THE General Radio EXPERIMENTER

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

GENERAL RADIO COMPANY WINS ARMY-NAVY "E"

Also IN THIS ISSUE

● **THE ARMY-NAVY "E" AWARD** for outstanding production of war materials was presented to the General Radio Company at exercises in Cambridge on February 16, 1943. The ceremony was attended by all employees of the Company, and by representatives of the Army and Navy, of local and state governments, and of local industry.

Speakers were introduced by Mayor John H. Corcoran of Cambridge. Governor Leverett Saltonstall of Massachusetts spoke briefly.

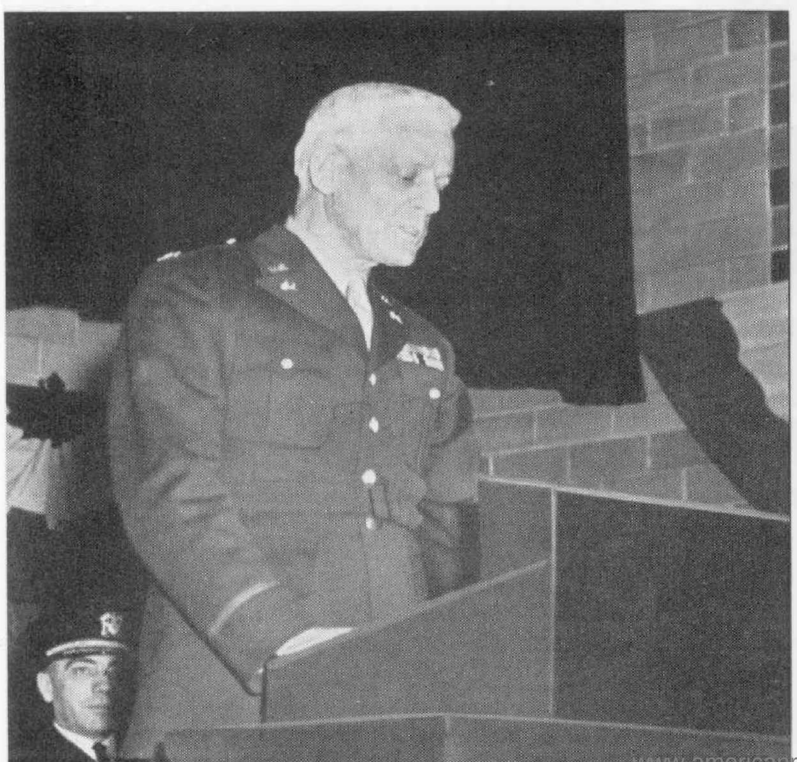
The "E" banner was presented to Melville Eastham, President of the General Radio Company, by Captain John J. Hyland, U.S.N. (Ret.), Inspector of Naval Material for the Boston district, and was accepted by Harold B. Richmond, Treasurer of the Company.

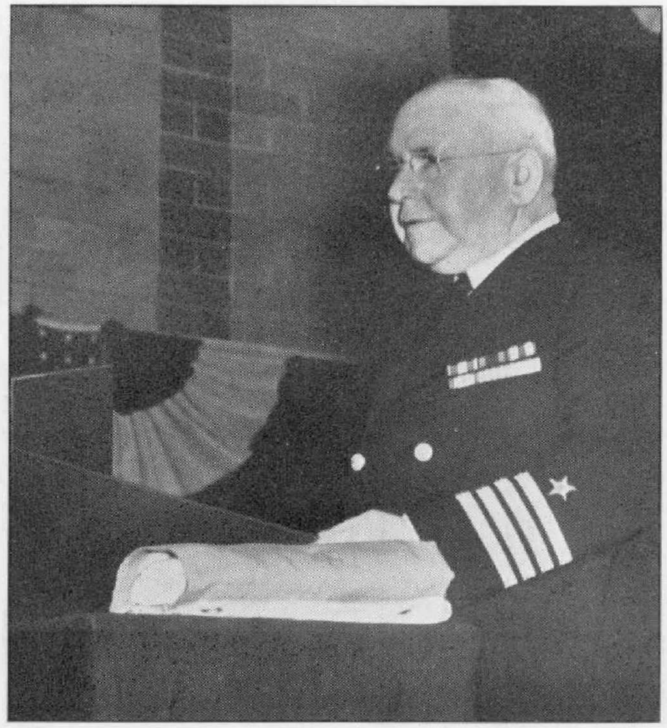
Colonel James H. Van Horn, U.S.A., Signal Officer for the First Service Command, presented "E" pins to a group headed by Charles H. Riemer, President of the General Radio Mutual Benefit Association.

Left to right: Mayor Corcoran, Captain Hyland, Governor Saltonstall, Mr. Riemer, Mr. Eastham, Colonel Van Horn

(*Right*) CAPTAIN HYLAND: "Without these instruments, vitally necessary in the calibration of all types of radio apparatus both at sea and on shore; without the instruments produced by your firm so necessary in the measurement of noises, of vibration on board ships and for many other uses, the efficiency of the fighting ships would be greatly reduced and the machinery, guns and fire control apparatus would not operate at the maximum efficiency for which they were designed."

(*Below*) COLONEL VAN HORN: "And let me point out that, without such equipment, effective joint action of the Army and Navy would be impracticable. This equipment is of utmost importance in establishing communications throughout our armed forces where tactical co-ordination is the essence of combat success."





(*Left*) MR. RICHMOND: "We have taken for our task the manufacture, and in many cases the design, of electronic equipment not generally available to our Government from other sources, and in many cases in quantities too small, and too difficult in technological design, to interest most manufacturing companies."

(*Above*) MR. RIEMER: "We are tremendously proud of the part our Company and apparatus are playing in this war. That pride, however, is tempered in the cooling waters of responsibility and obligation, for we conceive it an obligation to supply in quality and quantity — on time — sufficient instruments to shorten the war."

THE NOISE PRIMER

PART V — PRACTICAL APPLICATION OF THE SOUND-LEVEL METER

● **MANY DETAILS** of the operation of sound-level meters are ordinarily overlooked in both instruction books and theoretical discussions. This chapter is an attempt to answer some of the questions most frequently asked in correspondence and which have not already been mentioned in previous chapters.

Acoustic Conditions for Measurements

Part III described the procedure for correcting sound measurements for background noise level. In Part IV microphone placement was discussed. Another important factor that should not be overlooked is the acoustic condition of the room or space in which the measurements are made. Sound, like light, is reflected by some surfaces and absorbed by others. A porous, soft material or heavy fabric will absorb sound much as a black surface absorbs light. Similarly, a hard surface reflects sound as a white surface reflects light. A source of sound in a room may be likened to a source of light. The sound meter measures the sound pressure at any point just as a photoelectric exposure meter measures the light.

To complete the analogy, since sound-level meters have non-directional microphones, it should be assumed that the photoelectric cell of the exposure meter responds equally to light coming from all directions.

The reading of the exposure meter at any point in the room will depend not merely upon the intensity of the light source, but also upon the absorbing capacity of the walls. With completely flat, black walls the only light reaching the exposure meter will be direct from the lamp. With any other kind of walls the actual reading of the exposure meter will depend upon the reflection from the walls as well as the brightness of the lamp.

"Dead" Room Measurements

Exactly the same is true in sound measurements. Hence such measurements, so far as possible, are generally made under conditions of high acoustic absorption in order to avoid additional errors resulting from reflections. Reflections are entirely absent only when measurements are made outdoors at some distance from all buildings or other obstructions, or in a room, all interior surfaces of which are 100% absorbent. As a practical matter, such ideal locations are seldom available. For some types of measurements they are not absolutely necessary, and in others it is possible to minimize the effects of those reflections which cannot be avoided.

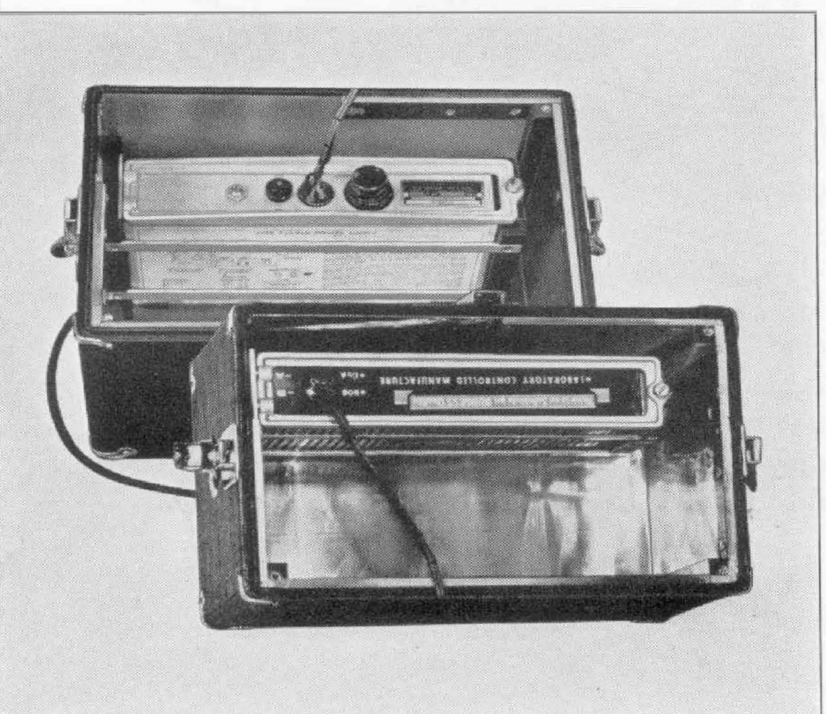
Radiation of Sound

Sound radiated from a small source varies in pressure inversely as the distance from the source. Hence, each time the distance between the sound meter and the sound source is doubled, the reading of the meter will decrease 6 db if no reflections are present. As a practical matter, the sound pressure around an average machine will pass through several minima and maxima as the sound meter is moved away, and then approach the inverse characteristic — that is, will decrease 6 db each time the distance is doubled, providing reflections are not present. This provides a convenient check on whether or not the surroundings are sufficiently non-reflective. Care should be taken in making this test that the background noise does not introduce serious error. This can be checked by turning off the machine under test and noting the reading of the sound meter on background noise alone. If the background noise is louder than 10 db below the machine noise, correction should be made for it.[11]

It is not always possible, particularly with large machines and small rooms, to obtain high absorption, or even to check absorption by the inverse law, as mentioned above. However, the effects of reflection can be minimized by making measurements fairly close to the machine, so that the ratio of direct sound to reflected sound is high. It is quite general, therefore, in checking large machinery to make an appreciable number of measurements at a relatively small distance and average them.

[11]See Figure 5 (February, 1943, *Experimenter*).

FIGURE 8. Both the TYPE 759-P50 Power Supply Unit and the Burgess type 6TA60 battery may be used interchangeably in the TYPE 759-B Sound-Level Meter, as shown here.



"Live" Room Measurements

In any room the average sound level will build up to an intensity such that the sound energy absorbed equals the sound energy radiated by the source. Hence in a "live" room — that is, one with high reflecting interior surfaces — the sound will build up to a very high level. This is obviously undesirable for ordinary measurements, but in certain applications it is a real advantage. If such a room has irregular or non-parallel wall surfaces, the level at any point is the result of multiple reflections of sound which originated from all sides of the machine under test. Hence the reading represents, in effect, an integration of the total sound radiated by the machine. The "live" room, therefore, may be very useful for *comparative* measurements, as when quieting a particular machine, since a single sound-meter reading taken at a distance from the machine may be used instead of the average of a large number of readings.

Production Testing

As a practical matter, in the production testing of equipment for noise level, it is seldom possible to obtain ideal acoustic conditions. Tests must generally be made under normal plant conditions of noise and acoustic reflection, and, as a matter of economy, must generally be limited to a few simple measurements.

If the machine under test is fairly noisy and the background noise level at least 10 db lower, it is usually satisfactory to make one or two measurements on each machine at points near the machine which experience has shown provide good indications of the general noise radiated by the machine. This means that, in general, the measurements will be made at the points of maximum noise around the machine and these measurements correlated with data taken on a few similar machines under more nearly ideal conditions.

A-C Power Supply

Where sound-measuring equipment is operating continuously, as in production testing, portability is not necessary, and batteries are undesirable because of the need for frequent replacement. Under these conditions use of a TYPE 759-P50 Power Supply Unit is recommended with either the TYPE 759-A or -B Sound-Level Meter.[12]

Vibration Pickup

When measuring fairly quiet devices, such as, for instance, electric clocks or speedometers, ordinary plant noise often makes acoustic measurements impractical unless special soundproof booths, etc., are constructed. In many such cases a vibration pickup may be used in place of the microphone. Sound measurements made under satisfactory acoustic conditions can be correlated with the vibration measurements on any particular type of machine and the vibration measurements then used in actual production testing under plant conditions. In this application the vibration pickup is merely used as a comparison device. Vibration pickups will be discussed in more detail in a later chapter.

Extension Cable

When the TYPE 759-A Sound-Level Meter was first announced in 1936, theorists suggested that the microphone mounting on the instrument would be a source of serious error. Previously, most sound-level meters had had the microphones on long cables. Theoretically, the presence of any object in the field around the microphone will distort the field somewhat and cause reflections which will affect the meter readings. As a practical matter, however, on the TYPE 759-A and -B Sound-Level Meters the placement of the microphone above the main body of the instrument is such that the reflection of sounds arriving in a horizontal direction is quite negligible, particularly in the ordinary frequency range of machinery noises. The meter should be used, of course, with the microphone end facing the sound source. The effect of reflections is further reduced in the TYPE 759-B Sound-Level Meter by the microphone design.

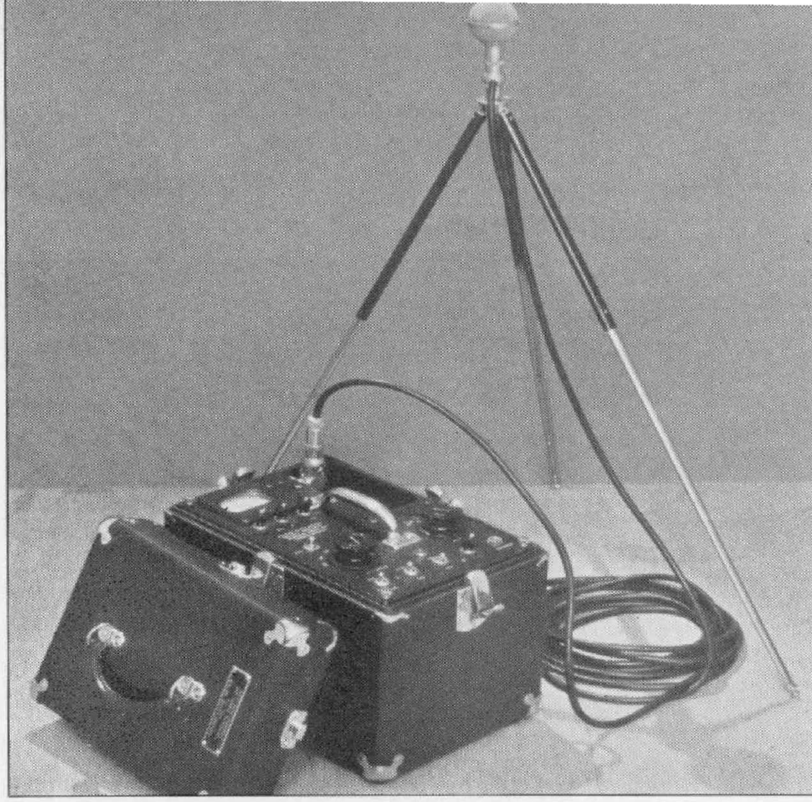


FIGURE 9. TYPE 759-B Sound-Level Meter used with microphone on a tripod.

The practicability of mounting the microphone directly on the sound-level meter is shown by the widespread adoption of this method of mounting by various other manufacturers.

An extension cable for the microphone is sometimes a convenience. For these applications special cables having good shielding and low losses have been developed. Since a crystal microphone is essentially a generator with a capacitive impedance, use of a long cable which is

[12]This power supply unit allows operation of the TYPE 759-B Sound-Level Meter over its entire range, or the TYPE 759-A Sound-Level Meter over the range down to 34 decibels. The power supply unit fits into the battery compartment of the sound-level meter. The power supply unit is completely described in the January, 1942, issue of the General Radio *Experimenter*.

in effect a capacitive load on the microphone results in a slight reduction in output. A cable correction is accordingly supplied, which should be added to sound-meter readings. The correction is not affected by frequency.[13]

Temperature and Humidity

Most sound measurements are made at normal room temperatures — that is, in the range from 60° to 80°F., but there are some instances where measurements must be made at abnormally high or low temperatures. Definite information regarding the temperature characteristics of microphones is generally lacking, since, as previously pointed out, the microphones were intended primarily for broadcast recording and similar uses, and variations which would be serious in noise measurements are of little importance in such work.

The microphone used on the Type 759-B Sound-Level Meter is of the piezo-electric type, utilizing a "bimorph" crystal, which is really two crystals cemented together in such a way that most of the temperature characteristics cancel out. Over the range from 24° to 115° Fahrenheit, cartridges of this type generate a substantially constant voltage at all frequencies up to 2000 cycles. Above this frequency there is some variation amounting to a maximum of ±0.5 db at 3000 cycles and ±1.5 db at 8000 cycles. These variations are well within the normal tolerances on microphones and are unimportant over the frequency range generally encountered in noise measurements.

The characteristic of a crystal microphone which changes most with temperature is its capacitance. The curve shown in Figure 10a shows the average capacitance of a microphone as used on the Type 759-B Sound-Level Meter as a function of temperature.

Cable Correction

So long as the microphone operates into a high impedance, this change in capacitance with temperature has little effect upon the output but, as the load on the microphone decreases in impedance, variations due to the internal capacitance of the microphone become more important. The Type 759-P21 Cable[14] is normally supplied with an attached celluloid tag, as shown in Figure 10b, giving proper corrections for different operating temperatures. This cable is 25 feet long and has a capacitance of 675 micromicrofarads. The correction for operating into other capacitances can be figured from the following formula:

$$\text{db} = 20 \log \left(1 + \frac{C_1}{C_2}\right) \qquad (3)$$

where C_1 is the capacitance of the cable and C_2 is the capacitance of the microphone at the particular temperature. For most practical purposes this can be read directly from Figure 10a. The correction does not change with frequency so long as any shunting resistance remains relatively high. The input resistance of the Type 759-B Sound-Level Meter is approximately 7 megohms.

The crystal units used in these microphones are coated with a moisture-proof compound, and consequently are unaffected by humidity. As with all Rochelle salt devices, the microphone should not be subjected to temperatures higher than 130° Fahrenheit, or permanent damage to the crystal may result.

Variable Sounds

The panel meter on standard sound-level meters such as the Type 759-B

[13] With the Type 759-B Sound-Level Meter and the Type 759-P21 Cable the correction at average temperatures is 2.5 db. With the Type 759-A Sound-Level Meter and the Type 759-P1 Cable the correction is 1.8 db.

[14] Owing to the shortage of critical materials, this cable is temporarily not available. The correction for any other cable can be computed from Equation (3).

(and TYPE 759-A) has definite ballistic characteristics, as specified by the American Standards Association. These standards presumably represent an attempt to obtain a reasonable compromise between the response of the ear to varying or transient sounds and what can be obtained in a practical indicating instrument. It is often desirable, however, to obtain a single reading representing an average sound level by means of a heavily damped meter, and for this reason the TYPE 759-B Sound-Level Meter (and some of the later TYPE 759-A's) is equipped with a slow-fast meter. This is controlled by a switch directly below the meter. The fast position gives the normal A.S.A. characteristic. The slow position provides a heavily damped meter response for averaging varying sounds. On steady sounds the meter will read the same on either position of the switch.

Why Use a Sound-Level Meter Anyway?

This and the preceding chapters have been mainly concerned with the actual practical side of sound-level measurements with no attempt to gloss over the difficulties or possible errors. An instrument can be used most intelligently only when its limitations as well as its advantages are known. It should be realized, however, that the limitations are inherent in the present state of the art and are not caused by cutting corners in the design of the instrument. The TYPE 759-B Sound-Level Meter, in particular, represents the best compromise among accuracy, convenience, ruggedness and portability which has been devised to date and its low price is an indication of clean-cut design and efficient manufacturing methods rather than of skimping.

Experts all agree that readings of a sound-level meter do not always check with a sound jury's estimate of loudness, for many reasons which seem insuperable by practical means in the present state of the art. This does not, however, mean that a sound-level meter is useless — quite the contrary. In fact, for many purposes the meter's characteristics are more useful than if they followed the ear exactly.

1. The meter gives a definite numerical reading which can be duplicated quickly, and which can be kept as a permanent record.

2. The meter can distinguish slight changes in level imperceptible to the ear. Several small changes, each one unimportant by itself, can add up to a very definite improvement.

3. The meter's readings are unaffected by the many human variables which enter into any sort of loudness estimates.

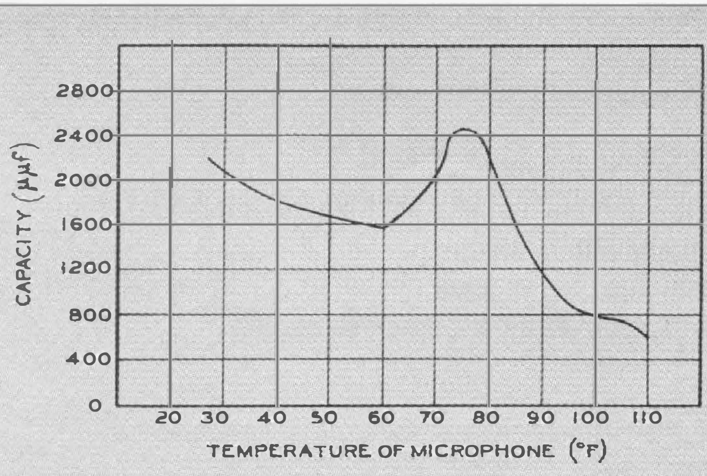


FIGURE 10 (a). Capacitance variation of microphone of TYPE 759-B Sound-Level Meter as a function of temperature.

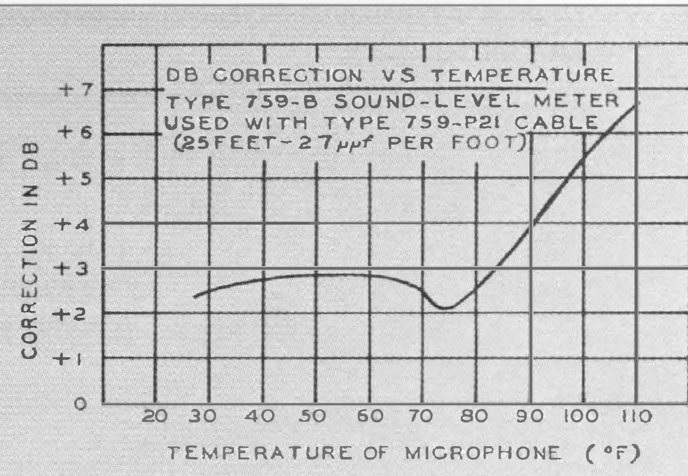
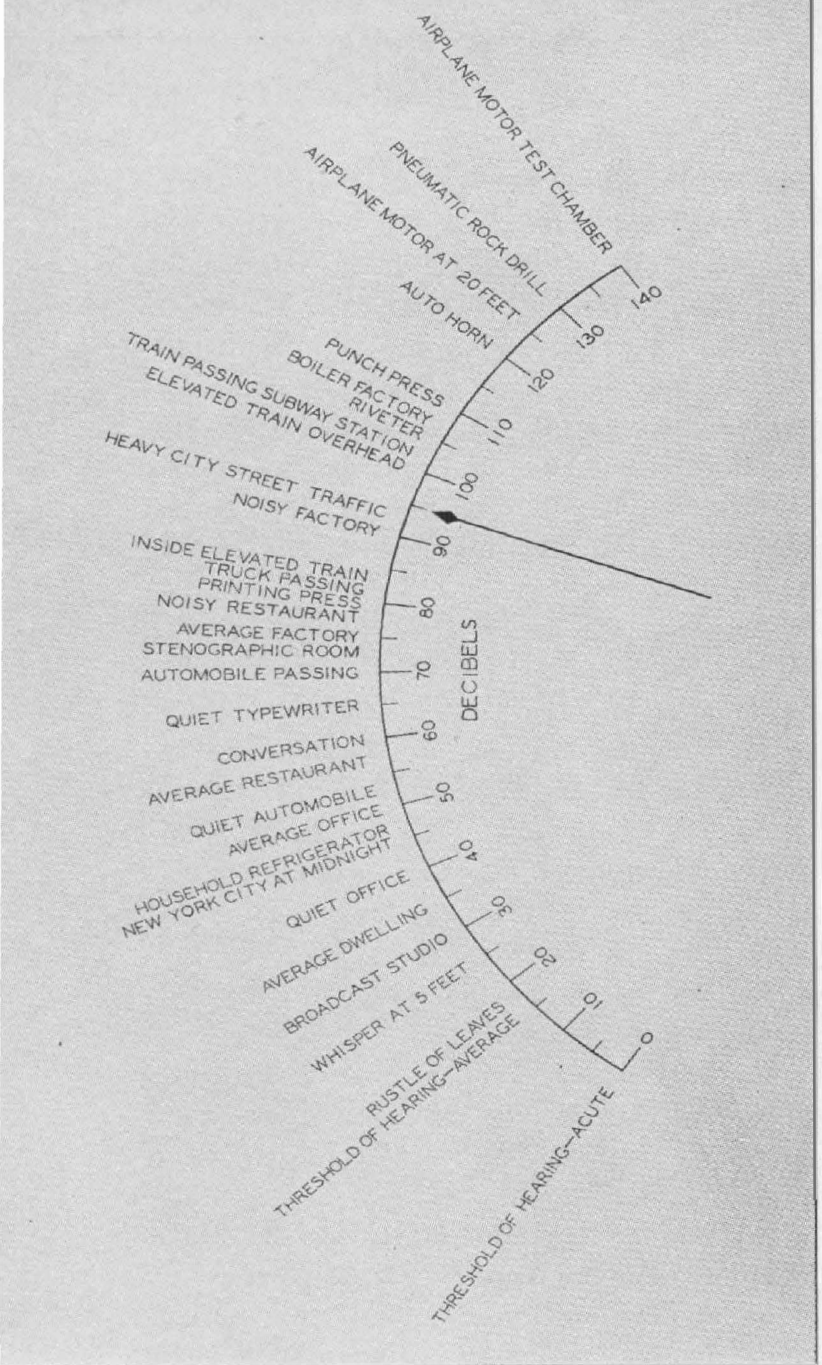


FIGURE 10 (b). Temperature correction for TYPE 759-B Sound-Level Meter when used with TYPE 759-P11 Cable.



4. The meter's frequency characteristic can be adjusted independently of the level.

5. The meter can, for purposes of physical analysis, etc., provide unweighted readings in terms of actual sound pressures.

6. The meter is unprejudiced by likes or dislikes for particular types of sounds.

These are by no means all the advantages of the sound-level meter, but they are most of the important ones. Only through actual use of the meter can an engineer become fully acquainted with its convenience, accuracy, and usefulness. To one who has used a sound-level meter, it is indispensable.

—H. H. Scott

(To be continued)

ERRATA

● **THE FOLLOWING ERRORS** have been noted in the February installment of *The Noise Primer.*

Page 2, 1st column, line 5: for 0.002, read 0.0002.

The caption for Figure 6 should read: "Relation between loudness and loudness level. . . ."

Figure 11. Scale of sound levels for typical noise sources.

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