

NOISE MEASUREMENT AND ACCEPTABILITY CRITERIA

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INSTRUMENTS FOR SOUND MEASUREMENT

There is probably a greater variety of instruments for measuring noise than for any other environmental factor of concern to industrial hygienists. Almost every measurement need can be satisfied with instrumentation available commercially today. Only those instruments more useful to the industrial hygienist will be discussed here.

Sound Level Meters

The standard sound level meter is the basic measuring instrument for the industrial hygienist.



General Radio Co., Concord, Massachusetts.

Figure 25-1. A Standard Sound Level Meter.

It consists of a microphone, an amplifier with calibrated volume control and an indicating meter. It measures the root-mean-square (rms) sound pressure level in decibels which is proportional to intensity or sound energy flow.

Sound level meters of the same type differ mainly in external shape, arrangement of controls, and other convenience features that frequently influence the selection made by a prospective user. A typical sound level meter is pictured in Figure 25-1.

Standards for sound level meters^{1, 2, 3} specify performance characteristics in order that all conforming instruments will yield consistent readings under identical circumstances. The more important characteristics specified are frequency response, signal averaging and tolerances.

TABLE 25-1

Relative Response of Sound Level Meter Weighting Networks

Frequency Hertz	Weighted Response, dB		
	A	B	C
31.5	-39	-17	-3
63	-26	-9	-1
125	-16	-4	0
250	-9	-1	0
500	-3	0	0
1000	0	0	0
2000	1	0	0
4000	1	-1	-1
8000	-1	-3	-3

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Three weighting networks are provided on standard sound level meters in an attempt to duplicate the response of the human ear to various sounds. These weighting networks cause the sensitivity of the meter to vary with frequency and intensity of sound like the sensitivity of the human ear.

The relative responses of the three networks are shown in Table 25-1 where the A, B and C weightings mimic ear response to low, medium and high intensity sounds respectively. Entries in the

table show relative readings of the meter for constant sound pressure level of variable frequency. These A, B and C meter response curves correspond to the 40, 70 and 100 phon equal loudness contours. The D-weighting network is provided on some sound level meters for approximating the "perceived noise level" used in appraising the offensiveness of aircraft noises.

The A-weighting network is the most useful one on the sound level meter. It indicates the A-weighted sound level, often abbreviated dBA, from which most human responses can be predicted quite adequately.⁴

Action of the indicating meter may be selected as "fast" or "slow." Relatively steady sounds are easily measured using the "fast" response. Unsteady sounds can be averaged with the more sluggish "slow" response to reduce meter needle swings.

The speed of meter response affects the readings obtained for transient sounds. For example,

the level of a whistle toot lasting 1/5 second would be indicated no more than 2dB low on the "fast" scale. On the "slow" scale, the level of a toot lasting 1/2 second would read 3 to 5 dB low.

American standard sound level meters are furnished in three types offering varying degrees of precision.¹ Designated Types 1, 2 and 3 in order of increasing tolerances, the Type 2 generally measures within 2 or 3 dB of true levels which is satisfactory for most purposes. Errors are about half as large with the Type 1 or "precision" sound level meter and about twice as large with the Type 3 "survey" instrument. These errors can be reduced somewhat by careful calibration.

Calibrators

The overall accuracy of sound measuring equipment may be checked by using an acoustical calibrator such as is shown in Figure 25-2. It consists of a small, stable sound source that fits over the microphone and generates a predetermined sound level within a fraction of a decibel. If the meter reading is found to vary from the known calibration level, the meter may be adjusted to eliminate this error. The acoustical calibration procedure supplements the electrical calibration incorporated in some meters to check the gain of all electronic components following the microphone. Sound level calibrators should be used only with the microphones for which they are intended in order to avoid errors and microphone damage.

Impulse Meters

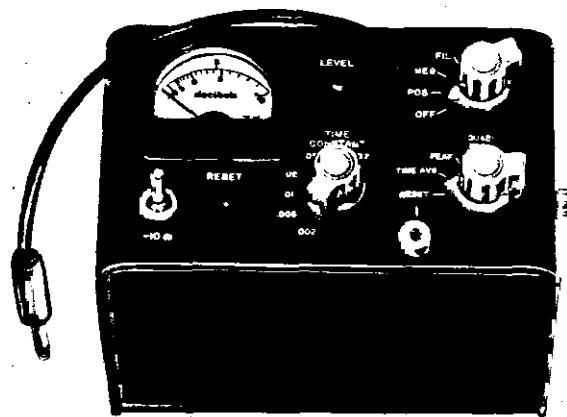
The sound level meter is too sluggish to indicate peak levels of transient noises lasting a fraction of a second such as those produced by hammer blows or punch press strokes. Such noises must be measured with a special meter that indicates the peak level.

Accessory impulse meters are available for connection to sound level meters and can be calibrated to indicate the peak level of the sound at the microphone. One of these is shown in Figure 25-3. In taking such readings, it is necessary to



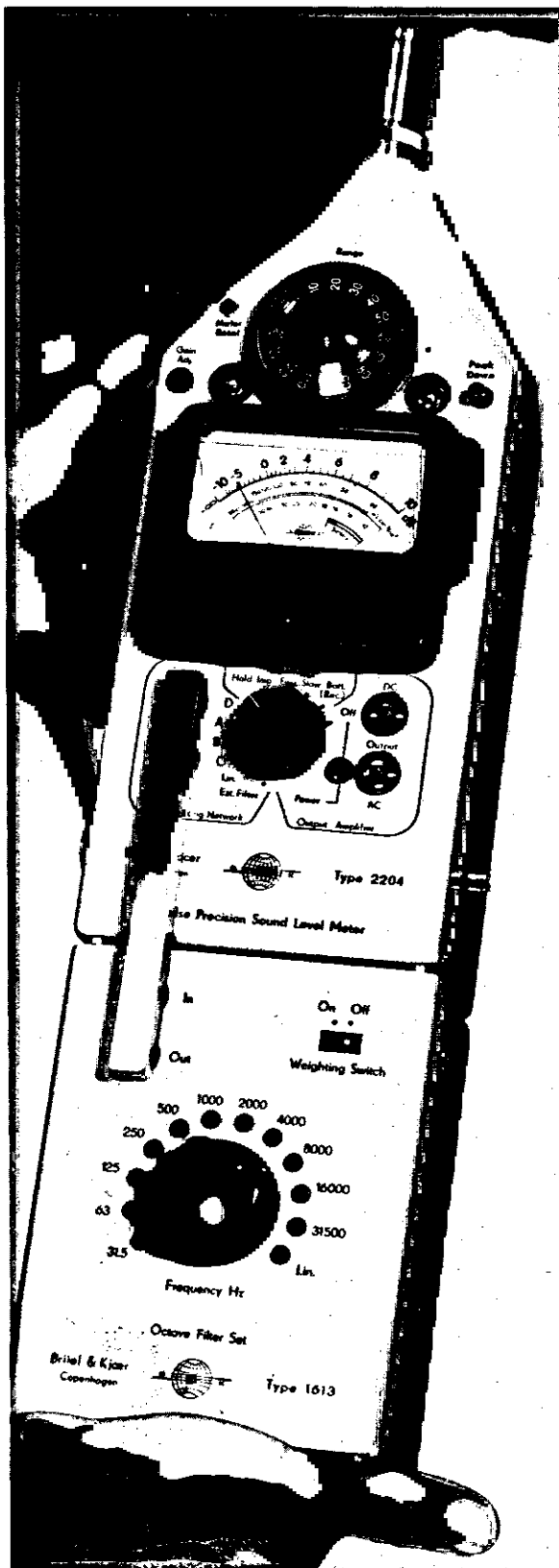
General Radio Co., Concord, Massachusetts.

Figure 25-2. A Sound Level Calibrator.



General Radio Co., Concord, Massachusetts.

Figure 25-3. A Noise Peak Meter for Connection to a Sound Level Meter.



B&K Instruments, Inc., Cleveland, Ohio.
Figure 25-4. A Precision Sound Level Meter with an Octave Band Filter Attached to the Base.

be sure that the upper sound pressure limit of the microphone is not exceeded as the indicated level will then be too low. The upper limit of the sound level meter can be extended by replacing the standard microphone with a less sensitive one that is linear to higher levels. Such microphone substitutions affect the calibration of the sound level meter and must be taken into account when interpreting readings.

The sound level meter in Figure 25-4 is equipped with a circuit for measuring impulse noise according to a German standard. It has a rather slow rise time in order that the indication of impulsive sound will correlate with the loudness perceived by the ear. For impulses that rise abruptly, the reading with this circuit is lower than would be found with a true peak meter. However, the instrument shown has been provided also with an instantaneous peak reading circuit that will indicate the true peak.

Frequency Analyzers

It is often necessary to know the frequency distribution of the sound energy. It is important in noise abatement, for example, since the reduction afforded by control devices varies with frequency. Such information is provided by one of the several types of sound spectrum analyzers available. They may be connected to the sound level meter or other sound sensing system. The electrical signal from the microphone is filtered by the analyzer circuitry so that only signals within a limited frequency range are transmitted to the indicating meter. Measurement of sound pressure level in contiguous frequency ranges provides data for a plot of sound pressure level versus frequency.

Octave band analyzers are the types most commonly encountered. An octave band filter set is shown attached to the lower end of a sound level meter in Figure 25-4. The frequency range of each band is such that the upper band limit is twice the lower band limit. Formerly, octave bands were described by these cut-off frequency limits such as 300 to 600, 600 to 1200, etc. Currently they are designated by the geometric mean of the cut-off frequencies which are called center frequencies. Thus, when the 1000 Hz band is mentioned, it is understood that it extends from 710 to 1420 Hz. The center and cut-off frequencies of octave band filters in common use are shown in Table 25-2.

Often bands narrower than octaves are required for pinpointing the frequency of a tone. In such applications, the one-third and one-tenth octave analyzers are quite valuable. Some of these can be coupled to a graphic level recorder which tunes the analyzer through the frequency range and simultaneously plots its output on a moving paper chart. This equipment is very useful in determining sources of noise in machinery since sound of a particular frequency must be generated by mechanical events such as the meshing of gear teeth, passing of fan blades, etc. which are repeated at the same rate.

Accessory Equipment

As most sound is generated by vibration of some body, it is sometimes desirable to study the

TABLE 25-2.

Center Frequencies and Limits of Octave Bands.

Traditional bands, Hz			Preferred bands, Hz		
Lower limit	Center freq.	Upper limit	Lower limit	Center freq.	Upper limit
19	27	38	22	31.5	44
38	53	75	44	63	88
75	106	150	88	125	177
150	212	300	177	250	355
300	425	600	355	500	710
600	850	1,200	710	1,000	1,420
1,200	1,700	2,400	1,420	2,000	2,840
2,400	3,400	4,800	2,840	4,000	5,680
4,800	6,800	9,600	5,680	8,000	11,360

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vibration as well as the sound. Accessory vibration pickups are available for most sound level meters to make such vibration analysis possible. They are generally accelerometers for which the electrical output is proportional to the acceleration of the surface to which they are attached. Types sensitive to the velocity or displacement of the surface are also available. Complete vibration meters are supplied too, for greater convenience.

The vibration signal may be examined for frequency content using any of the sound analyzers discussed earlier. In this way, vibration at a particular frequency may be correlated with the sound of the same frequency it produces. Calibrators are available for checking the sensitivity of the vibration pickup to reduce errors in measuring the acceleration of a surface.

The cathode ray oscilloscope is useful for observing the wave-form of a sound. It plots the sound pressure versus time on a television-type screen. From observation of the wave shape, it is sometimes possible to determine the mechanical process responsible for the noise. It is also possible to observe the peak pressures of impulsive sounds. Cameras are available for photographing the face of the cathode ray tube to obtain a permanent record of the wave form.

A graphic record of sound level may be obtained by connecting a sound level meter to a graphic level recorder which plots the sound level on a moving paper chart. The pen speed of the recorder must be capable of following the fluctuations in sound level if an accurate record is to be obtained.

The magnetic tape recorder can be used to store a sound for later analysis on replay. An instrument of broadcast quality must be used to obtain high fidelity reproduction of the sound on playback. For analysis on replay, the recorder output should be connected to the analyzer input by means of a patch cord. Too much distortion will

occur if the recording is played back through a loud-speaker and picked up with a microphone. If only the frequency content is of interest, then no precautions need be taken to keep track of level during recording and playback. However, if it is necessary to determine the true levels of the original noise on playback, careful recording of calibration tones must be undertaken. Generally, it is better to measure sound directly in the field if possible.

Sound Monitors

When sound level varies erratically over a wide range, it is difficult to describe the noise by meter readings. Therefore, statistical analyzers have been developed to assist in this process. They indicate the percentage of time that the sound level lies in certain predetermined level ranges. From these data, the mean level, standard deviation as well as other statistical indices may be calculated.

Another type of monitor evaluates noise exposures according to the rules established by the American Conference of Governmental Industrial Hygienists (ACGIH),⁵ which will be described in a section that follows. These instruments may be exposed to varying noise for a work day and will indicate whether this exposure limit has been exceeded. One of the battery-powered, wearable types is shown in Figure 25-5.

A different type of noise hazard meter recently developed integrates the effects of noise like the ear does.⁶ When exposed to non-impulsive noise of any duration, it indicates the amount of temporary shift in hearing threshold that a group of normal ears would experience in the same expo-



duPont de Nemours & Co., Wilmington, Delaware.

Figure 25-5. A Battery-Powered Noise Monitor That Can Be Worn by a Workman.

sure. Its reading is interpreted according to the theory that noise exposures producing little temporary hearing loss are not likely to produce much permanent hearing loss even after many repetitions.

ACCEPTABILITY CRITERIA

Criteria for the acceptability of noise are dictated by the effects which are to be avoided. The most important of these is hearing damage resulting from prolonged exposure to excessive noise. Another undesirable effect is speech interference or interruption of communications by noise. Annoyance is a third undesirable effect of noise more difficult to assess. There are also certain non-auditory effects of noise we are just beginning to recognize, which are discussed later in this chapter.

Hearing Damage

The damaging effect of noise on hearing depends on (1) the level and spectrum of the noise, (2) duration of exposure, (3) how many times it occurs per day, (4) over how many years daily exposure is repeated, (5) the effects on hearing regarded as damage and (6) individual susceptibility to this type of injury. All of these factors must be considered in establishing limits of acceptable exposures to dangerous noise.

Noise Evaluation. Early in the study of the effects of noise on hearing, it was learned that noise frequency as well as intensity influenced the effect produced. High frequency noise was found to be more damaging than low frequency noise of the same sound pressure level. Therefore, noise spectra were evaluated with standard octave band analyzers which were the only portable spectrum analyzers then available.

As knowledge of noise effects grew, some investigators began to feel that octave band analysis was a needlessly complicated evaluation of noise which could be replaced with the A-weighted sound level measured using a standard sound level meter. It seemed that the A-weighting network made the meter less sensitive to low frequency sounds to about the same extent that the ear is less susceptible to injury by these low frequency sounds.

In these studies, the damage to be avoided was impairment of ability to understand "everyday speech" as defined by the medical profession.⁷ This medico-legal definition allows some observable change in hearing thresholds not sufficient to affect ability to understand everyday speech significantly.

Steady Noise. All day exposure to steady noise has been investigated to determine the level at which hearing damage begins after many years of redundant exposure. Such studies are the basis for the curves in Figure 25-6 which indicate the risk of hearing impairment associated with exposure to a steady noise level at work.⁸ Each curve indicates on the vertical scale the percentage of workers that showed impaired hearing as defined by the medical profession after working continuously in the noise levels shown on the horizontal scale.

To interpret the Figure, note that the upper

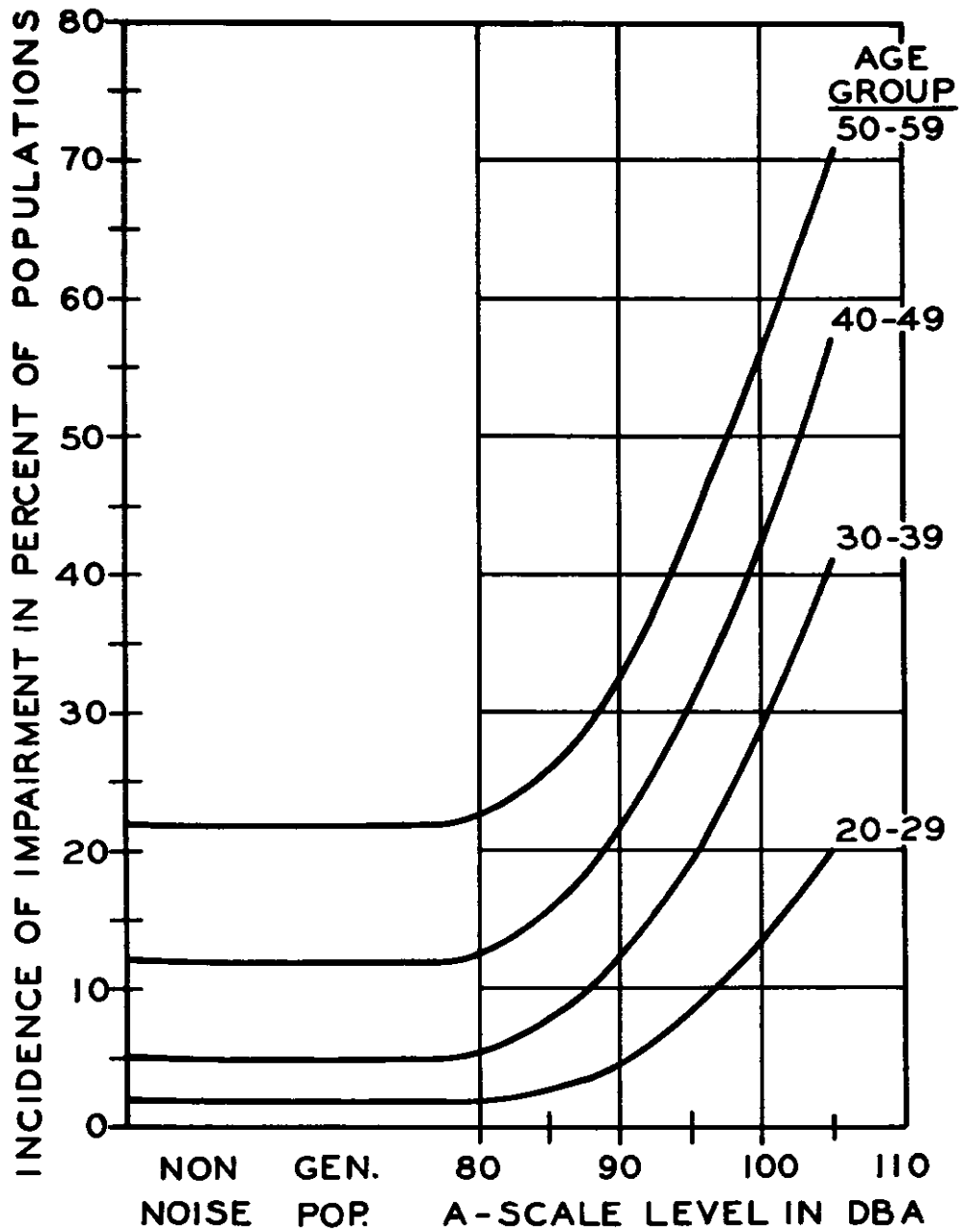
curve shows that in a group of 100 men aged 50 to 59 years, which has been exposed to 90 dBA at work for 33 years, 33 men should show evidence of impaired hearing. However, note that the lower flat portion of the same curve indicates that the general population and others not exposed to dangerous noise at work exhibit 22 cases of impaired hearing out of every hundred. Therefore, near-lifetime exposure to 90 dBA at work seems to produce about 11 more cases of impaired hearing per hundred surviving than would otherwise have occurred. As the data generating the curves of Figure 25-6 are not so consistent as the precise lines would indicate, this difference of 11 percentage points is about the smallest that can be considered significant. For lower age groups exposed for shorter periods, the increase in prevalence of impaired hearing is much less pronounced. The curves of Figure 25-6 suggest 90 dBA as one limit for steady exposure to continuous noise, a limit that has become rather widely accepted. Future standards may lower this limit.

Intermittent Noise. Most occupational noises are intermittent rather than continuous. Interrupting harmful noise allows the ear to rest and recover which reduces the likelihood of permanent damage.⁹ Such intermittent exposures have not been studied much because of the great complexities of exposure description. As a result, theories are relied upon to set limits for intermittent noise.

The theory most generally accepted postulates that the hazard of noise exposure increases in proportion to the average temporary hearing loss which the exposure would produce in a group of normal ears. This theory arises out of the observation that those noise exposures that ultimately produce permanent hearing loss also produce temporary hearing loss in normal ears. Conversely, those noise exposures that do not produce permanent hearing loss do not produce temporary hearing loss in normal ears. While the true relation between temporary and permanent hearing loss has not been established, it is logical to assume that those noise exposures that do not cause much temporary loss will not cause much permanent loss either. Any temporary threshold shift (TTS) that disappears before the next exposure to noise commences is considered acceptable.

On the basis of this assumption, results of TTS studies have been used to define safe limits for all day exposures to steady noise. These limits agree with those established by permanent threshold shift studies.

TTS studies have also indicated that intermittent noise is much less harmful than steady noise. The laws describing growth of TTS during exposure and recovery afterwards have been used to calculate exposures producing acceptably small amounts of TTS.¹⁰ Combinations of sound level, duration of exposure and degree of repetition that are considered acceptable for personnel exposures at work are shown in Table 25-3.¹¹ This method for appraising noise exposures was derived from the report describing hazardous exposure to intermittent and steady-state noise prepared by the National Academy of Science-National Research



Guidelines for noise exposure control. Sound and Vibration 4:21, 1970.

Figure 25-6. Prevalence of Impaired Hearing and Sound Levels at Work.

Council, Committee on Hearing, Bio-acoustics and Bio-mechanics, generally referred to as CHABA.¹² Maintaining exposures within the limits CHABA recommended will allow few additional cases of impaired hearing to occur.¹³

TABLE 25-3.

Maximum Permissible Sound Levels for Intermittent Noise When Occurrences Are Evenly Spaced Throughout the Day.

Total noise duration per day (8 hours)	Number of times noise occurs per day						
	1	3	7	15	35	75	160 up
8 h.	89	89	89	89	89	89	89
6	90	92	95	97	97	94	93
4	91	94	98	101	103	101	99
2	93	98	102	105	108	113	117
1	96	102	106	109	114	125	125
30 m.	100	105	109	114	125	(1½ h)	
15	104	109	115	124			
8	108	114	125	A-weighted			
4	113	125	sound levels,				
2	123	dBA					

Reproduced with permission from "Sound and Vibration" Bay Village, Ohio (4:16, 1970).

To use Table 25-3, select the column headed by the number of times the noise occurs per day, read down to the average sound level of the noise and locate directly to the left in the first column the total duration of the noise permitted for any 24 hour period. It is presumed that the noise bursts are evenly spaced throughout the work day so that an opportunity for rest and recovery between noise bursts exists. It is permissible to interpolate in the Table if necessary.

Table 25-3 shows that intermittency is as important as duration and level. For example, it shows that a continuous noise level of 91 dBA can be tolerated for 4 hours; 101 dBA can be tolerated also for 4 hours if it is presented in 15 evenly spaced bursts lasting 16 minutes each. Thus, the interruption of the higher noise reduces the effect on hearing to that which would be produced by a steady noise of equal duration 10 decibels lower. So you might say that the interruptions are equivalent to a 10 decibel noise reduction.

Impulsive Noise. Exposure limits for impulse noise are based on studies of the average TTS caused in normal ears by exposure to various impulses. Limits that will cause little TTS and, therefore, little expected permanent damage have been set.¹⁴ These limits are complicated to apply and, as a result, have not been widely used.

However, an approximate method of determining whether these limits are likely to be exceeded can be carried out with the sound level meter using

the C-weighting and "fast" meter response. To do so, set controls so that zero on the meter scale corresponds to a level of 130 dB. If the impulse does not cause the meter needle to jump above 125 dB (minus 5 on the meter scale), then it probably is not excessive.¹⁵

ACGIH TLV for Noise. The noise exposure limits expressed in Table 25-3 are inconvenient to use in practice. So, a simplification of the table was adopted in 1970 by the ACGIH as a threshold limit value (TLV) for noise.⁵ It is shown in Table 25-4. The simplification embodies the presumption that practically all noise exposures are interrupted at least a few times a day by meals or rest periods, machinery stoppages, etc. The limits of Table 25-4 correspond very closely to those of Table 25-3 for noises that occur three to seven times per day. Since these exposure limits do not take proper account of intermittency, they do not provide a true evaluation of hearing damage potential of the noise exposure. They are too liberal for absolutely continuous noise and too conservative for noise that is interrupted very frequently.

If an exposure consists of two or more noise levels, the combined effect must be considered. To do so, it is necessary to compute the ratio of the duration of each level to the duration allowed by Table 25-4. The sum of these ratios for all noise levels involved in the exposure must not exceed unity if the exposure is to be acceptable. Noise levels below 90 dBA are not considered in these calculations. The graph in Figure 25-7 is convenient for calculation of exposures involving several levels.

For impulsive sounds, ACGIH proposed a limit of 140 dB peak which is quite conservative compared to the recommendations of Coles et al.¹⁴

TABLE 25-4

Threshold Limit Values for Non-impulsive Noise Adopted by the American Conference of Governmental Industrial Hygienists

Duration per day, hours	Permissible sound level, dBA
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
¾	107
½	110
¼	115 max.

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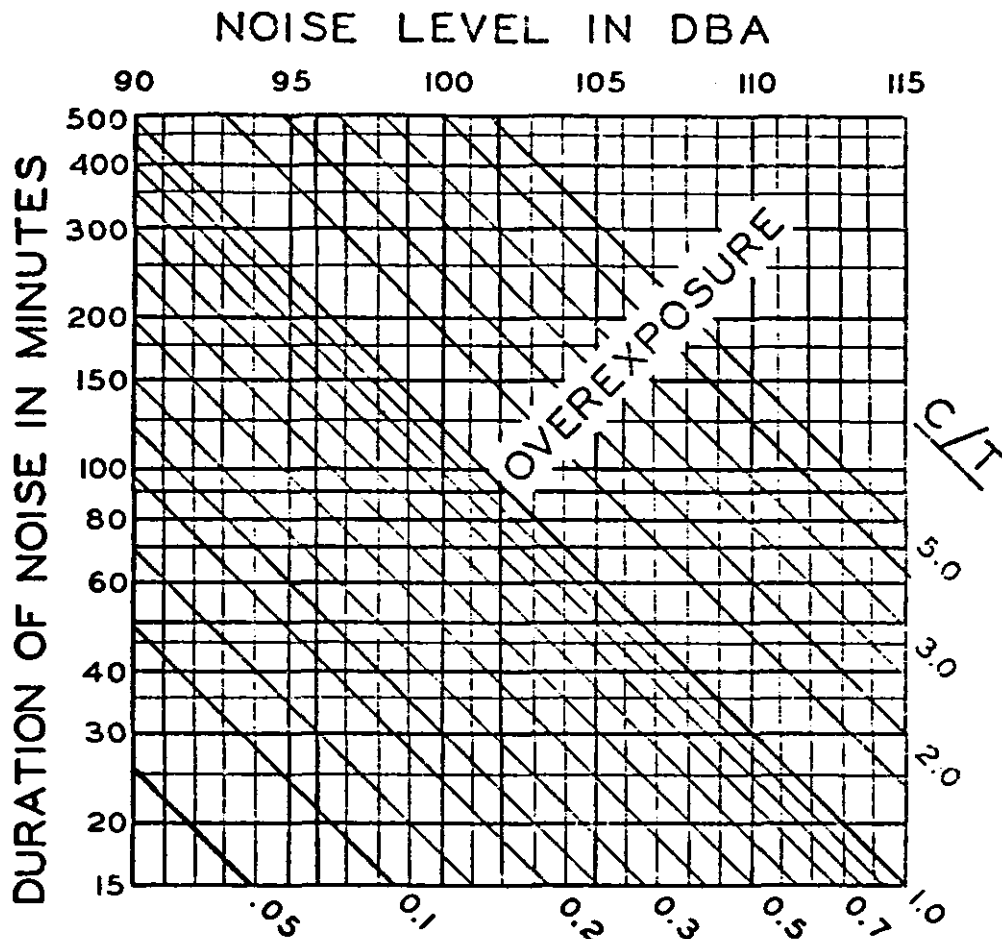


Figure 25-7. Graphical Presentation of ACGIH TLV for Noise. To use the graph, locate the point corresponding to the noise level and duration; then read off the exposure ratio C/T from the diagonal lines interpolating if necessary.

The ACGIH TLV for noise was accepted by the U.S. Department of Labor for promulgation under the provisions of the Occupational Safety and Health Act of 1970. It is being adopted also by many states for enforcement as part of their occupational health regulations.

Non-occupational Exposures. All that has been said up to now about hearing damage applies to the noise exposures at work. Medical evaluation of hearing handicap from occupational noise exposure disregards changes in hearing that do not affect ability to understand everyday speech significantly.

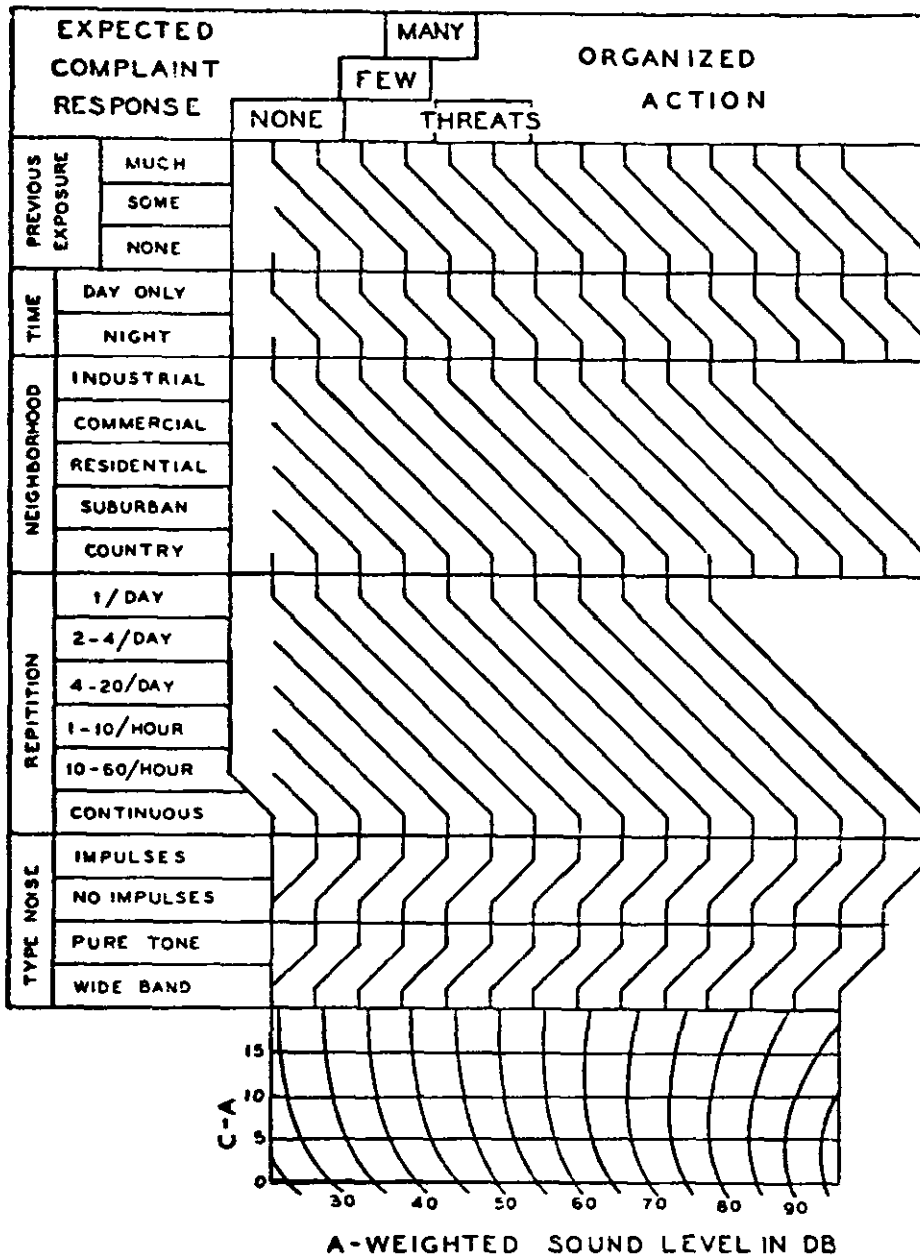
When it comes to the non-occupational exposures in transportation vehicles, public places, etc., none of these mitigating influences exist. Yet levels equalling those in industry are often encountered and there is a tendency to apply industrial standards when appraising the hazard. Stricter standards of safety should be imposed for non-occupational exposures so that no change in hear-

ing whatsoever can occur. Dr. Cohen has recommended limits 15 dB below the limits shown in Table 25-4.¹⁶

Speech Interference

Noise can mask or "blot out" speech sounds reducing the intelligibility of messages. Laboratory studies of these effects have appraised the disruptive potential of the noise by its "speech interference level" which is the average sound pressure level of 500, 1000, and 2000 Hz octave bands.¹⁷ The distances at which difficult messages can be conveyed reliably are shown in Table 25-5 as a function of speech interference level. Simple, redundant messages normally used at work can be understood at greater distances.

The speech interference level is closely related to the A-weighted sound level. It is lower by 7 decibels for most common noises. Using this conversion, the speech interference effects of various noises may be estimated from A-weighted sound levels using Table 25-5.



Botsford J. H.: Using sound levels to gauge human response to noise. *Sound and Vibration* 3:16, 1969.

Figure 25-8. Chart for Estimating Community Complaint Reaction to Noise.
 To use the chart, locate in the curved grid at the bottom the point corresponding to the sound levels of the noise under consideration (C-A is the difference between the C- and A- weighted sound levels). From this point, project directly upward into the first of the six correction sections bounded by the horizontal lines. When entering a correction section, follow the lane entered until reaching a position opposite the condition listed at the left which applies to the neighborhood noise under consideration, and then proceed vertically, disregarding lanes, until the next section is reached. In this way, work up through the lanes of the correction sections until reaching the top where the community reaction to be expected is shown.

Annoyance

Annoyance by noise is a highly subjective phenomenon which is very difficult to relate to the sound that causes it. Noises become more annoying as they get louder than the background noise on which they are superimposed. Noises that are unsteady or contain tones are most annoying as are those that convey unpleasant meaning.

Indoors, noise is likely to become annoying when the A-weighted sound level exceeds 30 dBA in auditoria or conference rooms, 40 dBA in private offices and homes, or 50 dBA in large offices or drafting rooms. Outdoors, a noise can be expected to prove annoying if it exceeds the background level by 10 dBA or more.

A procedure for rating the annoyance potential of a noise in the community is given in Figure 25-8.⁴ It provides a method for estimating community complaint reaction to a given noise condition.

TABLE 25-5
Maximum Speech Interference Levels
for Reliable Communication at Various Distances
and Vocal Efforts.

Distance, feet	Vocal Effort			
	Normal	Raised	Loud	Shout
0.5	76	82	88	94
1	70	76	82	88
2	64	70	76	82
4	58	64	70	76
8	52	58	64	70
16	46	52	58	64
32	40	46	52	68

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Non-Auditory Effects

Audible noise produces other effects which are just beginning to be examined.¹⁸ Laboratory studies have shown that noise reduces efficiency on some tasks, can upset the sense of balance, and can cause blood vessels to constrict, raising blood pressure and reducing the volume of blood flow. It causes the pupils of the eyes to dilate. Even when we are sleeping, noise can cause changes in electro-encephalograms and blood circulation without waking us. Noise can also cause fatigue, nervousness, irritability, hypertension and add to the overall stress of living. There is no convincing evidence so far that any of these effects become permanent and thus are deleterious to health.

Very intense noise below 1000 Hz can be felt as well as heard. Airborne vibrations can stimulate mechano-receptors throughout the body, including touch and pressure receptors and the vestibular organs. The respiratory system is affected by sounds in the 40 to 60 Hz range because of the resonance characteristics of the chest.

Sounds too high in frequency to be heard by the normal ear produce no significant effect when

they reach the body by air pathways. However, transmission of ultrasound into the body through fluid or solid media is more efficient and can produce cavitation of the tissue as well as deep burns.

Intense sound below the audible frequency range can cause resonant vibration of the eye balls and other organs of the body. Dizziness and nausea can result. Levels of 130 dB or more are required to cause these effects, and are not often encountered in industry.

SURVEY TECHNIQUES

One should become thoroughly familiar with operation of noise measuring instruments through study of operating instructions before attempting to make noise surveys. Set up the equipment and check its operation before embarking. At intervals during the survey, batteries should be checked as well as overall instrument calibration.

When transporting instruments, they should be protected from vibration and shock as much as practical. Instruments should also be protected from extremes of temperature. Overheating, such as might occur in the trunk of a car parked in the sunshine, can damage circuit components. Allowing the instrument to become very cold in a car parked overnight in the winter will result in condensation of water vapor in the instrument when it is used in a heated space the next morning. Water condensed from the air can cause electrical leakage resulting in low readings.

When conducting surveys, it is important to be assured that the meter indication is due to noise and not to other influences. One way of doing so is to listen to the meter output with a pair of headphones to learn whether the sound heard is the noise being measured.

Wind blowing across the microphone causes a rushing sound that is registered on the meter. Use of a wind screen can minimize this effect. Electric and magnetic fields can also cause needle deflections. This interference may occur around welding on large assemblies and becomes apparent when the meter needle does not move in step with the loudness of the noise heard. These electromagnetic effects can be reduced by reorienting the meter until minimum coupling with the electrical fields is obtained as indicated by minimum meter reading. One particularly troublesome location where electrical interference is observed is around electric furnaces. Here, the electrical interference and the noise are coincident so that it is easy to confuse these spurious signals with noise.

When taking readings, one should obtain representative data. The microphone should be moved about to determine that standing waves are not present. If they are, a spatial average should be obtained.

Exposure Surveys

When conducting exposure surveys of various kinds, the most important consideration is to measure levels that are typical of those at the auditor's location. It is not necessary, in fact it is undesirable, to measure sound right at the ear since diffraction around the head can alter the sound field. It is better to measure at some loca-

tion a few feet away where exploration with the sound level meter indicates levels are the same as at the auditor's location. When attempting to evaluate the potential for hearing damage, all factors of significance must be recorded such as sound level, duration, intermittency, etc.; necessary to make proper evaluation of an exposure, using Table 25-3.

If one is merely attempting to determine compliance with the regulatory limits shown in Table 25-4, then the ACGIH exposure evaluation procedure must be followed. When noise levels are too variable to allow this procedure to be carried out with a sound level meter and stop watch, a noise monitor may be used. Several of these are commercially available to compute automatically the fractional exposure according to the prescribed methods. One of these monitors is shown in Figure 25-5.

Source Determination

When attempting to locate sources of noise in a room or in a machine, the simplest approach is to probe the sound field with the sound level meter. The noise will increase as the source is approached and disclose its location. Extension cables can be used to remove the microphone from the meter for greater convenience in these explorations.

Another aid to locating the original sources of noise is spectral analysis of vibrating parts, the frequency of the sound will be the same as the frequency of the part vibration. Thus, narrow band analysis will often reveal frequencies that can be correlated with repetitive mechanical events or multiples thereof. These clues point to the mechanical disturbances responsible for the noise.

SUMMARY

A complete array of instruments is available for measuring steady, intermittent and impulsive noises. Sound level meters, calibrators, frequency analyzers, and accessory equipment are provided by several suppliers. Sound exposure monitors which can be worn by roving workmen record individual patterns of exposure that could be assessed in no other way.

Criteria have been established for avoiding permanent hearing loss resulting from steady, intermittent and impulsive sounds. The Threshold Limit Value for noise, adopted by the American Conference of Governmental Industrial Hygienists, has been accepted widely. Non-occupational exposures require stricter limits to provide complete protection.

Criteria for avoiding speech interference and complaints of annoyance are also available. Several non-auditory effects of noise are being studied, but no harmful effects that require safety criteria have been discovered yet. Techniques for surveying noise conditions are well developed so that any noise problem can be readily evaluated.

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