacs in an open delta.

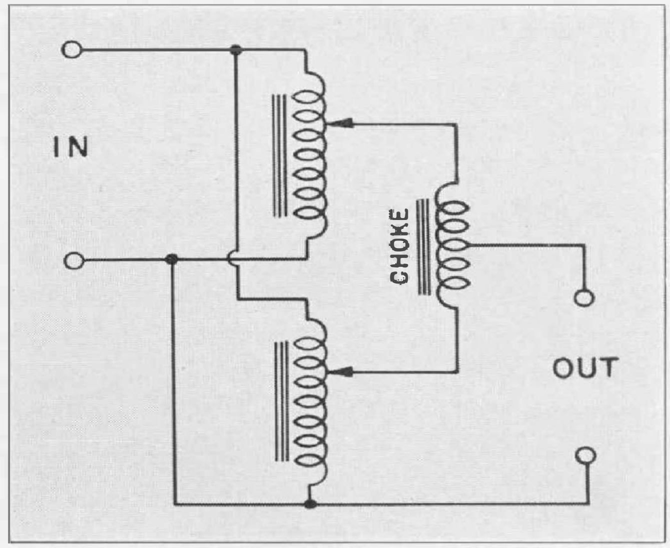



FIGURE 5. (*Right*) Connections for current-equalizing choke when Variacs are in parallel.

**TABLE I**

| *OUTPUT* | | | | | *INPUT* | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *KVA* | | *Line Current in Amperes* | | *3-Phase Line Voltage* | *3-Phase Line Voltage* | *Circuit* | *Type* | *No. Req'd.* | *See Figure* |
| *At Input Volt.* | *At Max. Volt.* | *Max.* | *Rated* | | | | | | |
| 18 | 16 | 45 | 40 | 0–270 | 230 | Y | 50-A | 3 | (1) |
| 26 | 26† | 45 | 40 | 0–345 | 345 | Y | 50-A | 3 | (1) |
| | | 31 | 20 | 0–460* | 230 | Y | 50-B | 3 | (2) |
| 25† | 16 | 31 | 20 | 0–540 | 460 | Y | 50-B | 3 | (3) |
| 30† | 19 | 31 | 20 | 0–560 | 560 | Y | 50-B | 3 | (3) |
| 12.5 | 8 | 31 | 20 | 0–270 | 230 | Open Δ | 50-B | 2 | (4) |

*Open-circuit voltage — regulation is poor for this connection.

†For outputs as great as this, the flux density is higher than normal, resulting in larger losses and a higher-than-normal temperature rise. The maximum output for 50° rise is 22.5 kva. The output listed can, however, be safely handled by the Variac for short periods.

to limit the flow of circulating current. Connections for such a choke are shown in Figure 6. For parallel operation of two TYPE 50 Variacs, TYPE 50-P1 Choke is available. This unit is mounted in a cast metal frame which can be fastened by the user in any convenient location in a two-gang assembly of TYPE 50 Variacs.

The power-handling capacity of two Variacs in parallel is, of course, double that of a single unit.

TYPE 50 Variacs are now available in two- and three-gang assemblies. Delivery can usually be made within two weeks after the order is received. Prices are listed below. — S. A. BUCKINGHAM

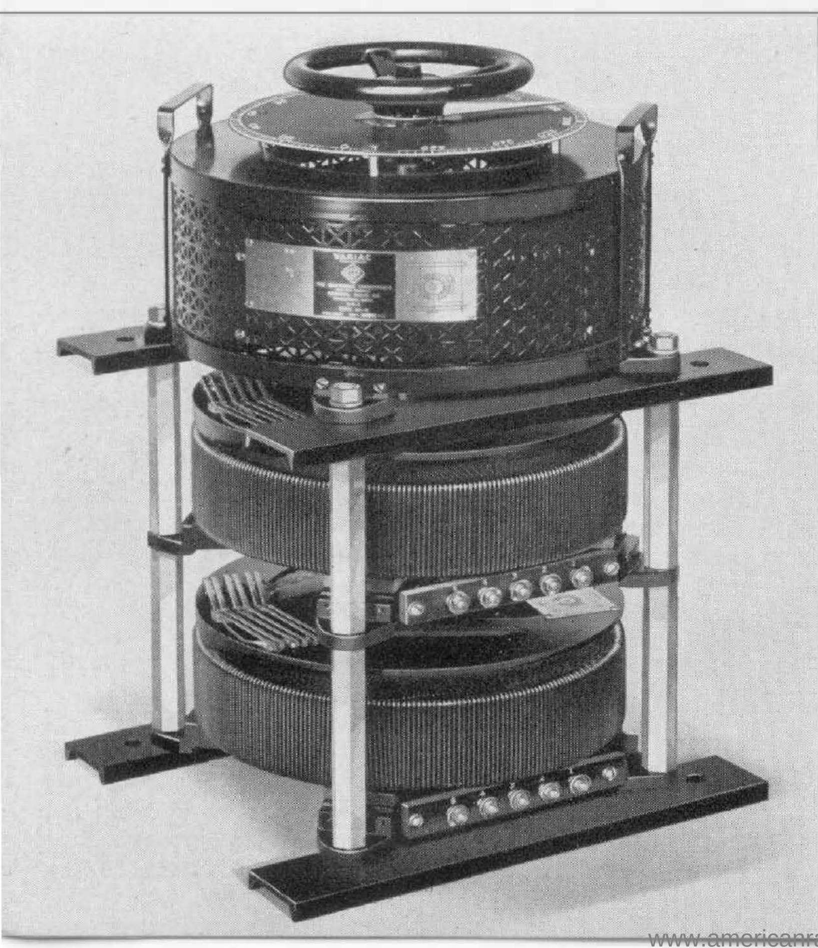


FIGURE 6. A three-gang assembly of TYPE 50-B Variacs.

www.americanradiohistory.com

## SPECIFICATIONS

**Mounting:** Unless the order specifies otherwise, ganged assemblies will be supplied for table mounting. This can be changed to panel mounting by loosening the shaft and sliding it through the assembly.

The standard shaft length will accommodate a 1½-inch panel. If the assembly is to be used on a thicker panel, this must be specified in the order, and a special long shaft will be furnished without extra charge.

The ganged assemblies cannot be used on a vertical panel without auxiliary bracing.

**Dimensions:** 2-gang, 15½ x 15½ x 17½ inches over-all; 3-gang, 15½ x 15½ x 25½ inches over-all.

**Net Weight:** 2-gang, 175 pounds; 3-gang, 250 pounds.

| *Type* | *Description* | *Code Word* | *Price* |
|---|---|---|---|
| 50-AG2 | 2-gang, Type 50-A | TOKENGANDU | $225.00 |
| 50-BG2 | 2-gang, Type 50-B | TOPAZGANDU | 225.00 |
| 50-AG3 | 3-gang, Type 50-A | TOKENGANTY | 335.00 |
| 50-BG3 | 3-gang, Type 50-B | TOPAZGANTY | 335.00 |
| 50-P1 | Choke | PARALLCHOK | 7.50 |

Variacs are manufactured under U. S. Patent No. 2,009,013.
The trade name VARIAC is registered at the U. S. Patent Office.

# A NEW SOUND-LEVEL METER

● **THE THREE YEARS** which have elapsed since the original announcement of the Type 759-A Sound-Level Meter have seen the transformation of sound-level measurements from a little-used and little-known laboratory procedure into a valuable and widespread commercial operation. The General Radio sound-level meter has been accepted in countless laboratories and industries as an accurate, convenient, and economical means for making the various noise measurements required by modern conditions and markets.

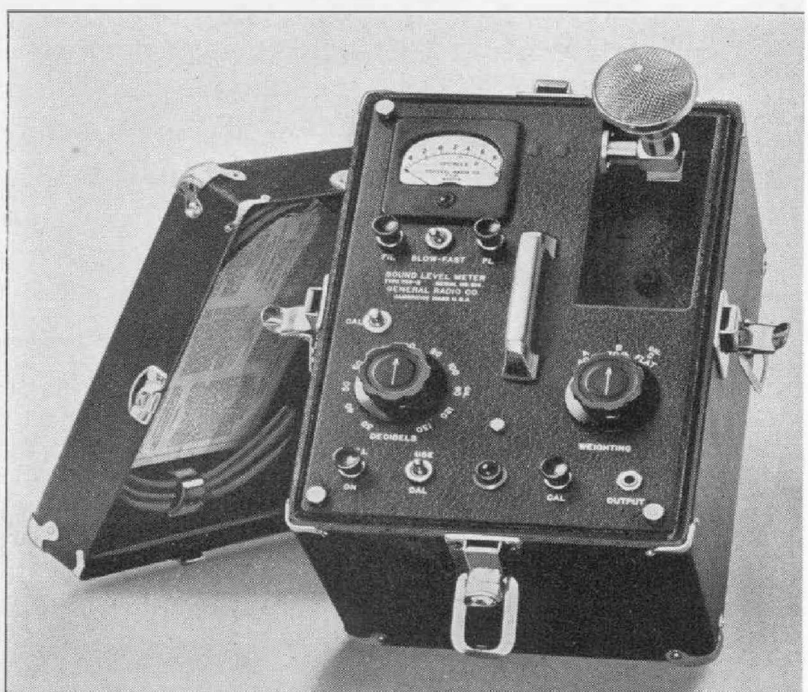
The experience gained in building many hundreds of these instruments has enabled the General Radio Company to produce an improved model known as the Type 759-B based upon the same principles as the previous type, but incorporating advancements and simplifications which provide even higher degrees of convenience and accuracy.

Of first importance is the microphone. An exhaustive study of the various types available on the market has led to the development of this special type. Throughout the A.S.A.* range of 60 to 8000 cycles its performance is substantially the same as the earlier model so far as frequency characteristic is concerned. The new unit, however, is more sensitive and rugged and is substantially unaffected by all ordinary changes in temperature and humidity. Use of this more sensitive microphone has allowed the designers to make other changes in the sound-level meter which improve its dependability and ability to withstand hard usage in the field.

For the convenience of the user the two attenuators have been combined,

* "American Tentative Standards for Sound-Level Meters for Measurement of Noise and Other Sounds," Bulletin Z24.3, American Standards Association.

Figure 1. View of the Type 759-B Sound-Level Meter with cover removed.




www.americanradiohistory.com

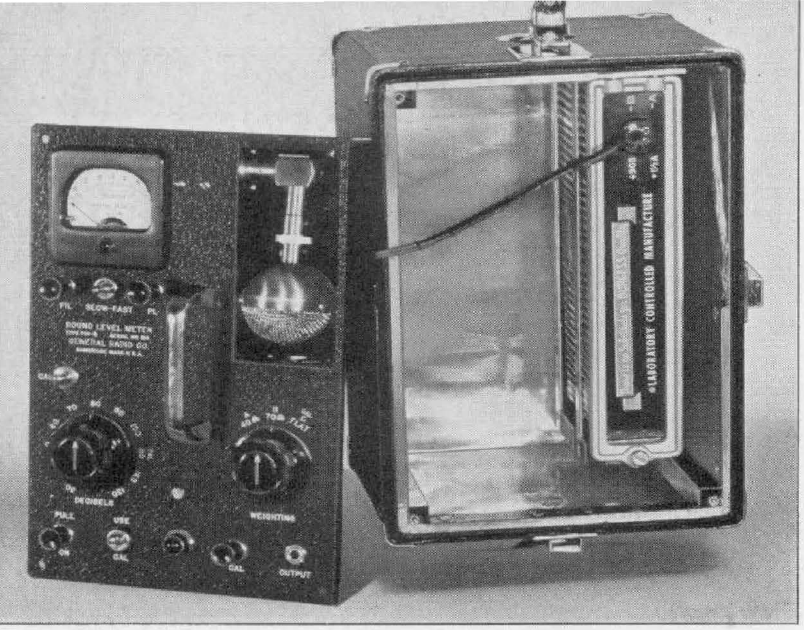


FIGURE 2. The power supply for the sound-level meter is a single block battery which mounts inside the cabinet. Connections are made with a plug as shown.

so that the main attenuator knob covers the complete decibel range. The range itself has been extended, so that the maximum level is now +140 db.

A further improvement is the provision of a slow-fast meter. With the control switch in the fast position the meter movement is the same as in the TYPE 759-A and corresponds to the A.S.A. specifications. Many users, however, have expressed a desire for a more heavily damped meter. Merely throwing the control switch to the slow position produces this result, thus simplifying the measurement of the average level of fluctuating sound.

Since the previous model sound-level meter was designed, many improvements have been made in vacuum tubes, and tubes of the latest 1.4-volt series are used in the new model. The additional gain available from these tubes, together with the more sensitive microphone, allows considerable simplification of the circuit. An important feature of the new circuit is the double output stage, one-half of which drives the indicating meter and the other connects to the output jack for use with an analyzer, external meter, or phones. There is no connection between the internal indicating meter circuit and this extra output circuit. This eliminates all rectifier distortion from the output and also makes the meter readings quite independent of what is connected to the output. The added convenience of these features will be readily appreciated by customers who use the sound meter with an analyzer.

Last but not least, the new sound-level meter uses a single block battery of the type used in portable radio receivers. Positive connection to the battery is made by means of a single plug. The battery both weighs and costs less than a set of batteries for the earlier model meter.

In spite of the improved design, the price of the new sound-level meter remains the same as that of the earlier model — $195.00. For most practical purposes the two meters are interchangeable, but the new meter is even more convenient and serviceable than the older one.

—H. H. SCOTT

The Type 759-A Sound-Level Meter is manufactured and sold under the following United States Letters Patent:

1. Patents of the American Telephone and Telegraph Company solely for utilization in research, investigation, measurement, testing, instruction and development work in pure and applied science.
2. Patent No. 1,871,886.

GENERAL RADIO COMPANY
30 STATE STREET - CAMBRIDGE A, MASSACHUSETTS
BRANCH ENGINEERING OFFICES
90 WEST STREET, NEW YORK CITY
1000 NORTH SEWARD STREET, LOS ANGELES, CALIFORNIA

www.americanradiohistory.com