THE General Radio EXPERIMENTER

VOLUME XVII No. 12 MAY, 1943

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

Also
IN THIS ISSUE

WPB ORDER M-293

● **EFFECTIVE ON MAY 1, 1943,** the War Production Board's General Scheduling Order M-293 went into effect. This Order covers a broad field of what are known as "critical common components" which include many things from jewel bearings to fire extinguishers.

General Radio equipment comes under a general heading of "Test Equipment." This includes nearly all General Radio instruments except Variacs, rheostats, knobs, and dials, and similar parts. The list of material as described in the Order is given on page 2.

Under the terms of the Order the WPB will schedule the deliveries of all of these materials. As a general rule, it is expected that the regular priority system will guide the organization of the shipping schedule. However, the WPB may change it around substantially in order to accommodate the most urgent requirements first.

After May 1 all orders for test equipment as defined by the Order must be accompanied by an approved Form PD-556. This is in effect another version of the old PD-1A. It is an application form which the prospective buyer sends to Radio and Radar Division of WPB for approval. One copy of the form is sent to the supplier with the order. We are prohibited from accepting orders after May 1 that do not have the PD-556 form attached.

IMPORTANT

● **BE SURE** to attach approved WPB Form PD-556 to all orders for instruments after May 1, 1943. Copies of PD-556 and Scheduling Order M-293 may be obtained from your regional War Production Board office.

Send PD-556 to the War Production Board, Radio and Radar Division (Reference: M-293), Washington, D. C., for approval.

This added complication will have at least one very useful result. It will be possible to schedule orders so that the most urgent war needs will be served first, and it does away with the necessity for any kind of priority certification. An approved PD-556 form supplements and replaces every other kind of priority certification that has been heretofore required.

Copies of Order M-293 and of Form PD-556 can be obtained from your local War Production Board.

TEST EQUIPMENT (ELECTRONIC)

AS SPECIFIED IN ORDER M-293

a. Generators of Audio and Radio Frequency Signals, except Rotary Type.

Radio frequency signal generators.
Radio frequency oscillators.
Audio frequency signal generators.
Audio frequency oscillators.

b. Frequency Measuring Equipment, including Standards.

Primary and secondary standards, and associated measuring equipment.
Interpolation oscillators.
Heterodyne detectors.
Audio frequency meters.
Electronic frequency meters.
Electronic deviation meters.
Wavemeters. Wave Analyzers.

c. Waveform Measuring Equipment.

Harmonic analyzers.
Cathode Ray Oscilloscopes.

d. Power Supplies (electronic) and Voltage Regulators.*

e. Impedance, inductance, capacitance, voltage, amperage, and resistance measurement equipment (except instruments controlled by Limitation Order L-203).

Impedance bridges.
Wheatstone Bridges.
Capacitance Bridges.
Precision Condensers.
Vacuum-tube Bridges.
Inductance Bridges.
Megohm Bridges and Megohmmeters.
Vacuum tube voltmeters.
Electronic tube-testers.
Output meters.
Q-Meters.
Electronic Volt Ohmmeters.
Volt Ohm Milliampere Analyzers.
Noise and Field Strength Meters.

f. Precision Standards of items in (e).

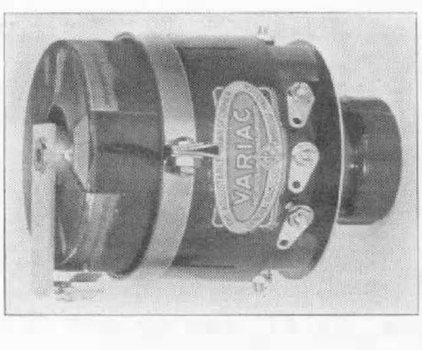
g. Electronic Speed Regulating Measuring Equipment.

Electronic Stroboscopic Devices.

h. Electronic Recording Devices, Graphical and Visual.

Oscillograph Recorders.

*This does *not* include Variacs.



TYPE 200-B VARIAC

TYPE 200-B Variacs are now shipped assembled for panel mounting, as shown at the left. At present, TYPE 200-B Variacs are available in small quantities on prompt delivery. Priority rating of orders should be AA-3 or better.

THE NOISE PRIMER

PART VIII

MAXIMUM ACCURACY IN NOISE MEASUREMENTS

● **PREVIOUS CHAPTERS** have covered the theoretical and practical considerations involved in making ordinary sound level measurements and analyses. The instruments used, the TYPE 759-B Sound-Level Meter and the TYPE 760-A Sound Analyzer, have been designed in accordance with accepted standards and are direct reading. For the most part, therefore, no auxiliary calibration or correction data are required.

In general, the accuracy of direct-reading measuring equipment can be improved by the use of individual calibration data, and this is particularly true in the case of sound-measuring equipment where, as has been previously pointed out, the microphone characteristic may deviate appreciably from theoretical perfection. This chapter, therefore, is devoted to information which the average user may not need and which is seldom available from manufacturers in published form. The necessary space is being devoted to it here on the theory that the user of instruments should know not only their limitations, but how these limitations may be minimized or overcome in those few cases where it may be necessary.

On average sounds, involving mainly frequencies between 60 and 3000 cycles, different makes and models of sound-level meters meeting the A.S.A. standards will generally read alike within a db or so, which is about all that can be expected in the present stage of microphone development. The degree to which the theoretical response curves must be approximated to meet the A.S.A. requirements was shown by the tolerances in Figure 2.[21] The so-called "noise of general character" for which a sound meter is corrected was shown diagrammatically in Figure 3.

There are, unfortunately, certain individual applications where the sound being measured differs greatly from the general noise of the A.S.A. standards,

[21] January, 1943, *Experimenter*.

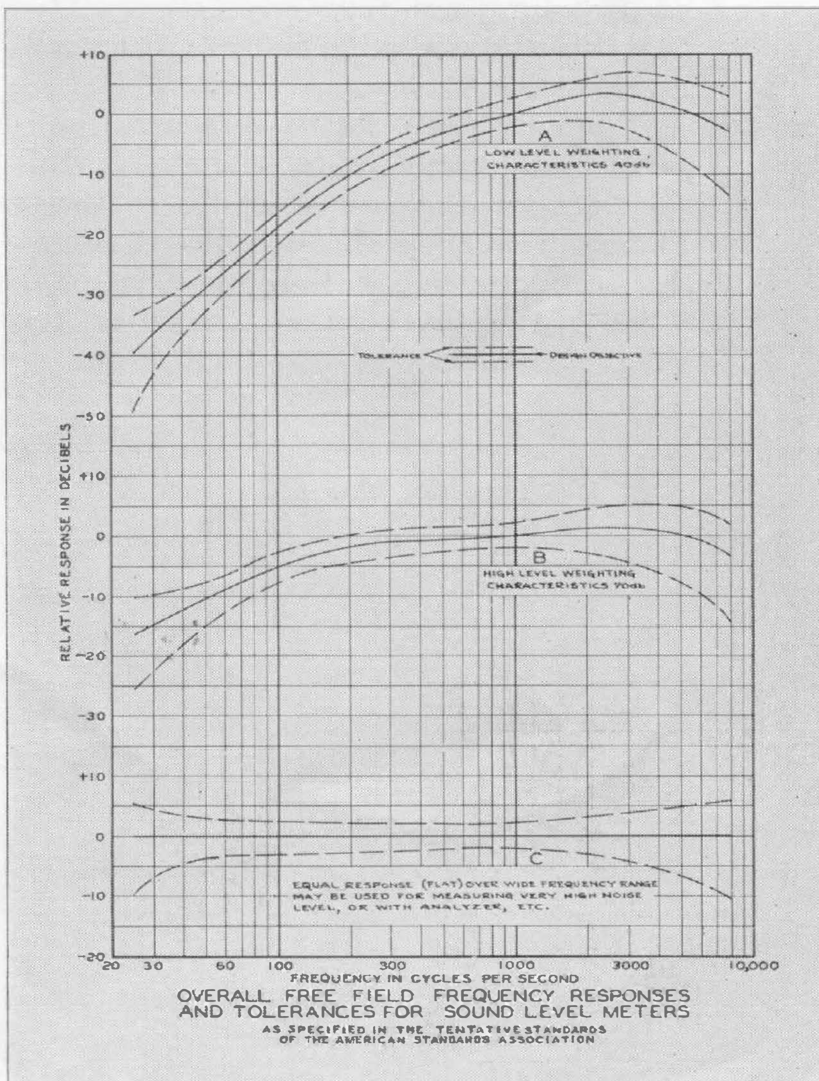


FIGURE 2. Design objective frequency-response curves between 60 and 8000 cycles for sound-level meters as specified by the American Standards Association (Bulletin Z24.3—1936). These standards do not specify the response below 60 cycles. The extended curves represent present practice as followed by the General Radio Company in the TYPE 759-B Sound-Level Meter. (As originally printed in Part I, the scale between 30 and 60 cycles was incorrectly drawn. The corrected plot is shown here.)

and different types of sound-level meters may not read exactly alike. In such cases the question of which meter is most nearly accurate is mainly academic and is liable to lead to unwarranted conclusions since the actual error will depend upon the characteristics of the sound. All microphones of the types commonly used with sound-level meters exhibit marked irregularities in the response curve above 3000 cycles, and some types are also irregular in the low-frequency region. The best procedure, therefore, is to correct for these irregularities, so that the reading will be the same as that which would be obtained by a theoretically perfect, but practically unattainable, sound-level meter — that is, one which followed the design objective curves exactly. This can be done when the response of the equipment at each frequency and the analysis of the sound are definitely known. This requires the use of a calibrated sound-level meter and an analyzer.

A microphone can of course be calibrated with respect to frequency, thus providing a curve showing the response at any frequency throughout its range. A complete calibration covering the whole sound-level meter, including the microphone, can be obtained from the sound-level meter manufacturer[22] or the Bureau of Standards. This provides the user with an exact knowledge of the sensitivity of his meter under a given set of conditions and at definite frequencies. In order to make use of the calibration it is necessary to know also the frequencies of the components which comprise the noise being measured. These may be determined with the sound analyzer. Analyzers, like sound-level meters, do not have perfectly smooth frequency characteristics, but the variations are generally small compared to those of the sound-level meter. However, for use with a calibrated sound-level meter, the analyzer should also be calibrated. This can be done by the manufacturer, or by the user, if he has a good audio-frequency oscillator available.

SOUND-LEVEL METER CALIBRATION

Figure 15 shows a typical sound-level meter calibration as supplied by the General Radio Company. The upper curve represents the over-all acoustical free-field response of the sound-level meter as determined in accordance with the A.S.A. standards, with the weighting switch set at the C position. The relatively smooth frequency response throughout the medium- and low-fre-

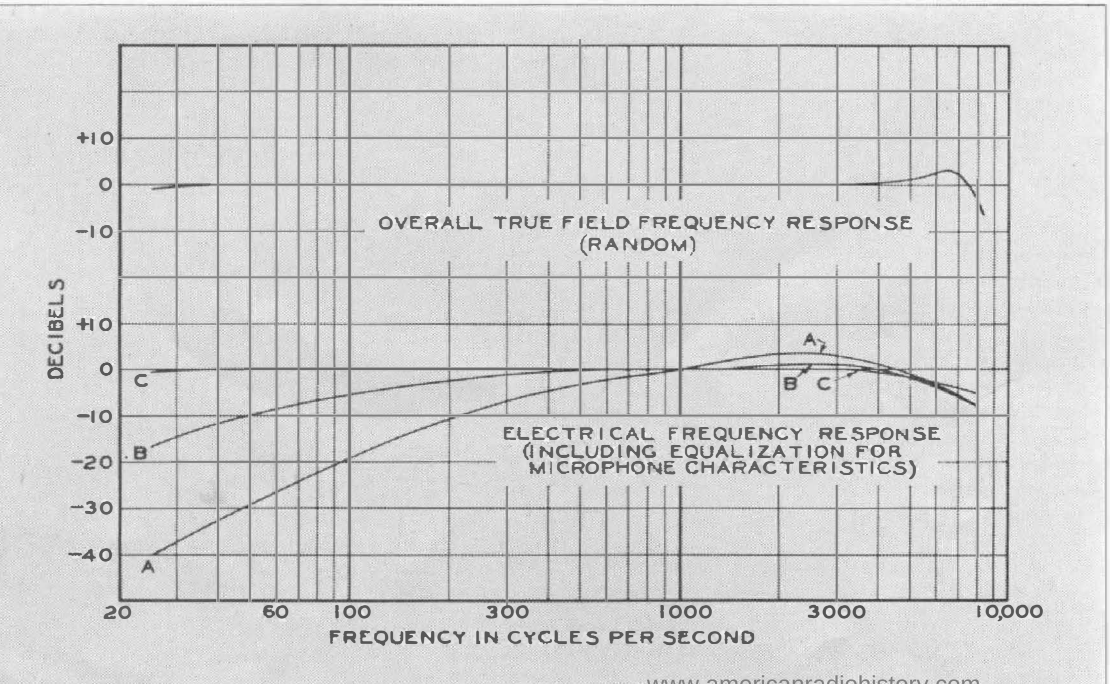


FIGURE 15. Typical average acoustical and electrical calibration curves for TYPE 759-B Sound-Level Meter.

[22] War conditions have caused temporary discontinuance of the General Radio Company's calibration service. It is expected, however, to be functioning again within a few weeks.

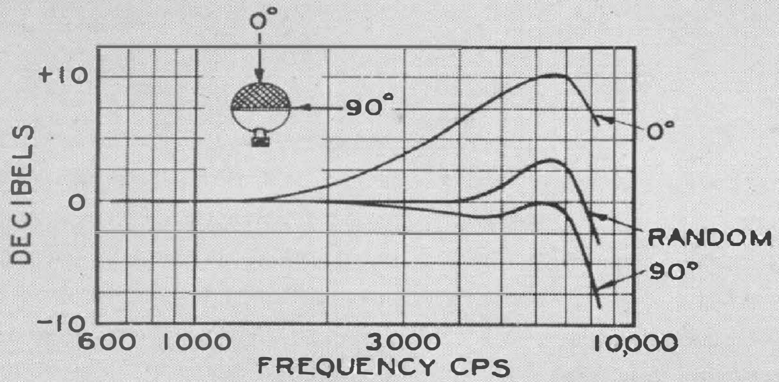


FIGURE 16. Typical curves showing the response of average TYPE 759-B Sound-Level Meters to sounds reaching the microphone at various angles. The random response which corresponds with the A.S.A. Standards represents the over-all characteristic, assuming that the sound arrives equally at all angles in a vertical plane.

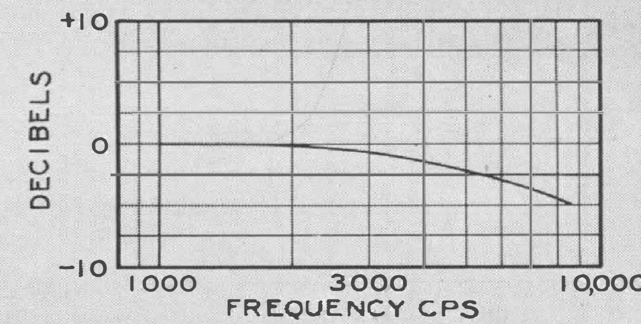


FIGURE 17. According to the A.S.A. Standards, a sound-level meter is calibrated for random response. Under conditions where all of the sound reaches the microphone from the horizontal (90°) direction the above corrections may be applied to the random microphone calibration in order to obtain better accuracy at high frequencies.

quency regions is characteristic of the piezo-electric type of microphone. The lower curves represent the electrical characteristics of the meter, exclusive of the microphone, for the three different weighting curves. These are similar to the curves shown in Figure 2 except for the modifications which are made to compensate for the microphone characteristics. Obviously, additional acoustical curves for the A and B weightings similar to that shown for the C can be plotted from these data, if desired, by merely applying the differences between the three curves for the electrical characteristics to the acoustical C curve.[23]

With all microphone calibrations it should be remembered that the response of the microphone varies somewhat with direction, particularly in a vertical plane. The acoustical curve shown in Figure 15 represents the random response obtained by averaging the characteristics measured at different angles, as specified by the A.S.A. Bureau of Standards calibrations, unless the customer specifies otherwise, are generally made at the so-called 90° angle of incidence (zero degrees is straight down toward the top of the microphone), which corresponds to a sound arriving at the microphone in a horizontal direction. The microphones are normally used in this position, but under practical conditions, as a result either of the size of the sound source or the presence of considerable reflected sound, much of the sound reaches the microphone at angles other than 90°. This is the reason for the A.S.A.'s averaging procedure.

Figure 16 shows the response of a typical TYPE 759-B Sound-Level Meter to sounds reaching the microphone from different directions. All sound-level meters using so-called non-directional microphones will have this general type of characteristic. The response of such microphones is generally symmetrical around a vertical axis. In order to make best use of a calibration curve, therefore, the angle at which the calibration was made should be known. Figure 17 shows the 90° response of a TYPE 759-B Sound-Level Meter microphone in terms of the random response. This curve is typical of this particular type of meter and may

[23] Bureau of Standards calibrations are plotted in terms of correction rather than actual sensitivity. Hence a Bureau calibration corresponding to the upper curve C in Figure 15 will be inverted. The Bureau does not measure the electrical frequency characteristics as shown in Figure 15, but the *differences* between these electrical curves can generally be obtained sufficiently accurately by taking the *differences* between the design objective curves in Figure 2.

be used for an additional correction where the user is certain that the sound is all reaching the microphone in a horizontal direction. This applies only when the microphone is placed at the same horizontal level as the sound source and the surroundings are substantially non-reflecting, so that only direct sound is reaching the meter.

Caution: It is obvious from Figure 16 that so-called non-directional microphones have unusual sensitivity to high frequencies at the zero degree angle. When measuring sounds involving strong high-frequency components, therefore, care should be taken that the sound strikes the microphone at an angle of 45° or greater, in order to avoid undue influence of these high-frequency components on the total reading. This is ordinarily taken care of automatically, since the microphone is normally used at or near the 90° angle — that is, side on toward the source.

Sounds reaching the microphone by reflection from surrounding objects will arrive at angles other than 90°. So long as this represents a random distribution, the process of averaging used in calibrating the microphone will tend to cancel errors. However, if by any chance some hard surface directly above the microphone reflects or focuses the high frequencies downward onto the microphone, serious errors may result. This possibility of error can be eliminated by covering such surfaces, if present, with felt, carpeting, or other absorbent material. Since only high frequencies are involved, it is a relatively simple matter to absorb them.

It is also possible, in specialized applications where strong high-frequency components are present and where equality of response in all directions in a horizontal plane is not necessary, to use the microphone at the zero degree angle — that is, aimed at the sound source and thus obtain a certain amount of directivity. A special calibration is necessary for this work, however, since the variations in microphone response as the zero-degree angle is approached are sufficiently large to make prediction of the zero-degree response on the basis of the random or 90° response of doubtful value. Figure 16 represents the average of a number of microphones. In any individual microphone the spread between the zero-degree and random reponse curves will vary enough so that the errors involved in applying these average curves would probably be as large as that caused by high-frequency reflections when using the microphone in the usual 90° position.

USING THE CALIBRATED SOUND-LEVEL METER

When the calibrated sound-level meter is used with an analyzer, correction for the microphone characteristic is relatively simple. The noise measurement and analysis should be made in the usual manner. If any of the important sound components occur at frequencies at which the sound meter deviates appreciably from the design objective curve (that is, the acoustical curve C in Figure 15 deviates substantially from a straight line), suitable corrections can be made.

For instance, assume a sound consists almost entirely of a strong component at 7000 cycles. From Figure 15 we find that the meter is 3 db too sensitive at this frequency, and from Figure 18 we find that the analyzer is ½ db low in sensitivity at this frequency. Thus we know that our reading is 2.5 db too high.

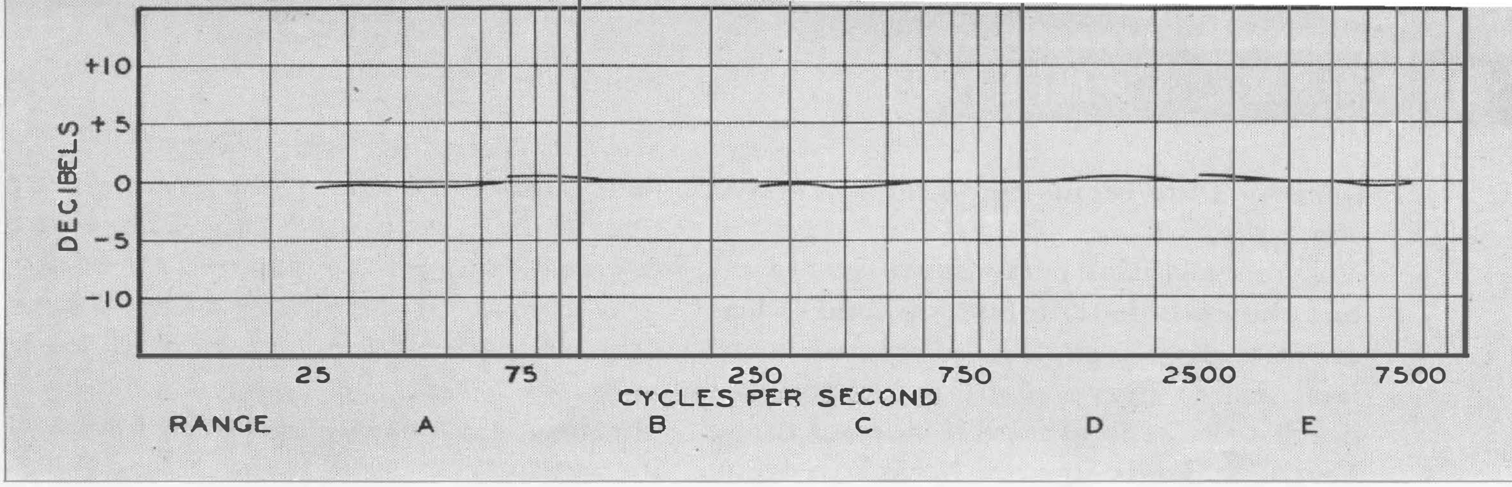


FIGURE 18. Typical response curve of TYPE 760-A Sound Analyzer. A calibration of this type may be made easily by anyone having a satisfactory audio-frequency oscillator and vacuum-tube voltmeter or other indicating device. All that is necessary is to maintain a constant voltage at the input of the analyzer, tune the oscillator to various frequencies throughout the range and at each frequency tune the analyzer to exact resonance and read the indicating meter.

For complex sounds the procedure is somewhat longer, but not complicated. Each component falling at a frequency where the meter calibration shows an appreciable irregularity should then be corrected as described above. Correction will then be

$$db = 10 \log_{10} \frac{S_2}{S_1} \qquad (4)$$

where S_2 is the sum of the squares of the relative sound pressures of the components, including those *corrected*, and S_1 is the sum of the squares of the relative sound pressures of the components *before correction*.

In general, all components lower than 10% of the loudest may be neglected in computing S_2 and S_1. However, it is important that the same components be used in computing both S_2 and S_1.

Relative sound pressures may be read directly from the percentage scale of the TYPE 760-A Analyzer. When S_2 is smaller than S_1 the correction will be negative, since the actual sound level will be lower than the measured sound level. This correction should be applied to the sound-level meter reading on the particular sound only.[24]

It is also possible, of course, by means of the analyzer to measure the absolute amplitude of each component individually in terms of decibels, convert all of these figures to relative *power* ratios, add them together and convert the sum back to decibels; and the answer should be the same. The first procedure outlined above is generally more accurate, however, since it automatically includes many low-amplitude components or random noise which may not show up in an analysis, but which, when added together, may constitute a measurable part of the total sound energy. It is also somewhat simpler, requiring less calculation. —H. H. SCOTT

(*To be continued*)

[24] This may be read directly from the General Radio Table I by considering $\frac{S_2}{S_1}$ as a power ratio.

SHIPMENT OVERDUE?

The high (or low) point in efficient expediting is reached when the customer calls to chide us about late delivery before we receive the order. A close second is the complaint about delivery when shipment has been made some time earlier, and investigation shows that the material has already been received. Both of these things happen, and more frequently than seems reasonable, even in war time.

Transportation systems are overtaxed, but they are doing a fine job, and delays are usually negligible. Personnel and facilities in every plant are carrying a much heavier load than in normal times. Errors and mix-ups are bound to occur. But we'll all have less trouble if we make sure that we're right before we squawk.

An inquiry about a shipment that has already been received wastes not only your time and ours but that of the transportation company as well, because they trace the thing from shipper to consignee, only to find that it was delivered some days earlier.

At the risk of being caught by our own suppliers in the same practices we deplore in others, we'd like to suggest a couple of rules for the harassed expediter.

1. Be sure the stuff has actually been ordered and the order accepted. As a corollary to this, if it's a repair job you're chasing, be sure you sent us the damaged instrument.

2. If shipment is overdue, check with your receiving department and with the ultimate user in your plant to be sure that the shipment has not been received.

Following these rules will save a lot of telephone calls and a lot of time. Both are valuable in war time.

—H. H. DAWES

SERVICE AND MAINTENANCE NOTES

● **IN THE PAST FEW MONTHS,** Service and Maintenance Notes, not previously available, have been prepared for the following instruments:

Type	*Description*
561–D	Vacuum-Tube Bridge
583–A	Output Power Meter
614–C	Selective Amplifier
616–C & D	Heterodyne Frequency Meter
617–C	Interpolation Oscillator
667–A	Inductance Bridge
676–A	50–Kc Quartz Plate
690–C	Piezo-Electric Oscillator
691–C	Temperature-Control Unit
692–B	Multivibrators
693–B	Syncronometer
694–C	Control Panel
698–A	Duplex Multivibrator
714–A	Amplifier
716–A & B	Capacitance Bridge
723–A, B, C & D	Vacuum-Tube Fork
727–A	Vacuum-Tube Voltmeter
729–A	Megohmmeter
757–A	U-H-F Oscillator
769–A	Square-Wave Generator
805–A	Standard-Signal Generator
913–A	Beat-Frequency Oscillator

Customers who requested the Service and Maintenance Notes for these instruments in previous applications have already received copies. However, if equipment in this list and in our latest catalog has been purchased since January, 1942, and the Notes are not in your files, copies will be mailed upon receipt of the type and serial numbers.

If the binder originally supplied will not accommodate the additional pages, another will be sent upon request to the Service Department.

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