

NOISE ENGINEERING

MEASUREMENT OF ROOM NOISE

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1. GENERAL

1.01 This practice is reissued to indicate an increase in the maximum permissible noise level.

1.02 Sounds in the air which are extraneous to the sounds which a person wishes to hear are here termed room noise. For example, if two persons are conversing, all sounds other than those of the conversation—such as the hammering of a typewriter, the rattling of papers, the roar from street traffic, the sounds coming from a loudspeaker in a nearby room, the sounds of conversations other than their own—are room noise.

1.03 Room noise, like line noise, may adversely affect telephone conversation by impairing the intelligibility of the received speech or by distracting the listener's attention. Room noise may also produce unfavorable effects in cases where telephone service is not involved. For example, it may decrease a person's capacity to work or it may impair his enjoyment of a musical program, etc.

1.04 The noise level experienced in a particular room depends largely upon the acoustical treatment. Architects and interior decorators have at their disposal a wide selection of materials and techniques for controlling acoustical noise. Through their use, modern telephone operating rooms and office areas, and to some degree equipment rooms, provide relatively quiet working conditions. However, the number, types, and importance of the noise sources in or near a room will affect the noise level also. Of the individual sources, some, such as fans, cause a fairly steady noise; whereas, others, such as bells, cause relatively high noise conditions for only short intervals and with a frequency of occurrence which depends on the nature or usage of the source. Other sources, such as doors slamming, introduce a single sharp noise peak each time they occur. As the overall noise at any point in the room is the composite result of the noises from all sources, this noise, obviously, will vary widely from instant to instant.

1.05 The noise levels encountered in different types of locations will vary considerably, as will the levels for a particular type of location. Also, there are variations in the noise condition at a particular location from hour to hour, day to night, and season to season. For engineering purposes there is usually employed the average noise level during the hours in which the activities in the particular room are normal or of particular interest.

1.06 The noise level of interest in a room is usually at the location in the room occupied by people carrying on their work. In an operating

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room the point of interest is at or near the heads of the operators at the switchboard.

2. METHODS OF MEASURING

2.01 A sound level meter consists of a microphone to transform the sound energy into electrical energy, amplifiers to intensify these electrical oscillations, frequency weighting networks, and an output meter to indicate the level of the sound.

2.02 As in the case of most quantities, the measurement of noise is relative, i.e., the noise is measured as being more intense than some arbitrarily selected reference or zero. The reference sound level now commonly used corresponds roughly with the weakest sound that can be heard by an observer with acute hearing in a quiet place. The USA Standards Institute's Technical Committee on Sound Level Meters has defined the reference point for sound level comparison as 0.00004 Newton/square meter (0.0002 microbar). The magnitude of a noise is then referred to as so many decibels above this reference sound level, and is usually expressed as "(−)dB sound pressure level" or dBt.

2.03 The measurement of complex noise by a sound meter, such as is encountered in room noise, requires an electrical network for weighting the energies at different frequencies in a manner similar to that in which they are weighted for loudness by the ear. The relative weightings of the various frequencies depend upon the level of the noise, that is, the weightings are different for low than for high sound levels. To take this variation of weighting with level into account, USA Standard S1.4-1961 requires three networks.

2.04 Network A simulates the response curve of the ear to single frequencies of equal loudness at 40 dB sound level. All room noise levels cited in earlier sections of the Bell System Practices are in terms of this weighting network unless otherwise specified. Networks B and C correspond to 70 dB loudness and flat weighting respectively. The former represents the response of the ear to single frequencies having sound levels of approximately 70 dB, and the flat network the corresponding response for levels of about 100 dB.

3. APPLICATION OF ROOM NOISE MEASUREMENTS

3.01 Circumstances where the measurement of room noise may be desirable are many.

Among these are investigations of noise conditions in telephone operating rooms, business offices, commercial offices, etc. The noise in the street often is a contributing factor to the noise in a room. Its measurement also may be desirable.

3.02 Room noise measurements have the following objectives:

- (1) To determine the existing noise levels.
- (2) To determine the change in noise levels resulting from the application of remedial measures to the noise producing sources or by increasing the absorption factor of the room.
- (3) To determine the noise levels of individual sources of noise.
- (4) To determine situations where the noise levels may be hazardous to hearing.

3.03 Although no definite rules can be given on when to make a noise survey, any noisy environment which is judged to be "loud" may be suspect. This loudness judgment may come from an occupant or a visitor. For example, a difficulty in communication, i.e., interference with speech at normal levels, may be indicative of excessive noise levels, or rooms in which mechanical equipment is operating may be suspect. A general alertness to the problem of environmental noise is recommended.

3.04 The United States Department of Labor, in Rules and Regulations enacted by Congress, specifies standards for noise in the working environment. ♦These rules, as set forth in the Federal Register, Volume 34, Number 96, dated May 20, 1969, follow.♦ Note the dBA in this context refers to dB acoustical as read on the A scale of a standard sound level meter.

Occupational Noise Exposure

(1) (a) The maximum permissible steady (or equivalent) noise level in the working environment shall not exceed ♦90 decibels♦ as measured on the A scale of a standard sound level meter at slow response.

(b) In all cases, feasible engineering controls must first be determined and implemented. Methods of control in the working environment include reducing the amount of noise produced

at the source, reducing the amount transmitted through the air, and substituting quieter machinery or procedures. If the noise levels cannot be restricted within the maximum permissible (or equivalent) level by such methods, employees hearing shall be safeguarded by adequate personal protective equipment.

(2) If the variations in noise level involve maxima at the intervals of 1 second or less, it is to be considered steady. If the intervals are more than 1 second and the duration of the maxima are less than 1 second each, maximum is to be considered as 1 second. Where the noise is not steady, the equivalent steady noise level is determined by the following procedure: The duration over 1 week of each clearly distinguishable sound level is located in Column 1 of Table A, and the partial noise exposure index is read at the intersection of this row with the appropriate sound level column. The partial noise exposure indices thus obtained are added arithmetically. The sum is the composite noise exposure index. The continuous noise exposure equivalent for the composite noise exposure index is then read from Table B.

(3) In all cases where the noise levels regularly excess 90 decibels on the A scale in such a manner as to be likely to cause any impairment to hearing (AA00 method*) to the employees, then annual audiometric examinations shall be performed on such exposed employees. Records of the audiometric examinations shall be available for examination by a qualified industrial hygienist, physician or safety engineer representing the U.S. Department of Labor. Positive action shall be taken to assure that audiometric examinations and noise level readings shall be done in accord with the applicable standards of the United States of America Standards Institute.

(4) (a) At the request of an employee (or former employee), a report of the employee's audiometric examinations, as shown in records maintained by the employer pursuant to (3) above, shall be furnished to him. The report shall be in writing and contain the following statement:

This report is furnished to you under the provisions of the U.S. Department of Labor, Safety and Health Standards (41 CFR Part 50-204). You should preserve this report for future reference.

(b) The former employee's request should include appropriate identifying data, such as social security number and dates and locations of employment.

*Guide for Conservation of Hearing in Noise, 1964: Sub-Committee on Noise Research, American Academy of Ophthalmology and Otolaryngology, Callier Hearing & Speech Center, 3819 Maple Avenue, Dallas, Texas 76219.

3.05 To determine the extent of the noise problem, a screening noise survey should be made with a sound level meter and the measurements evaluated in accordance with 3.04. Noise that exceeds 90 dB on the A scale of a standard sound level meter is a potentially hazardous condition. A hazardous condition is one in which some individuals on regular exposure over a given length of time will show some permanent shift in hearing level. Noise below the critical level, although not potentially hazardous, may still be annoying and may adversely affect the performance of individuals in the vicinity.

3.06 Measurements of the ambient sound pressure levels that do approach the hazardous condition suggest that a more detailed analysis is required. The detailed analysis examines the audible frequency spectrum by measurements in octave bands. An octave band is a band of frequencies where the highest frequency is twice the lowest. The measurements in each octave band, plus information on duration of the noise, when entered in published curves, give the length of time an individual can tolerate the noise without permanent hearing loss. For a discussion of octave band acoustical noise analysis see "Hazardous Exposure to Intermittent and Steady-State Noise," published by the Committee on Hearing and Bioacoustics (CHABA) in *The Journal of the Acoustical Society of America* Vol. 39, No. 3, March, 1966, by Kryter, Ward, Miller, and Eldredge. The *Industrial Noise Manual, Second Edition* published by the American Industrial Hygiene Association (1966) gives some information on ways to reduce hazardous noise levels.

3.07 Section 870-190-100 discusses the nonhazardous, but often annoying acoustical noise problems that may be encountered in operating rooms and similar locations. The noise measuring apparatus and procedures discussed below may be applied in such situations to locate annoying noise levels and their sources, and to verify noise reduction following steps taken to reduce the noise.

**TABLE A
DURATION/WEEK**

HOURS	MIN-UTE	SOUND LEVEL dBA																								
		80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120	122	124	126	128
	10								5	5	5	5	10	10	15	20	25	30	40	50	55	70	90	110	140	165
	12								5	5	5	10	10	15	20	25	30	35	45	55	70	85	105	135	165	200
	14								5	5	5	10	15	15	20	30	35	45	55	65	80	100	125	155	195	
	16							5	5	5	10	10	15	20	25	30	40	50	60	75	90	115	145	180		
	18							5	5	5	10	15	15	20	30	35	45	55	70	85	105	130	160	200		
	20							5	5	10	10	15	20	25	30	40	50	60	75	95	115	145	180			
	25							5	5	10	15	20	25	30	40	50	65	75	95	120	145	180				
	30						5	5	10	10	15	20	30	35	45	60	75	90	115	145	170					
	40						5	5	10	15	20	30	40	50	65	80	100	125	155	190						
	50						5	10	15	20	25	35	45	60	80	100	125	155	190							
1	60				5	5	10	15	25	30	45	55	75	95	120	150	185									
	70				5	5	10	20	25	35	50	65	85	110	140	175										
	80				5	5	15	20	30	40	55	75	100	125	160	200										
1½	90				5	10	15	25	35	45	65	85	110	140	180											
	100			5	5	10	15	25	40	55	70	95	125	155	200											
2	120			5	5	10	20	30	45	65	85	115	150	190												
2½				5	5	15	25	40	55	80	105	140	185													
3			5	5	10	15	30	45	70	95	130	170														
3½			5	5	10	20	35	55	80	110	150	200														
4			5	5	5	10	20	40	60	90	125	170														
5			5	5	10	15	25	50	75	115	160															
6			5	5	10	15	30	55	90	135	190															
7		5	5	5	10	20	40	65	105	160																
8		5	5	10	15	20	45	75	120	180																
9		5	5	10	15	25	50	85	135																	
10		5	5	5	10	15	25	55	95	150																
12		5	5	5	10	20	30	65	115	180																
14		5	5	10	15	20	35	75	135																	
16		5	5	10	15	25	40	85	150																	
18		5	5	10	20	30	45	95	170																	
20		5	10	15	20	30	50	105	190																	
25		5	10	15	25	40	65	135																		
30		10	10	20	30	45	75	160																		
35		10	15	20	35	55	90	190																		
40		10	15	25	40	65	190																			

4. NOISE MEASURING APPARATUS

4.01 Environmental noise surveys should be made with a sound level meter conforming to USA Standard S1.4-1951 or the latest revision. These meters are provided with the three weighted scales, A, B, and C. Most of the readings are taken on the A and C scales. A number of sound level meters and octave band analyzers which meet the USA Standards are commercially available. Some of these are listed below. The most compact

instrument is the General Radio Model 1565-A. The General Radio Model 1551-C is bulkier, but is more sensitive. It can be used to measure lower levels but needs accessory equipment to measure higher levels. The Bruel and Kjaer Type 2203 is the most sophisticated instrument, and may be used in conjunction with the Bruel and Kjaer Type 1613 octave and filter set to provide octave band level measurements. The combination 2203 plus 1613 is battery-operated and fully portable. Octave band measurements may also be made with the

TABLE B
CONVERSION SCALE

COMPOSITE NOISE EXPOSURE INDEX	EQUIVALENT CONTINUOUS SOUND LEVEL dBA
10	80
15	82
20	83
25	84
30	85
40	86
50	87
60	88
80	89
100	90
125	91
150	92
180	93
210	94
250	95

General Radio Model 1558 octave band analyzer with the microphone. The accurate use of octave band analyzers does require a certain measure of skill, and level analysis should therefore be carried out by trained personnel.

SOUND LEVEL METERS	OCTAVE BAND ANALYZERS
Bruel and Kjaer 2203	Bruel and Kjaer 2203 + 1613
General Radio 1565-A	General Radio 1558 + 1560-P6
General Radio 1551-C	

5. MEASURING SOUND LEVELS BY THE METER METHOD

A. Location of the Microphone

5.01 For indoor measurements the meter is set up in such a way that the transmitter pickup is placed at the spot where the magnitude of the room noise is to be measured. If the room noise is to be measured from the standpoint of its effect on telephone conversations, the pickup should be located approximately at the point normally occupied by the ear of the telephone user. When street noise is a factor in the overall room noise, it may be desirable to measure this factor by locating the transmitter approximately in the plane of one or more typical windows with the window wide open.

5.02 For outdoor measurements of noise such as street noise, etc., the transmitter may be located on the roof of an automobile or on a suitable tripod. The location should be at least three feet above ground.

5.03 When measuring the noise in an operating room, the point of interest is at an operator's position. A vacant position located at about the middle of the switchboard having both adjacent positions occupied should be selected for making the noise measurements. The transmitter should be set up at the idle position by means of an adjustable tripod at approximately the location usually occupied by the operator and at ear level. It is desirable to make noise measurements at two or more such typical positions, the number usually depending upon the total number of positions at the switchboard.

B. General Method of Operation

5.04 As room noise is generally quite variable, it is necessary to decide upon the way of reading the sound meter. In the past, it has been the practice to read either the average peak value of the noise (in much the same way as average peak values are read on a volume indicator) or the general average or both. For individual noises, such as the slamming of a door, the difference between the average and the peak meter readings may be very large. For ordinary types of room noise, the mean difference between the average and the average peak values will usually be only about 2 dB. To avoid the difficulty of obtaining correlations between various methods of reading a

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sound meter, different methods have been investigated to select the one which gives the most accurate results, particularly between various observers and by the same observer at different times.

5.05 The recommended method of reading sound meters consists of reading as closely as possible the instantaneous deflection of the meter at 3- to 5-second intervals until a total of 50 readings has been obtained. The room noise level for the conditions under investigation is then the average of these 50 readings. This method is capable of somewhat more precise definition than methods which involve mentally averaging the noise over a period of time.

5.06 A convenient way to learn this method is to use a watch for measuring the time intervals. The meter is covered with one hand and, when a 5-second interval has elapsed, the hand is lifted and the first possible reading is made by noting the position of the needle at the instant the meter is uncovered. The needle is usually in continuous motion and the reading should represent the instantaneous position of the needle regardless of whether it is on an upswing, downswing, or at a peak position. It is usually possible to form a mental image of the scale at the instant the hand is removed. The meter is again covered and the process repeated. It is desirable to practice in a location where the noise is not too variable as it may be necessary to adjust the potentiometer to keep the meter on the scale and this is difficult for inexperienced observers. Experienced observers will not find the use of a watch or covering the meter necessary. When two observers are available, having each take 25 of the instantaneous readings involved in a particular measurement is desirable to still further eliminate the personal element and to compare the results of the two observers.

5.07 In making room noise measurements where strong magnetic fields are known to exist, certain steps unusual to the normal procedure described above for making the usual sound level measurements should be taken to make certain that the meter indications are for the sound field rather than for the magnetic field. Such magnetic effects are present if meter readings are obtained with no microphone attached to the sound meter. These effects may often be eliminated by orienting the meter, or by removing the meter to a point where relatively small and unimportant magnetic fields exist. Relatively long shielded leads may

be used between the microphone and the meter, when arranged for use with an external microphone.

C. Selection of Conditions for Measurement

5.08 Since the room noise in a given location will in general not be constant, it will be necessary to exercise judgment in selecting the conditions under which the noise is to be measured. Conditions as nearly normal as possible are desirable. In this connection, it should be noted that room noise includes not only noise originating in the room or other place where a measurement is to be made but also external noises, such as noise caused by street traffic. In considering the effect of room noise on telephone or other conversation, all those sounds in the room which may be detrimental to the conversation, such as other conversations, should be included as room noise. The sound meter cannot discriminate between noise and desired sounds nor can it pick out one noise from a combination of noises unless this noise has considerably greater intensity than the other noises at the location of the microphone.

5.09 The presence of the measuring personnel tends to alter the behavior of people in the room so that unless care is taken to overcome this influence, normal conditions may not be obtained. None of the noises which would normally be present at the locations of a particular telephone while it is in use should be discontinued while measurements are taken. On the other hand, if noises exist which would be discontinued while the telephone is used, these should not be included in the measurements. Particular care should be taken to see that the noise produced by extraneous conversations is typical for conditions as they would be when the telephone is in use. Room conditions which would affect the noise, such as the position of windows (open or closed), should be adjusted to be typical.

5.10 Care should be exercised in the choice of the locations of the sound pickup. Changes in the distance from the source of the noise to the pickup may result in large changes in measured noise levels. For steady noises consisting of one or more prominent single frequencies such as electric fan noise, standing wave effects may produce large changes in the measured noise level for small changes in the position of the pickup. Where these effects are noted, an average value for several positions and orientations of the pickup

is generally the most satisfactory; although for certain applications the maximum value may prove more useful. Certain types of noise, especially high frequency, are more directive than others. This must sometimes be taken into account in determining the best location for the sound pickup.

5.11 The short time variations in room noise are frequently large. In obtaining a typical value of noise for a given location, a sufficient number of measurements spread over a sufficient interval of time should be taken so that short time variations in the noise level are adequately taken into account.

5.12 In cases where the effect upon room noise of some change in the room condition is desired, it will be necessary to devise some way of eliminating the influence of chance variations in the noise. Especially in cases where noise data are to be used as a guide in determining methods of reducing the noise, special attention may be paid to the magnitudes and rates of occurrence of the peak noises caused by particular sources. Observations may be made of the causes of the majority of such noise peaks whose magnitudes are such as to affect the reading obtained on the sound meter. A study of data of this kind in correlation with other factors, such as room characteristics, number of people in the room and their occupations, will often give a clue as to the most effective noise reduction measures.

D. Response to Sounds of Short Duration

5.13 Occasions may arise when it will be desirable to measure the peak noise levels of a particular noise source in a room. The following characteristics of the noise measuring sets regarding their ability to read peak noise of short durations will be helpful.

5.14 For essentially continuous sine wave inputs in the voice range, the rectifier is such that the meter readings in dB are proportional to the logarithms of the weighted power input. The time response characteristic of the indicating meter in these measuring devices is such that full deflection is obtained on pulses lasting 0.2 second or more. A peak deflection on the meter is, therefore, a noise impulse integrated over 0.2 second. For very short impulses, if the meter is set so as to obtain the indication equivalent to the average power over the 0.2-second period, the actual peak overloads the amplifier and this tends to reduce

the meter reading. To minimize this overloading effect, the reading should be obtained at as low a point on the indicating meter scale as practicable, i.e., between 0 and -7 dB.

6. PROCEDURE FOR MEASURING ACOUSTICAL NOISE

6.01 The following step-by-step procedure is appropriate in making noise measurements.

- (1) Position the microphone as described in 5A.
- (2) Select A weighting on the sound level meter.
- (3) Read the A-weighted noise using the technique described in 5B.
- (4) Record the noise level.
- (5) Evaluate in accordance with 3.04.

7. ACOUSTICAL NOISE OBJECTIVES

7.01 The response of various people to acoustical noise varies greatly. Noise that merely annoys one person will not bother another, or may be extremely troublesome to someone else. Thus, a single numerical requirement, or limit, for an acceptable level for room noise has not been set. Some sources on architectural design of rooms give ranges of 5 to 10 dB in which the noise level in certain common types of rooms occupied by numbers of people might fall. However, these do not specifically include operating or equipment rooms. Tables in these sources do, of course, include office spaces. The *Industrial Noise Manual* referred to in 3.06 includes such tables, which might serve as a guide in specific cases.

7.02 The criteria in 3.04, extracted from the Department of Labor Rules and Regulations, provide a basis for judging whether noise in a given situation is likely to result in permanent hearing loss to persons spending more or less time in the given environment.

7.03 If the 85-dB level stipulated in 3.04 is not exceeded, the sound environment may be considered safe in terms of risk of hearing loss. Sound level reduction may still be important, however, to reduce interference to speech or to obtain comfortable working conditions. Sound levels may be reduced by controlling equipment noise or by the use of earplugs or earmuffs. Information

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on this may be found in the *Industrial Noise Manual* referred to in 3.06.

7.04 If the critical levels are exceeded, information is needed on the length of time each person is exposed to the noise, and on how much time is spent out of the noise environment between exposures. Sound pressure levels in each octave band should then be obtained at the exposure locations with an octave band analyzer conforming to USA Standard Z24.10-1953 or the latest revision. The octave band levels together with the exposure information may be utilized to determine the damage risks by means of information published by the Committee on Hearing and Bioacoustics (CHABA) of the National Research Council, also

referred to in 3.06. From the CHABA report calculations can be made to determine how much time personnel may be exposed to a given octave band noise level without risk of hearing loss, or by what amount the noise level will have to be reduced to eliminate the risk of hearing loss.

7.05 It must be remembered that there are wide variations in the susceptibility of individuals to hearing loss due to high sound levels. Whenever personnel are expected to operate in ambient levels approaching the damage risk criteria, periodic audiograms should be obtained to insure no individual is incurring hearing loss. The criteria recommended are conservative, however, and take into account individual differences.