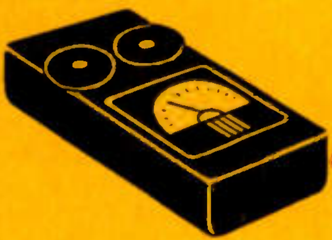
A PRIMER of NOISE MEASUREMENT



GENERAL RADIO COMPANY

INTRODUCTION

THE Primer of Noise Measurement is written for the many people who are anxious to know something about noise reduction but who lack either the time or the background necessary for a detailed, formal treatment of the subject. No textbook this; if you like your acoustics garnished with graphs, you're invited to step into the General Radio *Handbook of Noise Measurement*. But if your preferences allow nothing more mathematical than page numbers, this is for you.

Most of our story is about a small, battery-operated, sound-measuring instrument known as a Sound-Survey Meter. This easy-to-use tool will handle the more basic measurements quickly, simply, and accurately. For more exacting measurements, you'll need more advanced instrumentation, and perhaps even a noise specialist. But whatever your noise problem, the best way to start out is with a clear understanding of the principles involved. That way you'll avoid the expense of wrong guesses, and, if you do require the help of a professional, you'll at least speak his language.

WHAT IS SOUND?

THERE are two ways of looking at sound: It is, first, a rapid variation in atmospheric pressure[1]. That is sound in its objective sense. When the pressure variation reaches your ear, it produces a reaction. This reaction — your own interpretation of the variation in pressure — is what you normally think of as sound. Generally speaking, our methods of sound measurement consist of measuring the "rapid variation in atmospheric pressure," and then, by means of knowledge gained through experiment, interpreting these results in terms of human reaction.

If we ask ourselves what there is about sound that we might measure, two characteristics come to mind immediately: loudness and pitch. Neither loudness nor pitch can be measured directly by our instruments, however, because these terms refer only to the peculiar ways in which our hearing mechanisms respond to and interpret sound. Man-made instruments are less sophisticated, and measure, instead, sound pressure, which is closely related to loudness, and frequency, closely related to pitch. By sound pressure we mean the actual pressure exerted by the sound wave, and by frequency we mean the rapidity with which the pressure alternates, measured in cycles per second.

[1]Or water pressure, if you are a fish.

SOUND-PRESSURE LEVEL

IN sound measurements we use the term "sound-pressure *level*" rather than "sound pressure," because the actual pressures involved in sound waves cover such a tremendous range that it isn't convenient to express them as we might express barometric pressures, for instance. Instead, using a very small part of normal atmospheric pressure as a reference, we convert sound pressures into their ratios to this reference, which is usually 0.0002 microbar (abbreviated μbar). Then we arbitrarily squeeze the whole range of ratios so that the numbers from 0 to 135 represent the sound pressures of all the sounds we are ever likely to hear[2]. We call these sound-pressure levels, and use the decibel as the unit of measure. The decibel, as you can see from the above, isn't itself a quantity of pressure, but is based on a ratio of sound pressure to a specific reference level. The value mentioned above is usually used in sound measurement, and is often appended to a sound-pressure level statement thus:

80 db (re 0.0002 μbar).

[2]To do the squeezing we call upon an old high-school friend, the logarithm.

Using accepted methods of measurement, we would find that at a distance of 80 feet from the tail of a jet fighter, for instance, the sound-pressure level might be about 130 decibels (or "db"). The sound-pressure level of conversational speech at three feet is about 60 db. The "accepted methods" and the distance from the noise source are vital to a solid understanding of the decibel indication, and to say a certain noise is "70 db loud" with no further information makes about as much sense as saying that the tide was twice as high. Place and method of measurement are needed, as well as the basis of comparison (reference level), for complete understanding.

Decibels, because of their logarithmic heritage, do not behave normally when added together. Thus, when you add 70 db to 70 db you get 73 db and not 140 db. A doubling of the sound power results in a 3-db increase in sound-pressure level. Figure 1 shows how to add two sound-pressure levels within 14 db of each other. If one is more than 14 db greater than the other, you can forget about the weaker one.

THE SOUND-SURVEY METER

THE General Radio Type 1555-A Sound-Survey Meter is a compact, portable, battery-operated instrument for conducting sound surveys. It contains a microphone, amplifier, meter, and weighting networks. Sound is detected by the microphone, and amplified to a level the meter can handle. The weighting networks are ingenious contrivances used to tell something about the frequency of the noise, and their use will be covered later. All this weighs less than two pounds, and can be stuffed into your pocket (if you don't mind the bulge).

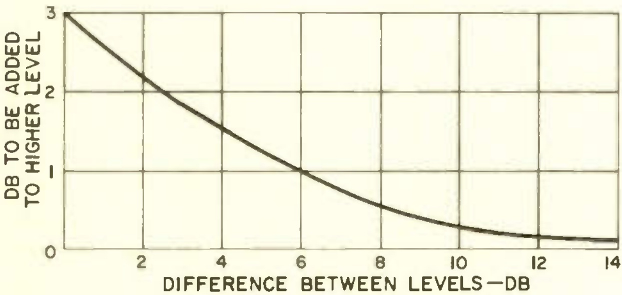


Figure 1. How to Add Decibels.

To operate the Sound-Survey Meter, just position it so that the end with the big hole in it (the microphone end) is pointing in a direction roughly perpendicular to the direction the noise is coming from, with your body out of the noise path. Be careful that when measuring one noise you don't point the microphone toward it or toward another noise source that might confuse the issue. Turn the FUNCTION switch to the A, B, or C position; turn the LEVEL control until the meter reads on scale, and read the sound-pressure level directly from the sum of LEVEL control and meter reading. For instance, if, with the LEVEL control at 70, the meter reads +3, the sound-pressure level is 73 db. Another way of doing it is to turn the LEVEL control until the meter indicates 0 and then to "read between the lines" on the LEVEL control. If, for instance, the meter indicates zero with the LEVEL control set about halfway between 70 and 80, the sound-pressure level is 75 db. (The db's here are understood to be "re 0.0002 μbar.") If the meter pointer bobs about, simply use the average reading. Be sure to record the weighting network (A, B, or C) used.

Don't forget that the db values you measure apply at one particular point of measurement. Usually, you measure noise at the place where the listener is stationed, but certain test codes for appliances, motors, and the like may dictate that the measurement be made at a specified distance from the noise source. At any rate, it's wise practice to make note of all the environmental conditions that could affect measurement, such as:

Nature and dimensions of floor, walls, and ceiling,

Description and location of nearby objects and personnel,

Location and types of any secondary noise sources,

Description of device under test,

Positions of observer and microphone,

Ambient temperature,

Weighting network used,

Date and time,

Name of observer,

Serial numbers of equipment, etc.

Only when you have the whole story before you can you make well-founded comparisons of sound-pressure levels.

MAINTENANCE OF THE

THERE are a few considerations concerning care of the Sound-Survey Meter that can affect accuracy of measurement. The batteries that power the meter must, of course, be in good condition. There are two batteries in the Sound-Survey Meter — a flashlight cell for filament power and a 30-volt battery for plate power. Before making any measurement, first turn the FUNCTION switch to PL and FIL to check the batteries. If the meter pointer deflects beyond the red line for both PL and FIL, the batteries are all right.

Just as every watch must be checked against a reliable time standard every so often to insure accuracy, so should the Sound-Survey Meter be calibrated from time to time. General Radio Company will be glad to calibrate your Sound-Survey Meter free of charge if you bring it to any of their offices. For the do-it-yourselfer, the most accurate method of calibration consists of placing a Type 1552-B Sound-Level Calibrator on top of the Sound-Survey Meter (what, you have no Calibrator?) and applying a 400-cycle, 2-volt signal[3] to the calibrator. With the FUNCTION switch at C and the LEVEL control at 100, the indicated sound-pressure

[3]You can get such a signal quite simply from the Type 1307-A Transistor Oscillator.

level should be 97 db. If the meter is more than 3 db off, the batteries and tubes should be checked, and replaced if necessary.

If the foregoing calibration procedure seems unnecessarily involved for your needs, you can use much simpler day-to-day methods of checking your Sound-Survey Meter. For instance, when you first receive your instrument, and know it's working properly, measure the sound-pressure level of some convenient noise that is not likely to change much from day to day. Many offices have reasonably uniform noise levels during the working part of the day. Or, hold the meter at arm's length and say, "I feel rather silly talking to a Sound-Survey Meter," noticing the noise level with the FUNCTION switch set at A or B. If you make this same check later, in the same location with the same background noise conditions, the answers should usually come out to within 2 or 3 db of each other.

The Sound-Survey Meter is subject to the limitations of its electrical parts. Its crystal microphone, for instance, will do just what any Rochelle salt crystal microphone will do if exposed to very high temperatures—expire. The maximum safe temperature is 115° F. Extremes of humidity and temperature should be avoided. (The Sound-Survey Meter does not operate under water.)

Finally, the limitations inherent in the simplicity of the Sound-Survey Meter must be recognized. A good basic tool it is; a means of conducting detailed noise analyses it is not. Just as a doctor might begin an examination by taking the temperature and pulse of a patient, the sound sleuth might start off by measuring sound-pressure level. Then, just as the doctor might call for an X-ray, the noise-measurer might call for the Sound-Level Meter (the Sound-Survey Meter's more educated brother, about which more later), or any of several other weapons from the General Radio sound-measuring arsenal.

The most important things to remember from what has been said so far are that sound-pressure level, measured in decibels, is related to loudness, and that frequency, measured in cycles per second, is related to pitch. The Sound-Survey Meter is essentially a device for measuring sound-pressure level, but, because it is equipped with weighting networks, it will also reveal something about the frequency of a noise.

ABOUT THESE WEIGHTING NETWORKS

IT is because our reasons for measuring noise usually involve people that we are more interested in the reaction to sound than in sound as a physical phenomenon. Sound-pressure level, for instance, can't be taken at face value as an indication of loudness, because the frequency of a sound has quite a bit to do with how loud it sounds. For this and other reasons it often helps us to know something about the frequency of the noise we're measuring.

Weighting networks — the Sound-Survey Meter's way of finding out about frequency — are called that because each is "weighted" in favor of certain frequencies, and discriminates against others. Very low frequencies are discriminated against quite severely by the A weighting network, moderately by the B network, and hardly at all by the C network. Thus if the measured sound level of a noise is considerably higher with B or C weighting than with A weighting, much of the noise is likely to be of low frequency. Hardly the most accurate method of frequency analysis, this, but a very useful approach to many noise problems.

Although certain weighting networks are recommended for specific types of measurements (for instance, the A network for speech-interference measurements), it is always a good idea to measure a noise on all three weighting networks and to record all data. The A weighting network happens to give a better indication of certain subjective effects than do the other networks, so we use it when we're interested in those aspects of a noise. The C weighting network, on the other hand, indicates plain sound-pressure level, without adding any gimmicks to qualify the response. The B network is neither as "honest" as the C network in indicating sound-pressure level nor as helpful as the A network in indicating speech interference, for example. All three weighting networks have reasons for being there, and it never hurts and often helps to measure noise with all three.

You can extend the range of measurement with the C weighting network by setting the FUNCTION switch to C +30. With the switch in this position, the indicated sound-pressure level is the sum of meter reading and LEVEL setting, plus 30.

The term "sound level" or "noise level" is often used to indicate a weighted sound-pressure level. Thus the Sound-Survey Meter is really a simplified Sound-Level Meter. The term "Sound-Level Meter" is reserved for another GR instrument, similar to the Sound-Survey Meter but with added refinements, in order to meet the requirements of American Standards Association Specification Z24.3 — 1943.

TECHNIQUES OF USE

THERE are, broadly speaking, three reasons why we measure noise: (1) to reduce interference with speech, (2) to eliminate potential hazards to hearing, and (3) to reduce noises that are objectionable simply because they annoy. There are other reasons, such as the enforcement of municipal noise codes, investigation of building sites by architects, trouble-shooting of machinery, etc., but these are basically related to the others, and the tactics of detecting and reducing speech interference, annoyance, and hearing damage include most of the techniques associated with the Sound-Survey Meter.

SPEECH INTERFERENCE

NOISE that interferes with speech is not only annoying, but can be downright menacing if it interferes with spoken or shouted warnings. Because the sounds that have about the same frequencies as speech are the worst offenders, the A weighting network gives the best indication of the speech interference or "masking" ability of a sound. Using the A weighting network and the curves of Figure 2, you can easily tell how much noise your conversation will tolerate. For instance, suppose you wanted to speak in a normal voice and be fully understood at 12 feet. The curve labeled NORMAL VOICE crosses the 12-foot vertical line at

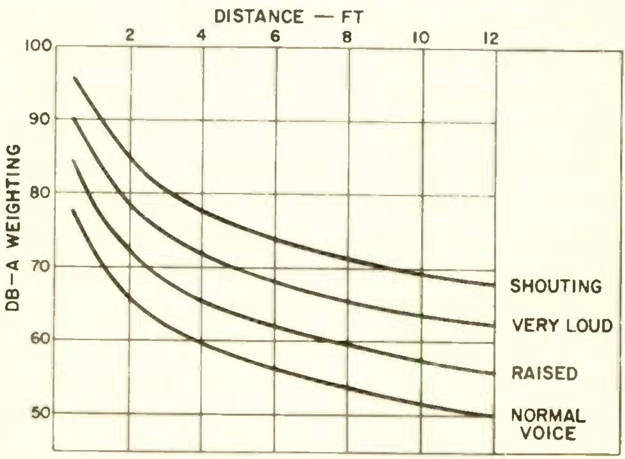


Figure 2. Speech Interference Levels.

50 on the horizontal scale. This means that a noise level of over 50 db on the A weighting network will probably interfere with your conversation. If you're willing to shout, you can tolerate 68 db (A weighting) and be heard at 12 feet. If the A-weighted noise level is over 90 db, you can see from the curves that, if you had to warn someone of danger, your shouts wouldn't have much of a chance even two feet away. All the data used here assume that the speaker faces the listener, that the spoken material is not familiar to the listener, and that there are no reflecting surfaces nearby.

Telephone conversation will be difficult if the sound level (A weighting) is above 70 db, and impossible at "A" levels above about 85 db. Maximum levels have been recommended for private offices (40 to 50 db), small conference rooms (less than 40 db), secretarial offices (60 to 65 db), drafting rooms (55 to 65 db), school rooms (less than 40 db), and many other locations. This means that if, for instance, you were going to install a conference room in a specific area, you could compare the noise level in that area with an accepted standard to find out how much noise reduction is necessary. All of the above levels are with A weighting, and are, of course, rough guides only.

ANNOYANCE

CERTAINLY any noise that interferes with speech is apt to be annoying. All annoying sounds, however, do not necessarily interfere with speech. And, while we can state approximate criteria for speech-interference surveys, the problem of annoyance is less easily pinned down. The sounds of a faucet dripping, a barely audible ping from the engine of a brand-new car, chalk squeaking on a blackboard — these are commonly annoying sounds that might show up as quite harmless on a Sound-Survey Meter. The Sound-Survey Meter is, after all, not a psychoacoustical instrument. But wait—isn't it true that the louder the drip, ping, or squeak becomes, the more annoying it is? There is, apparently, a connection between loudness (and therefore sound level) and annoyance. We exploit this fact by trying to reduce annoyance by reducing loudness by reducing sound level.

HEARING DAMAGE

THE hearing ability of a person usually decreases gradually after the age of 20. This normal decrease, called presbycusis, shows up as a loss of sensitivity, especially at higher frequencies. Other possible causes of hearing loss are disease, accident, and exposure to excessive noise.

Susceptibility to hearing damage from noise varies widely among individuals, and it is impossible to state categorically that "so many db causes hearing loss." Reaction also depends on the type of noise and on how long the person is exposed to it. A sound level of over 80 db on the B weighting network would justify further analysis of the noise. A B-network reading above 100 db should be regarded as probably unsafe for daily exposure over a period of months and would warrant noise-reduction measures or ear protection. For short-term exposures, say less than one hour, levels about 20 db higher than the above values are considered safe by many authorities.

OTHER USES

SOUND-SURVEY Meters have found wide acceptance by architects, engineers, and consultants in the planning of buildings, studios, schoolrooms, and other structures where proper acoustical design is important. Teachers find the Sound-Survey Meter useful in demonstrating principles of elementary physics, and singers and musicians have used the instrument to good advantage in evaluating projection.

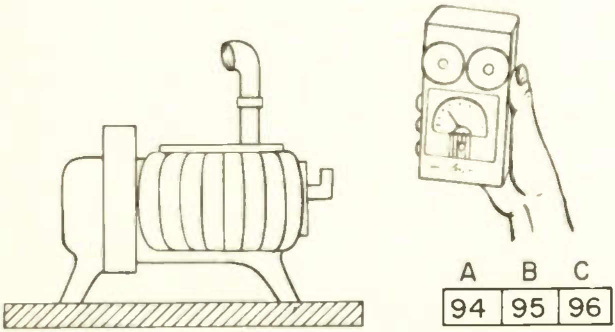
OTHER EQUIPMENT

FOR all its wondrous features, the Sound-Survey Meter is by no means the ultimate in sound-measuring equipment. Detailed analysis of noise is a job for the Sound-Level Meter, Octave-Band Analyzer, and perhaps Impact-Noise Analyzer. The Sound-Level Meter is the cornerstone of any noise-measuring array. Performing all the functions of a Sound-Survey Meter, it also includes a choice of fast or slow meter response, and offers its output to any of several types of analyzers, which cannot be used with the Sound-Survey Meter.

The most convenient and conventional way of analyzing the frequency distribution of noise is by means of an Octave-Band Analyzer. The General Radio Type 1550-A Octave-Band Analyzer allows you to "tune in" any of eight frequency bands to find out the sound level in that band. This type of analysis is especially desirable in the investigation of so-called broad-band sounds, such as hissing, swishing, or buzzing noises. To analyze a noise that has a characteristic pitch—such as the whine of a rotating machine — the narrow-band Type 760-B Sound Analyzer might be called in. Impact noises present special problems, and a special instrument — the Type 1556-A Impact-Noise Analyzer — is the proper way to handle them.

NOISE-REDUCTION METHODS

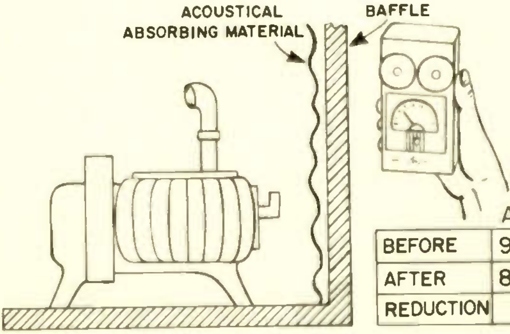
THE man, who, finding a noise level too high, concludes, "We'll just slap some acoustical tile here and there; that ought to take care of it," is apt to be surprised at the results. Not that acoustical tile isn't a good way to reduce noise — it often is. But this type of approach is like shoving some penicillin into a person at the first hint of sickness. The more prudent course is to conduct a thorough analysis of the noise, from this decide what to do about it, and check results by further analysis. This procedure insures that you're reducing noise at the frequencies you're most concerned with. Generally those frequencies are about the same as speech frequencies.



A noisy machine, with most of the sound energy at higher frequencies.

To reduce noise level you can either attack it at its source or change its path to the listener. It's usually a good idea to consider modification of the noise source first. Such modifications may take many forms, from the adding of extra lubricant to changing the entire process. Just remember that the important thing is to reduce vibration, and you can reduce vibration by reducing the energy that causes it, changing the coupling between this energy and the object that actually radiates the sound, or changing the radiating structure.

Changing the path of the noise may be as simple as moving the noise source and listener farther apart, or turning the noise source around. The acoustical environment can be changed by the addition of

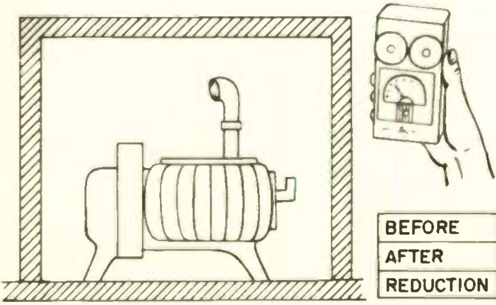


	A	B	C
BEFORE	94	95	96
AFTER	89	90	92
REDUCTION	5	5	4

The baffle and absorbing material provide a noticeable reduction, but the noise level is still high.

absorbing material, mainly useful near the source, in the room where the noise originates, and for those at some distance from the source. (Absorbing material is normally of little use to a listener who is three feet away from the noise source.)

Attenuating structures placed either at the listener (ear plugs, cotton, earmuffs) or along the route of the noise (walls, barriers, enclosures) show varying degrees of efficiency. Barriers are not as effective as total enclosures, but do help to shield high-frequency sound. A total enclosure around the noise source is one of the best methods of reducing noise level, but the enclosure must be complete and impervious for worthwhile results. An enclosure of acoustical tile alone, for instance, is not

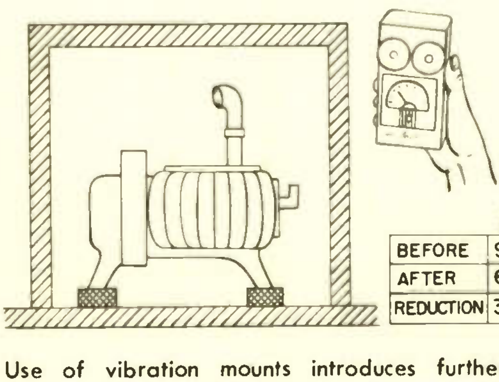


	A	B	C
BEFORE	94	95	96
AFTER	70	78	86
REDUCTION	24	17	10

The rigid sealed enclosure brings about a really worthwhile reduction at all frequencies.

usually effective, because the noise can leak through. Massive, leakproof walls, floor, and ceiling — perhaps with acoustical treatment on the inside of such an enclosure — constitute the best all-around protection against noise. Drawings on these pages show the effects of various treatments on the sound levels produced by a noisy machine of uncertain pedigree.

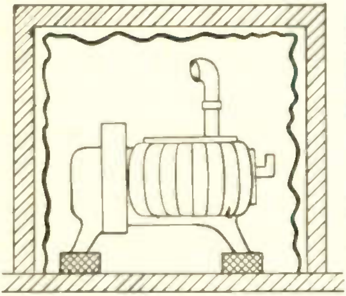
A thorough noise-reduction program often requires the use of a Sound-Level Meter and analyzer, but this in no way detracts from the usefulness of the Sound-Survey Meter. Even after the noise-reduction program is finished, the smaller instrument will prove an invaluable means of spotting changed noise conditions or new noise sources quickly and unobtrusively, before the effects become serious.

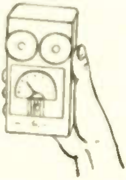


	A	B	C
BEFORE	94	95	96
AFTER	64	72	78
REDUCTION	30	23	18

Use of vibration mounts introduces further reduction, especially at lower frequencies.

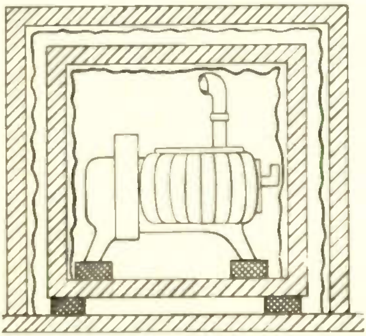
If your noise problem is a real dilly, your best course is to secure the service of an expert. Someone who has studied noise and who has a long background of experience can often recommend a more economical solution than will occur to the beginner. The more that you know about noise and how to handle noise problems, the better you will be able to use the services of an expert.

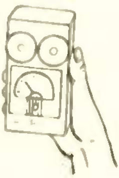




	A	B	C
BEFORE	94	95	96
AFTER	59	68	75
REDUCTION	35	27	21

Acoustical absorbing material used inside the enclosure brings the noise level way down.





	A	B	C
BEFORE	94	95	96
AFTER	46	57	66
REDUCTION	48	38	30

Double sealed enclosures, with vibration mounts and absorbing linings, changes former loud noise to a faint purr.

CONCLUSION

IN order to make this booklet as simple as possible, we have avoided many subjects that you might have found interesting, if not downright enchanting. This is the price of brevity, but to those who want to become impressively learned on the subject of noise measurement, we offer[4] the *Handbook of Noise Measurement*. This 176-page manual includes dozens of useful charts and tables, and comprises, in easy-reading form, an invaluable reference book for any noise-measurer. There are a number of other books and papers on this subject, and bibliography is included in the *Handbook*. For current information we recommend especially the periodical *Noise Control*, published by the Acoustical Society of America.

You can obtain more literature on noise measurement, as well as advice on instrumentation, at any of the General Radio Offices listed on the back cover of this booklet. Or write to us at West Concord, Mass., and we'll try to help you out.

[4]For $1.00, that is.

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