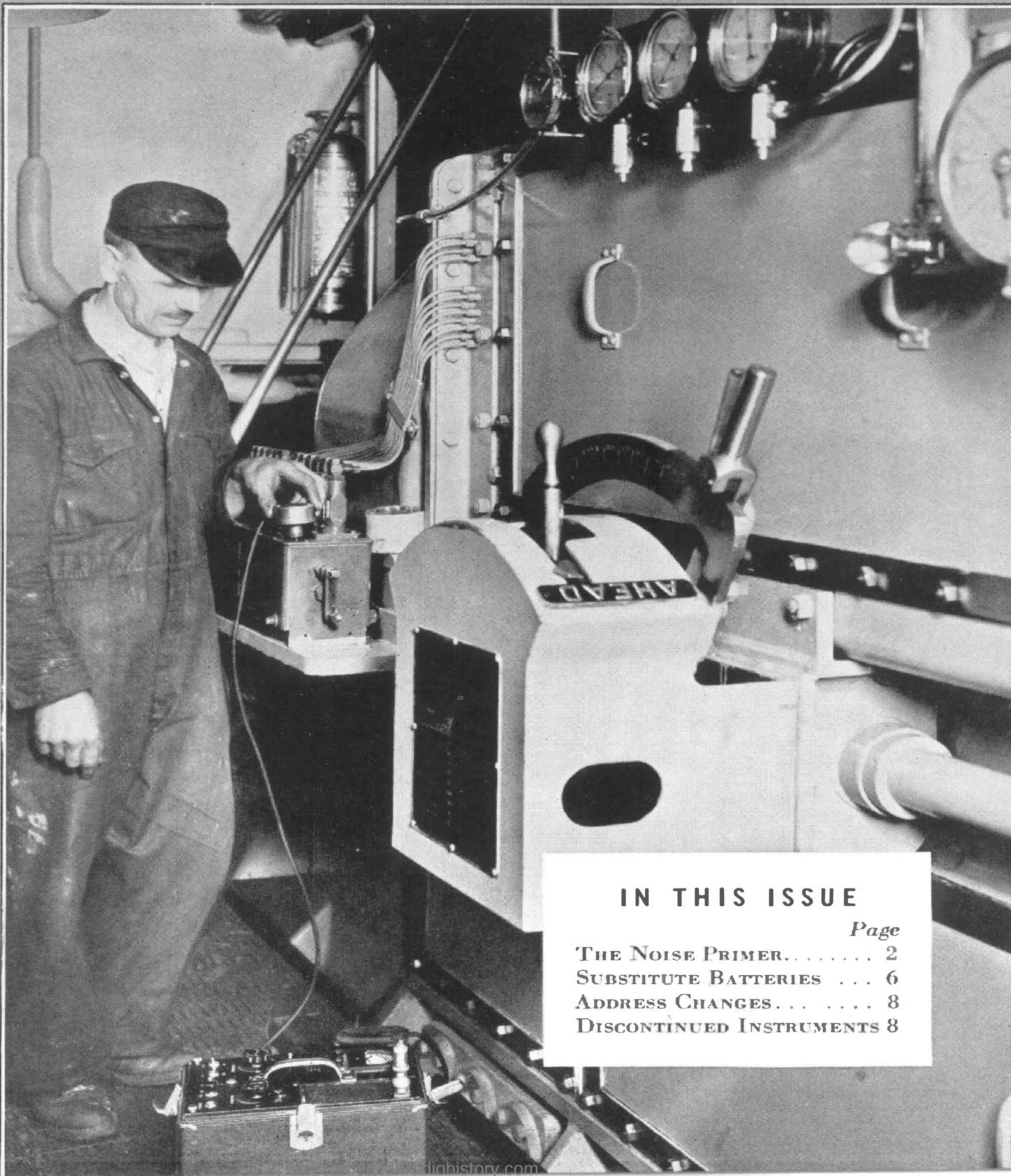
THE General Radio EXPERIMENTER

VOLUME XVII No. 8 JANUARY, 1943

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS



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COVER PHOTOGRAPH
Measuring Vibration on a Diesel Trawler with the Sound-Level Meter and Vibration Pickup.

THE NOISE PRIMER

● **IN THESE DAYS OF SECRET DEVELOPMENTS** there is much technical information which cannot be published and many new developments which cannot be advertised for general sale. This is a good time, therefore, to provide additional information covering instruments and techniques which were developed and known before the war.

With this issue, we begin a short series of articles dealing with the measurement and analysis of acoustic noise and mechanical vibration. To many it will be an old story, but for a number of industrial users of General Radio sound and vibration measuring equipment it may provide the answers to many of their questions.

Bulletins 20 and 30 ("The Technique of Noise Measurement" and "The Technique of Noise Analysis," respectively) have been in print for several years, and the General Radio Company has also published several other bulletins and *Experimenter* articles covering the general subject. However, most manufacturers of sound and vibration measuring equipment (and General Radio is no exception) are inclined to overlook as obvious many small details of theory and procedure which baffle the uninitiated. These articles are, therefore, both an apology for this "everybody-ought-to-know-that" attitude and a real attempt to help the many who in the past have had no more reason to know about sound measurements than the communications engineer has had to know about blowers or turbines.

Most manufacturers are convinced that customers never bother to read instruction books. Not to defeat their purpose, then, these articles must of necessity be brief, and we only hope that we haven't left out anything of real importance to you.

PART I—TO BUY OR NOT TO BUY

(If you don't have a high priority rating, reading this part may be a waste of time.)

Treatises on sound and vibration measurements generally start with a long-winded discussion as to their importance, but this is now so well known that we shall assume that you wouldn't be reading this at all if you weren't convinced. We shall therefore dispense with all unnecessary formalities.

The aura or mystery which surrounded early sound measurements has gradually been dissipated. The long-haired scientist who waved the microphone, gazed at the meter, went into a trance and came out with a lot of mysterious numbers has gone, along with the notion that ability to tolerate noise is a mark of giant brain power. There is still plenty of work for the consultants—on problems of a temporary or unusually difficult character, but all measurements connected with the normal development or manufacture of a product are now generally carried out by the manufacturer's own engineering or production staff.

If, in the design, manufacture, or sale of your products you have regularly to measure or to analyze noise or vibration, you or others in your organization should be able to make the measurements quickly and accurately. For shorter jobs, you must balance the cost of the equipment (which is now surprisingly low) and the time against the possible consultant's fee. One important thing to remember is that, once the equipment is purchased, you have it, and it will also be very useful, perhaps invaluable, on future problems. The demand for quietness and freedom from vibration is becoming more insistent. Do not, therefore, assume that your present problems are only temporary, or that you will never have any more like them. Do not deny your organization the advantages now of something you will probably need even more as time goes on. Noise and vibration are not merely annoyances which may affect the sale of a product or lower the efficiency of a worker. They are often evidences of defects in design and manufacture which seriously affect the life of the equipment and in many cases the safety of the user.

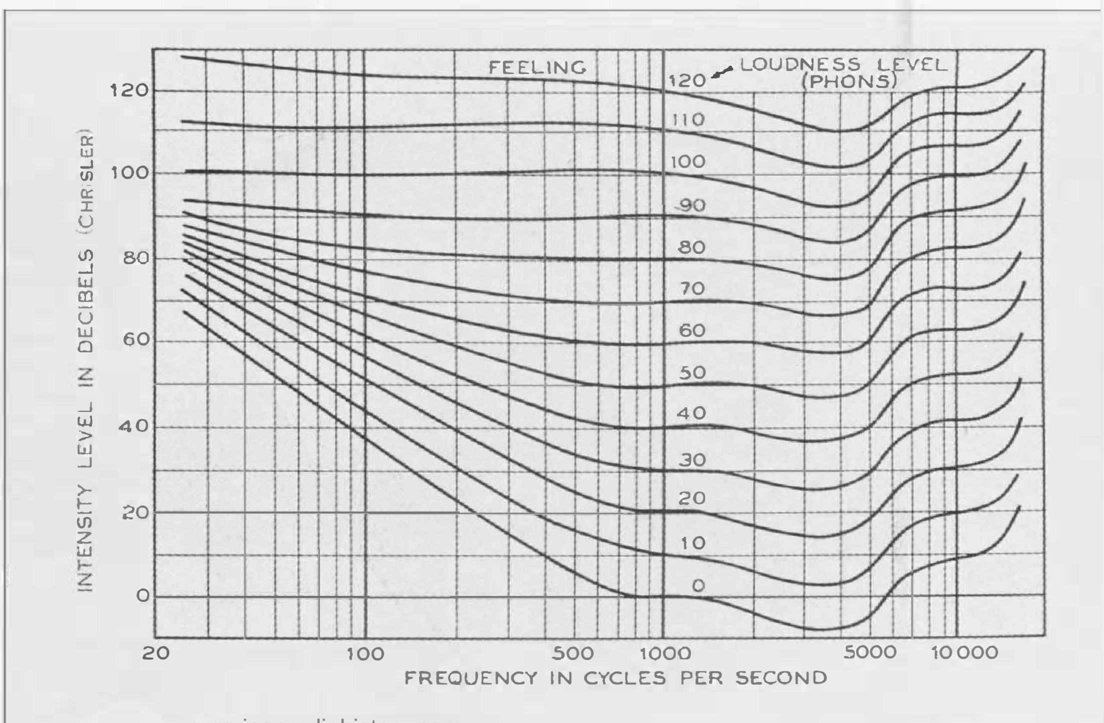
PART II—THE SOUND-LEVEL METER

Similarity to Ear

The sound-level meter or, as it is often called, the noise meter, is essentially a device for measuring the amplitude of rapid alternations in the air pressure. It does not measure the frequency, or pitch, at which such alternations take place. When these alternations occur within a certain range of frequencies they affect the ear and are known as "sound" or "noise." The sound-level meter is intended, therefore, to provide a simple means of obtaining objective measurements which can be correlated with the response of the average ear.

Don't think that the sound-level meter is perfect in this respect. Not enough is now known about the ear to enable us to duplicate its response perfectly and, even if it were, the necessary equipment would be complicated, bulky, and expensive. Furthermore, for many engineering problems the conventionalized response of the sound-level meter is more useful than an exact ear response would be, since the ear response, by its complicated nature, is not subject to simple mathematical or physical analysis. As long as we realize

FIGURE 1. Equal-loudness contours for the average ear.[1]



its limitations the sound-level meter is a most useful device, and certainly the best thing for its purpose which can be devised at the present time.

As an example of the many complicated characteristics of the ear, Figure 1 shows the familiar Fletcher-Munson curves, which are constant-loudness contours of the average ear in terms of frequency and loudness level. These indicate that the frequency-response characteristics of the ear are not constant, but vary with the loudness of the sound. For instance, at low sound levels the ear is relatively insensitive to low frequencies, but at high sound levels it hears them almost as well as the higher frequencies.

The best known makes of sound-level meters are more or less alike. They are all intended to follow the standards as set forth by the American Standards Association,[2] and with the passing of time all leading manufacturers have adopted similar mechanical and operating features. For most purposes they may be considered interchangeable, but in some few cases their readings will not be identical, although the meters may all meet the standards.

Microphone Limitations

A glance at Figure 2 will show one reason why this is so. The tolerances, which may seem excessively wide to those previously unacquainted with acoustical measurements, are made necessary by the limitations in available microphones. Most microphones were originally designed for use in the reproduction of music and speech and are not for purposes of quantitative measurement. There are many factors entering into the reproduction of speech and music (such as the ear, room acoustics, and the properties of the instruments and voice) which make it useless to maintain an absolutely flat or smooth frequency-amplitude characteristic in the microphone, particularly if it must be obtained at the expense of sensitivity or other desirable properties. Hence the

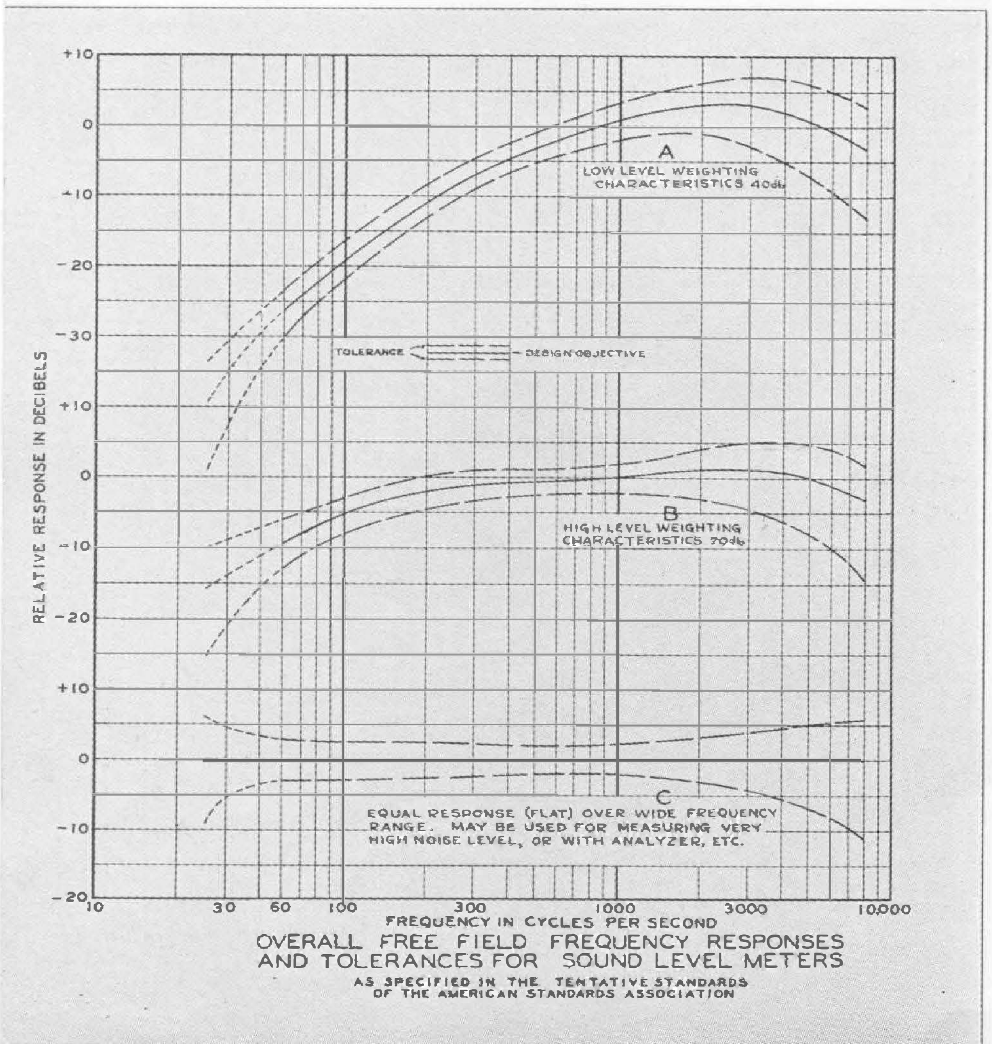


FIGURE 2. Design objective frequency-response curves between 60 and 8000 cycles for sound-level meters as specified by the American Standards Association (Bulletin Z24.3—1936). These standards do not specify the response below 60 cycles. The extended curves represent present practice as followed by the General Radio Company in the TYPE 759-B Sound-Level Meter.

characteristics of standard microphone types vary considerably from a straight, flat line, particularly in the extreme upper and lower parts of the audible range. While, in many cases, the microphones used for sound measurement are improved in this respect over those commonly used for broadcasting and recording, the perfect microphone is yet to be developed, and present types all represent a compromise in order to get the best possible combination of good frequency response, stability, ruggedness, and sensitivity. The tolerance curves of Figure 2 represent the maximum deviations from a given design objective to be expected with the best of present microphone types. So far as the electrical circuits in the sound-level meter are concerned, it is possible to make these follow any particular characteristic with a high degree of accuracy.

The microphone, then, is the weakest link in the sound-level meter, but the situation is actually much better than the tolerance curves would seem to indicate. Figure 3 shows, in column 2, the relative sound pressure in average noise for the various frequency bands tabulated in column 1. It will be noted that the high frequencies become progressively less important, so that for most purposes components above 3000 cycles may be omitted altogether without serious error. Since a sound-level meter, in order to meet the standards, must have a certain amount of response up as far as 8000 cycles, it follows that, for sounds of general character, it will read quite accurately, providing it has a good low-frequency response, which is much more important.

Of course, there will always be some sounds with strong components above 3000 cycles or at very low frequencies, and it is on this type of sound that the greatest error will generally occur. The most serious discrepancies among different meter types generally happen when a strong component is at a frequency where one microphone has a valley in its response curve while the other has a peak. As an extreme, at 8000 cycles a possible difference of 15 decibels could result from this cause alone with meters meeting the standards in every way. In actual practice, however, differences even a fraction as large as this are uncommon, and occur only in exceptional cases. Also, errors from this cause may be almost entirely eliminated through the use of an analyzer and a calibrated microphone, as will be described later.

A. S. A. Frequency Response Curves

Now that we know the worst that can occur, we can forget it for a while and go on to more practical and important aspects of the sound-level meter. It should be noted that the curves in Figure 2 bear a close resemblance to those in Figure 1 and were actually derived therefrom. Since the A.S.A. committee realized that it was neither desirable nor

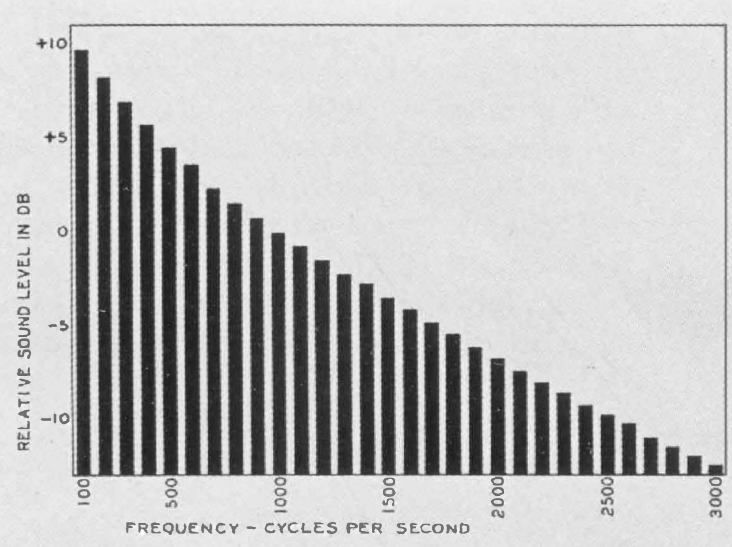


FIGURE 3. Chart of the relative contribution to total noise level made by 100-cycle bands over the frequency spectrum, as obtained from analyses of noises of a general character. (From A.S.A. Bulletin Z24.3 — 1936.)

practical to duplicate the ear response exactly, the curves for two representative levels (40 and 70 db) were taken from Figure 1, modified for random free-field response and smoothed.[3] The flat response (C) was added for use where measurements of actual physical sound pressures were desired and at very high sound levels, where the ear response is fairly constant.

In addition, the A.S.A. standards (Z24.3) define various terms and units, specify other tolerances, and how the microphone is to be calibrated. Many of these points will be discussed in later articles. The standards are the result of some years' experience in the design, manufacture, and use of sound-level meters, and are now in the process of revision in some minor details. These revisions are not of the nature that will make present types of meters obsolete, however, but rather bring the standards more in line with what can be accomplished in the present state of the art by the leading manufacturers. Complete information regarding the modified standards will be supplied as soon as it is available. — H. H. Scott

(To be continued)

REFERENCES

[1]These curves are now incorporated in the American Standard for Noise Measurement, Bulletin Z24.2 — 1942, published by the American Standards Association, 29 West 39th Street, New York, N. Y. (price 25 cents). They were originally published in a paper by Harvey Fletcher and W. A. Munson of the Bell Telephone Laboratories entitled "Loudness, Its Definition, Measurement, and Calculation" and published in the Journal of the Acoustical Society of America, Vol. VI, No. 2, pp. 82-108, Oct., 1933. Curves of a similar nature, but based on earlier data, were published by B. A. Kingsbury, "A Direct Comparison of the Loudness of Pure Tones," Physical Review. Vol. XXIX, p. 588, 1927.

The Fletcher-Munson curves were based on a group of individuals whom later experience has shown to have somewhat better than average hearing. More recent tests, as reported by Dr. Fletcher, have indicated that for the average person the threshold of hearing is somewhere between 10 and 20 phons.

[2]American Tentative Standards for Sound-Level Meters for the Measurement of Noise and Other Sounds (A.S.A. Bulletin Z24.3 — 1936).

[3]The curves in Figure 1 represent measurements made on one ear at a time (monaural) with a plane wave — that is, a wave striking the ear at a single given angle. The irregularities above 1000 cycles are due in large part to diffraction effects caused by the shape of the head or the outer ear. The curves in Figure 2 have been modified to duplicate as nearly as practical the response of the ear to sounds arriving equally from all directions. The smoothing allows the curves to be more easily duplicated by simple electrical circuits and is justified by the fact that binaural hearing eliminates many of the irregularities present in the curves of Figure 1.

SUBSTITUTE BATTERIES FOR BATTERY-OPERATED EQUIPMENT

● **THE PRESENT DIFFICULTY** in obtaining new batteries above the requirements for current instrument production has necessitated a curtailment of our regular policy of maintaining a stock of replacements, and users should try to buy them locally.

The standard batteries recommended for General Radio instruments may not be available in some localities. Substitutions of different types or combinations of different types are quite permissible if certain precautions are observed. The substitutes must have the same voltage as the standard types and be capable of delivering as much current. When these are mounted externally the leads used must be at least as large as the connecting leads in the instruments. In some cases, shielding is necessary. The following table should be helpful if the standard batteries are not readily available.

SUBSTITUTE BATTERIES FOR BATTERY-OPERATED EQUIPMENT

Type		*Batteries*	*Possible Substitutes*
419-A	Wavemeter	1 No. 6 Dry Cell	Shortage unlikely.
544-B	Megohm Bridge	2 No. 6 Dry Cells 3 Burgess 5308	Shortage unlikely. 1 90-volt block and 1 45-volt block, mounted externally.
613-B	Beat-Frequency Oscillator	2 No. 6 Dry Cells 3 Burgess 5308	Shortage unlikely. Any 135-volt combination, mounted externally, if necessary.
625-A	Bridge	2 Burgess 2370	Any 4.5-volt combination; dry cells are satisfactory.
650-A	Impedance Bridge	4 No. 6 Dry Cells	Shortage unlikely.
723-A	Vacuum-Tube Fork	1 Burgess 4FA	1 No. 6 dry cell, mounted externally.
		2 Burgess Z30N	Any combination supplying 90 volts; leads must be short.
724-A	Wavemeter	1 Burgess 4FA	Not recommended; any change in dimensions or location will affect the calibration.
727-A	Vacuum-Tube Voltmeter	3 Burgess 2F (1.5-volt) 2 Burgess W20P1 (30 v) 1 Burgess W58P (7.5 v)	External batteries giving the same voltages can be used, but leads must be short.
729-A	Megohmmeter	1 Burgess 2F2H (3 v) 2 Burgess W30BP (22½, 45 v)	See Type 727-A.
759-A	Sound-Level Meter	2 Burgess 4FA (1.5 v) 2 Burgess Z30N (45 v) 1 Burgess F2BP (3 v)	If external batteries are used, battery box must be shielded and leads must be short. Battery box shield must be connected to instrument shield.
759-B	Sound-Level Meter	1 Burgess 6TA60	If external batteries are used, see Type 759-A, above. One user has reported that two small 45-volt batteries and one 1.5-volt unit, which will fit in the battery compartment, can be obtained at Sears-Roebuck retail stores.
760-A	Sound Analyzer	3 Burgess Z30N 4 Burgess F2BP	See Type 759-A.
761-A	Vibration Meter	1 Burgess 6TA60	See Type 759-B.
814-AM	Amplifier	2 No. 6 Dry Cells 3 Burgess 5308 1 Eveready 950	Shortage unlikely. Any 135-volt combination. Any 115-volt flashlight cell.
814-AR	Amplifier	2 Burgess 4FA 3 Burgess Z30N 1 Burgess 2370	Same as Type 814-A, above.

ADDRESS CHANGES AND ADDITIONS TO THE "EXPERIMENTER" MAILING LIST

● **WE HAVE RECEIVED** a number of complaints lately from *Experimenter* readers who have not received the last few issues of the *Experimenter*. We regret the delay in making address changes and in adding new names to our mailing list, but the cause is entirely beyond our control. Owing to the press of other war work, the company that cuts our mailing list stencils is unable to give us deliveries better than 60 days.

In some cases, *Experimenters* are delayed where no address change is involved. This is usually caused by a damaged stencil, which necessitates the cutting of a new one.

We can only ask your indulgence, and we will do our best to make the delay as short as possible. When your new stencil is received, back issues that you have missed will be mailed to you automatically.

A number of readers whose addresses are continually changing because of war conditions are now having the *Experimenter* sent to their homes to be forwarded. This is an excellent way to be sure of receiving all issues.

DISCONTINUED INSTRUMENTS

In order to conserve materials and facilities necessary for the production of more urgently needed equipment, the following items have been discontinued:

TYPE 449-A Adjustable Attenuator

TYPE 713-BR Beat-Frequency Oscillator (Relay Rack Model)

The TYPE 713-BM (Cabinet Model) is still in regular production.

THE General Radio EXPERIMENTER is mailed without charge each month to engineers, scientists, technicians, and others interested in communication-frequency measurement and control problems. When sending requests for subscriptions and address-change notices, please supply the following information: name, company name, company address, type of business company is engaged in, and title or position of individual.

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