NOISE CONTROL

CONTENTS PAGE

1. GENERAL

1.01 This section provides standards for Noise Control. These standards are provided for use in the design of new buildings or building additions that are intended to house telephone equipment that meets the requirements of Bell System Practice 800-610-164, "New Equipment-Building System (NEBS), General Equipment Requirements."

1.02 This practice supercedes Section 9.7 of Specification X-74300, "NEBS Building Engineering Standards (BES)." Whenever this section is reissued, the reason for reissue will be listed in this paragraph.

2. SCOPE

2.01 Acoustical noise may be defined as that sound which produces varying degrees of human discomfort dependent on the sound intensity and pitch (frequency). The discomfort can range from annoyance to pain. It is an established fact that excessive, persistent noise can result in permanent loss of hearing. However, the degree of such impairment is dependent on the exposure time.

2.02 Acoustical noise is measued in decibels. By definition, a decibel is 10 times the logarithm to the base 10 of a ratio of two powers. Because the range of acoustic power in most buildings is about one billion to one (10^9:1) it is convenient to relate these powers on the reduced range logarithmic decibel scale. The power ratio is taken by comparing the actual acoustic power to the statistical "threshold of bearing" standard of 10^{12} watts, or $2X10^{-5}$ N/M^2 pressure level. Noise measurements made for the determination of health effects use a weighting network of series of filters that have known response characteristics. This network is identified and measurements are given in dB(A). Also available for noise measurement are B, C, and D weighting networks. The present OSHA* standard for noise allows exposures to 90 dB(A) for an 8-hour work day. Proportionately less time is permitted for exposures at higher levels of sound intensity.

2.03 Below approximately 80 dB(A), no hazard to health is believed to exist. In the range of 50 to 80 dB(A), people may find the sound annoying to varying degrees, depending on the frequency, the nature of the sound, its duration, and the type of social or business activity. Annoying noise alters personnel performance and accelerates mental fatigue.

2.04 In Bell System telephone switching rooms where electromechanical and solid-state equipment predominates, sampling measurements of acoustical noise and voice audibility verify that sound levels do not pose a threat to health and are rarely discomforting. Data obtained in typical telephone equipment rooms show that noise levels are in the 60- to 80-dB(A) range, varying with the telephone traffic density. Below 62 dB(A), noise complaints are rare. At or above 70 dB(A), the frequency of noise complaints increases, particularly from personnel whose job functions require frequent telephone or other voice communications. This section describes types of noise that might be encountered, noise control strategies, measurement methods, and standards for noise control.

3. TYPES OF ACOUSTICAL NOISE

3.01 The noise spectrum in the audible range (20 Hz to 20 kHz) is influenced by the characteristics of the source(s) and the surroundings. The American National Standards Institute classifies noise as steady or nonsteady. Steady noise without discrete tone or narrowband peaks is referred to as "broadband." The noise from a typical high-velocity air-conditioning system is classified as "steady, broadband," while the noise of many power tools or items such as electrical transformers can be classified as "steady with discrete tones." Nonsteady noise is fluctuating or intermittent in time. Impulse noise is a high-pressure, short-term wave such as that produced by a door slamming or the deactuation of a large electrical circuit breaker.

3.02 Telephone equipment room noise can be classified as "broadband," but the weighted sound intensity and noise spectrum will vary due to telephone traffic fluctuations. Sound pressure level changes are particularly noticeable in electromechanical switching offices.

3.03 Figure 1 shows the range of measured sound fields and the general noise spectrum in a large telephone equipment room containing electromechanical equipment. At the upper limit of the sound field, no health impairment problems exist. However, in areas of the same room where clerical or supervisory functions are performed, sound levels above 60 to 65 dB(A) can be troublesome as the excess noise is distracting. Figure 2 shows the general curves of measured sound levels in small rooms housing computer facilities (such as CAMA-C) and in a large No. 1 ESS administrative area.

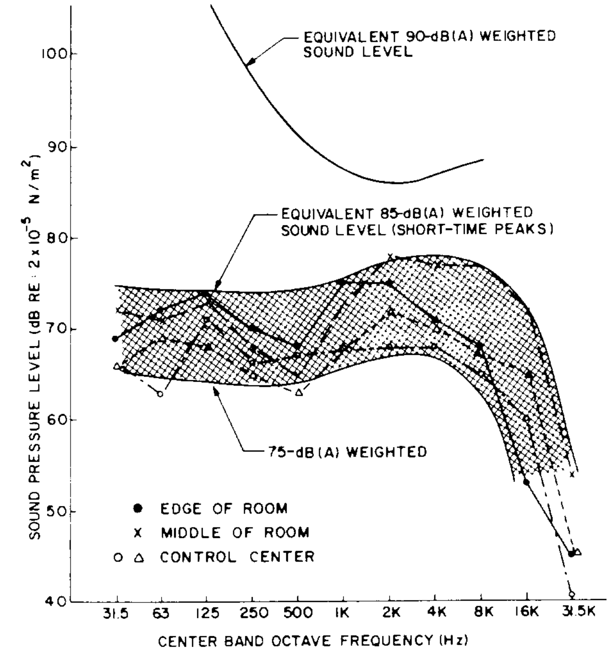


Fig. 1—Sound Pressure Level Range in Switching Areas of Large No. 4 Toll Switching Office

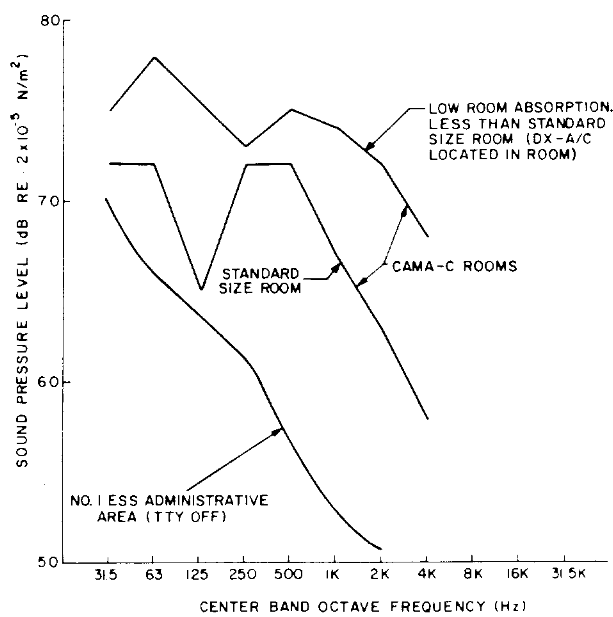


Fig. 2—Typical Sound Pressure Levels in CAMA-C and No. 1 ESS

4. ACOUSTICAL NOISE CONTROL

4.01 Virtually every problem in noise control involves three basic elements: a source, a path, and a receiver. Before a noise problem can be solved, the dominant source of noise must be known and the transmission paths understood.

4.02 Noise control does not necessarily involve reduction of the undersirable noise level. For example, masking of the noise with still another sound is sometimes possible. However, this section stresses the methods of material applications that are used to reduce undersirable sound to acceptable levels. In designing for noise control, standard curves are widely referred to in determining the acceptable level of sound in the environs. One widely accepted standard is identified as Noise Criteria (NC) and is partially reproduced in Fig. 3. The curves shown cover the range of NC-50 to NC-70 over the frequency spectrum from 63 to 8000 Hz. Each of the curves represents a sound level which has been subjectively determined to be suitable for a particular group or type of indoor functional activity.

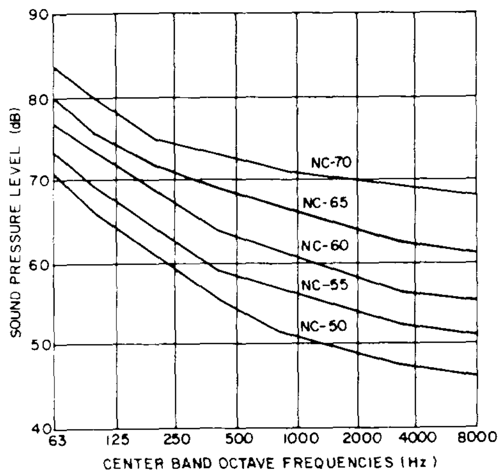


Fig. 3—Noise Criteria Curves

4.03 Sound energy arriving at a surface is partially absorbed, reflected, and transmitted as shown in Fig. 4. The fraction absorbed, reflected, and transmitted is established by the surface material properties and other factors described in the following paragraphs.

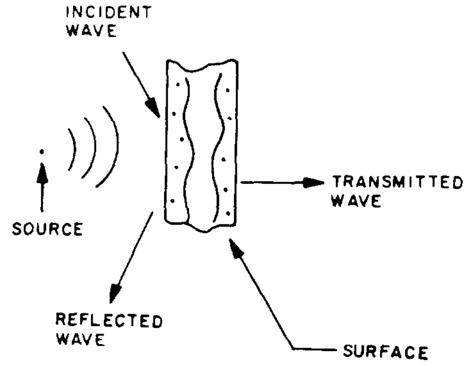


Fig. 4—Sound Wave Paths

SOUND ABSORPTION

4.04 Materials which are good sound absorbers are comparatively lightweight and porous; for example, fiberglass. Materials which limit transmission are dense and nonporous; for example, a concrete wall.

4.05 The sound absorption process basically involves converting sound energy into heat energy through frictional interaction of the porous surfaces and the moving air molecules. Sound absorption by surfaces is limited and is most pronounced in the near zones of the absorbing surfaces. Calculation methods, however, are based on the entire enclosed zone. The decibel reduction due to room absorption is:

$$\text{dB reduction}_{\text{absorption}} = 10 \log \frac{A_2}{A_1}, \qquad (1)$$

where A_1 and A_2 equal the summation of the number of Sabine absorption units of each surface before and after treatment, respectively.

4.06 Equation (1) shows that each doubling of the number of absorption units results in a 3 dB decrease in the noise level within the room.

4.07 The absorption coefficient of a material is dependent on the frequency of the incident sound; therefore, equation (1) should be used to predict the absorption in each octave frequency band. Most of the published data are provided for the octave bands from 125 to 4000 Hz. When a single Noise Reduction Coefficient (NRC) absorption number is provided, it should be recognized that the value represents the average of the coefficients at 250, 500, 1000, and 2000 Hz; however, absorption at any given octave band may differ significantly from the average. Table A lists several typical absorption materials. Other materials are tabulated in the reference documents.

TABLE A

SOUND ABSORPTION OF MATERIALS

Material	Absorption Coefficient Frequency (Hz)						NRC Number
	125	250	500	1000	2000	4000	
Reflecting							
Brick	0.03	0.03	0.03	0.04	0.05	0.07	0.05
Painted Concrete Block	0.1	0.05	0.06	0.07	0.09	0.08	0.05
Glass	0.18	0.06	0.04	0.03	0.02	0.02	0.05
1/2" Gypsum Board	0.29	0.10	0.05	0.04	0.07	0.09	0.05
Plaster on Lath	0.14	0.10	0.06	0.05	0.04	0.03	0.05
3/8" Plywood	0.28	0.22	0.17	0.09	0.10	0.11	0.15
Absorbing							
Coarse Concrete Block	0.36	0.44	0.31	0.29	0.39	0.25	0.35
14 oz/yd^2 Drapery	0.07	0.31	0.49	0.75	0.70	0.60	0.55
18 oz/yd^2 Drapery	0.14	0.35	0.55	0.72	0.70	0.65	0.60
2" shredded wood fiberboard	0.32	0.37	0.77	0.99	0.79	0.88	0.75
Thick, porous material with open facing	0.60	0.75	0.82	0.80	0.60	0.38	0.75

ATTENUATION OF TRANSMITTED SOUND

4.08 Sound is transmitted through an enclosure by excitation of the enclosure surface by the incident waves. The sound attenuation through a wall varies with the frequency of the wave and the weight per unit area of the surface. Sound attenuation is due to slight yielding of the wall and heat exchange between the cooler expansion and the warmer compression waves. Three frequency-dependent zones exist in which the sound transmission characteristic differs (see Fig. 5). These zones are normally identified as:

(1) Stiffness and resonance controlled

(2) Mass controlled

(3) Wave-coincidence controlled.

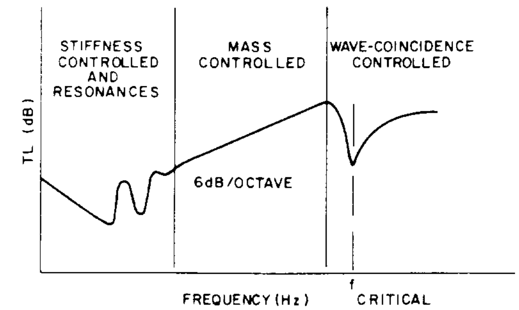


Fig. 5—General Transmission Loss of Structures

4.09 Above the first several stiffness modes, the wall panel becomes mass controlled. In this zone, which extends up to the critical frequency, the attenuation curve will increase at a 6 dB(A) per octave slope.

4.10 At the higher frequencies (greater than the critical frequency), the attenuation of sound across the wall is reduced by an effect called "wave-coincidence." Longitudinal free bending waves are induced into the surface by the air waves. When the airborne wavelength equals the bending wavelength, the critical frequency is reached. As this implies, a wave at grazing incidence (ie, 90°) has no significant transmission. However, as the frequency is increased, there is always some angle at which the sound wave effective wavelength matches that of the surface and as a result transmission is increased.

4.11 In the stiffness and wave-coincidence zones, calculations can only be approximated. In the mass controlled zone, the transmission loss can be calculated accurately.

4.12 The transmission loss (TL) through a wall can be determined if the transmission coefficient, τ, at the frequency of interest is known

$$\text{T.L.} = 10 \log \frac{1}{\tau} \text{ dB} \quad . \qquad (2)$$

If the wall is a composite* construction, then

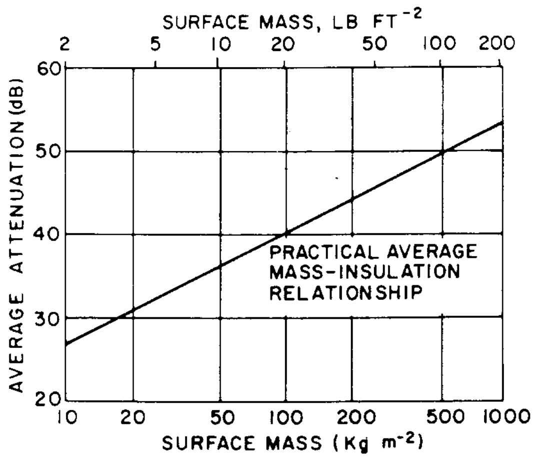
$$\text{T.L.} = \frac{\sum_{i=1}^{n} S_i}{\sum_{i=1}^{n} S_i \tau_i} \text{ dB} \quad , \qquad (3)$$

where

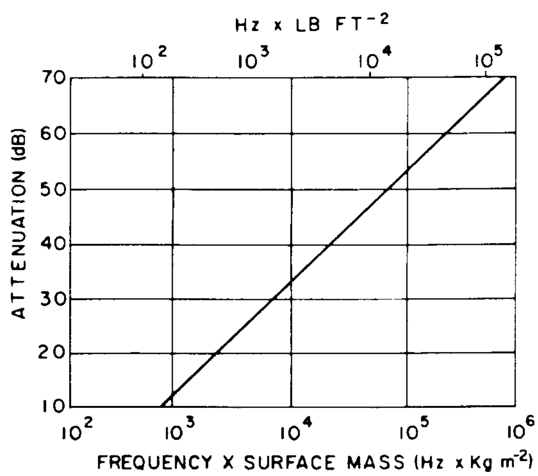
S_i = Area of each i^{th} surface in ft^2
τ_i = The transmission coefficient, a frequency-dependent ratio of the transmitted acoustic power to the incident acoustic power. For wall openings, τ_i = 1 at all frequencies.

* A composite wall includes areas of the total surface which differ in form, eg, windows, doors, wall openings, etc.

4.13 Normally, the transmission coefficient, τ, or the transmission loss is published for the materials commonly used in sound control. Figure 6 (a and b) can also be used in lieu of equation (1) to predict the transmission loss if the weight per unit area is known. Just as with sound absorption calculations, the transmission loss should be determined in each octave frequency band.



(a) average



(b) frequently

Fig. 6—Mass Low Attenuation

4.14 Where rigorous control is not required and conservative design margins can be applied economically, the Sound Transmission Coefficient (STC) rating of the material may be used to provide a quick solution to a noise problem. The STC is a single-number rating of transmission loss for airborne sound at different frequencies. Table B lists transmission loss data for several construction elements.

TABLE B

SOUND TRANSMISSION LOSS OF DOORS, PARTITIONS, WALLS

Building Construction	Transmission Loss [dB(A)]						
	Frequency (Hz)						STC Rating
	125	250	500	1000	2000	4000	
Louvered door, 25% open area	10	12	12	12	12	11	12
1-3/4" hollow wood core door; no gaskets, 1/4" air gap	14	19	23	18	17	21	19
2" plaster on metal lath	20	22	22	27	36	42	24
1/8" single pane glass	18	21	26	31	33	22	26
2 x 4 studs, 16" o.c., with 1/2" gypsum both sides	10	28	33	42	47	41	32
1-3/4" solid wood core door with gaskets	29	31	31	31	39	43	34
1/4" x 1/8" double plate glass window with 2" air space	18	31	35	42	44	44	39
2 x 4 staggered studs, 16" o.c. with 1/2" gypsum both sides	23	32	40	51	53	44	41
4-1/2" brick with 1/2" plaster both sides	34	34	41	50	56	58	42
6" concrete block wall, painted	37	36	42	49	55	58	44
2-5/8" steel channel studs with 2 layers 5/8" gypsum board both sides	27	34	48	55	50	57	45
8" concrete block wall with 3/4" wood furring, gypsum lath and plaster both sides	43	47	47	55	58	60	52
9" brick with 1/2" plaster both sides	41	43	49	55	57	60	52

4.15 The building engineer must recognize the parameters which affect transmission loss. In the mass-controlled region, increasing the mass of the structure increases the transmission loss but does not necessarily reduce wall excitation. Effects of the latter may slightly reduce the expected transmission loss. The building engineer should bear in mind that the highest transmission loss is achieved using limp, heavy, highly damped materials.

DAMPING MATERIALS

4.16 Damping materials usually reduce the noise effects of a high amplitude, resonating structure or offset the noise transmission increase associated with wave-coincidence above the critical frequency. Damping materials are most effective on sheet metal panels to reduce "rattling" and on surfaces subjected to high impulse loads.

SOUND BARRIERS

4.17 Use of absorption materials to modestly lower room sound levels are fairly effective except directly at the noise source. One way to reduce the noise in the immediate vicinity of the source is with the use of barriers (ie, partial enclosures). Single-panel barriers can be designed to provide good unidirectional sound reduction if the length and width dimensions exceed the wavelength of the lowest frequency of interest by at least 50 percent.

4.18 The directional barrier's effectiveness is somewhat independent of mass or thickness. However, use of a barrier will increase the sound energy on the source side unless sound absorbing material is applied to the panel. Absorption also minimizes reflection of sound waves to other areas, so plans to employ barriers should include application of absorbing materials to the source side of the panel.

4.19 The following guidelines are useful in designing partial enclosures:

(1) Where large noise reductions are required, open areas should be kept to a minimum.

(2) Enclosure walls without tops should be as high as possible and located close to the noise source.

(3) Partial closures are more effective in irregular rooms.

The effectiveness of a partial enclosure can be estimated by using the following equationsıı:

$$\text{dB loss} = 10 \log\left(\frac{W_r}{W}\right)_{\text{initial}} - 10 \log\left(\frac{W_r}{W}\right)_{\text{final}}, \qquad (4)$$

where

$$\frac{W_r}{W} = \frac{\sum_{i=1}^{n} S_{oi}\,\beta_i}{S_o + S_a\,\alpha_a} \qquad (5)$$

and

W_r = Sound power radiated

W = Sound power of the reverberant field

S_{oi} = Total open area, ft^2

(The surface areas, S_{oi} are determined from an imaginary box encompassing the noise source. Box dimensions are established by the partial enclosure surface(s) and projection of the surface edges to form a rectangular parallelopiped.)

S_a = Acoustically treated surfaces, ft^2

α_a = Absorption coefficient

$\alpha_a = 0$ for untreated walls

β = 1/6 for rear opening, 1/3 for sides and top opening, 1 for front opening.

Example: Consider a single predominate noise source in a room with an acoustic level of 68-70 dB(A). Other sound sources exist but the levels are at least 10 decibels lower and thus contribute negligibly to the room environment. It is desired to reduce the room sound level to 65 dB(A) or less in an area of the room where people are located. A partial enclosure is proposed to isolate the noise source which is contained in a 2 feet by 1 feet by 4 feet high cabinet. Initially, one could consider a partial enclosure measuring 6 feet by 6 feet with two, 3 feet by 6 feet sides as shown in Figure 7(a). Assume that the enclosure has negligible sound absorption. Calculate the approximate sound reduction of the directional enclosure. The procedure is as follows:

Step 1: Use the dimensions of the proposed partial enclosure to define the open areas from which the noise is radiating. For example, the initial open areas, $S_{oi}$are the sides of the rectangular parallelopiped as shown in Figure 7(b), excluding the floor side. (If the source is close to a wall, the latter is also excluded with the floor.)

Step 2: Using equation (5):

$$\text{Calculate: } \frac{W_R}{W}_{\text{initial}} = \frac{(36)(1) + (36)(1/6) + (3)(18)(1/3)}{(36) + (36) + (3)(18) + 0} = 0.476$$

With the partial enclosure assumed in position

$$\text{Calculate: } \frac{W_R}{W}_{\text{final}} = \frac{(36)(1/6) + (18)(1/3)}{36 + 18 + 0} = 0.222$$

then from equation (4):

$$\text{dB loss} = 10 \lg 0.476 - 10 \lg 0.222 = 3.3 \text{ decibels}$$

Because of possible differences in assumed and actual values of B, it is likely that the calculated 3.3 decibel reduction would be considered marginal. A partial enclosure with surface absorption could be evaluated next for effects. For this example, a material with a 0.6 NRC number is selected. Using equation (5) again:

$$\frac{W_R}{W}_{\text{final}} = \frac{(36)(1/6) + (18)(1/3)}{(36) + (18) + (36)(.6) + (2)(18)(.6)} = 0.123$$

Reapplying equation (4), the calculated sound level reduction achieved by the partial enclosure with sound absorbing surfaces is:

$$\text{dB loss} = 10 \lg 0.476 - 10 \lg 0.123 = 5.9 \text{ decibels}$$

The absorbing wall surfaces provide an acceptable design solution for the example problem. The indicated 2-3 decibel margin would offset the extent of any uncertainty in the calculated value.

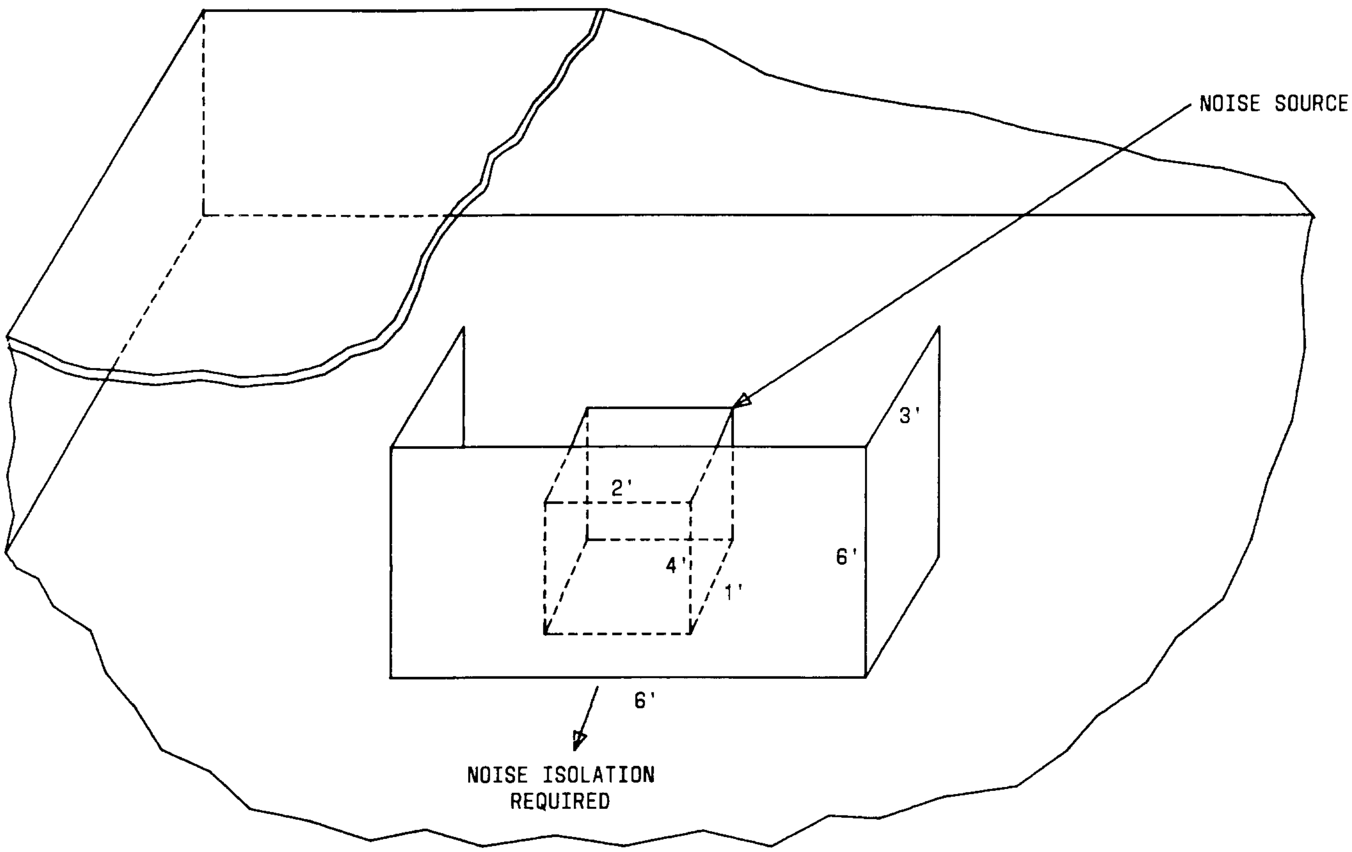


FIGURE 7a

PARTIAL ENCLOSURE AT A NOISE SOURCE
(EXAMPLE CASE)

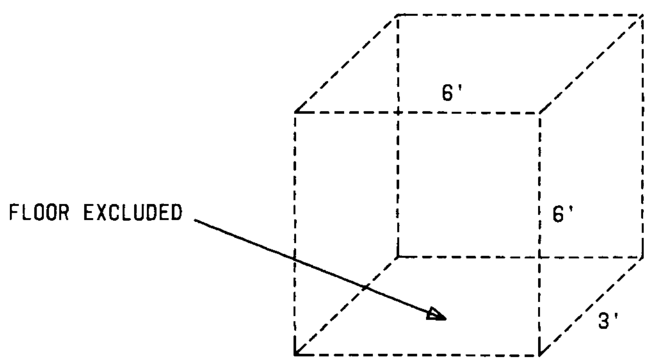


FIGURE 7b

RECTRANGULAR PARALLELOPIPED (BOX) FORMED AROUND NOISE SOURCE TO DETERMINE INITIAL OPEN AREAS, S_{oi}
(EXAMPLE CASE)

Fig. 7—Rectangular Parallelopiped (Box) Formed Around Noise Source to Determine Initial Open Areas, Soi (Example Case)

MATERIALS FOR SOUND TREATMENT

4.20 Abundant information describing the acoustical properties of materials is available in textbooks covering the subject of architectural acoustics; these data are supplemented by supplier catalog data. Many of the materials for sound treatment in buildings are composite forms, and their absorbing or transmission properties are usually determined experimentally by acoustical laboratories. The Industrial Noise Manual[12] is an excellent source for sound properties data.

5. NOISE MEASUREMENT

5.01 Sound measuring instrumentation is available from many suppliers with widely ranging sophistication and capability. The small pocket-size sound level meter is usually used most frequently but is limited to the A, B, and C weighted network circuits; the ability to perform engineering analysis with the data obtained is limited. However, the pocket size is useful in obtaining measurements to establish conformance to codes. At times, by comparing the A, B, and C scale readings, a judgment can be made regarding the general frequency band in which the highest intensity of the noise exists.

5.02 Portable, hand-carried units usually have increased capability. One such unit, the Model 2209 Impulse Precision Sound Level Meter provided by Bruel and Kjaer, is shown in Fig. 8. This instrument can be used to measure impulse noise as well as continuous sound. The instrument uses a condenser microphone and contains four weighting response networks. An optional part of the Model 2209 is a filter bank which provides data at 11 center band octave frequencies from 31.5 Hz to 31.5 kHz. The output data are visually displayed in decibels, and a signal jack is available for tape recording. Vibration measurements can also be made using an optional piezoelectric pickup and a matched impedance cable (factory calibrated set). By substituting quick-change display scales, the vibration parameters of velocity, displacement, or acceleration can be read directly in the selected octave bands.

5.03 Other sound level meters with added functional capabilities are available, but model selection should be made only after carefully considering the need and planned use. As indicated, if the use is merely to verify conformance to codes, the least expensive pocket-size sound level meter will suffice. If field troubleshooting is anticipated, a portable hand-carried model with octave band filtering is, at the least, required.

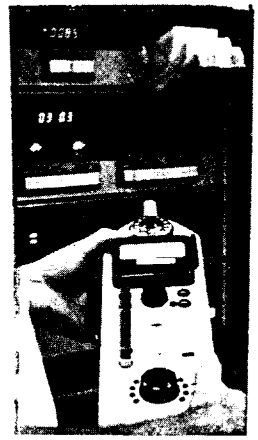


Fig. 8—Portable Sound Meter With Weighting Network and Octave Bands Frequency Selection

6. INVESTIGATION OF NOISE COMPLAINTS

6.01 Bell System telephone equipment designed to the sound limits given in Section 800-610-164 complies in all respects with the current OSHA laws. However, noise control may be required in areas of equipment rooms where people are occupied in supervisory or equipment monitoring functions because the noise level could be sufficient to distract or prevent clear communications.

6.02 Figure 9 is a guide to investigating employee complaints of noise. Basically, measurements are made to determine whether the noise is above levels expected from the equipment. Levels above 75 dB(A) require investigation by equipment manufacturers or Bell Laboratories developmental departments before remedial action is taken. When the noise level exceeds 65 dB(A), the work activities in the area and the arrangement of work location should be assessed in accordance with Figure 9 procedures before introducing noise reduction changes. Where measurements show noise levels above the standards, people should be moved or design improvements implemented by local engineering or industrial consultants.

7. REFERENCES

American National Standards Institute—ANSI S1.3-1971 "Methods for the Measurement of Sound Pressure Levels"

Annotated OSHA Regulations—Vol 1 National Fire Protection Association, 2nd Edition, November 1972

Beranek, L. L.—Noise and Vibration Control, McGraw-Hill Book Co

Handbook of Noise Measurements—General Radio Co

Acoustic Noise Measurements—Bruel & Kjaer

Beranek, L. L.—Noise Reduction, McGraw-Hill Book Co

Egan, M. D.—Concepts in Architectural Acoustics, McGraw-Hill Book Co

Purkis, H. J.—Building Physics: Acoustics, Pergamon Press

Day, B. F., Ford, R. D., Lord, P.—Building Acoustics, Elsevier Publishing Co, Ltd., N. Y.

Bannister, R. L. Pizzirusso, J. F.—The Law and Acoustic Enclosures, Machine Design, June 24, 1971

Phillips, W. G., Shadley, J. R.—Curbing Noise With Partial Enclosures, Machine Design, April 4, 1974

Industrial Noise Manual, 2nd Edition—American Industrial Hygiene Association

Section 760-340-150—Acoustical Noise Treatment—Noise Reduction.

8. NOISE STANDARDS

8.01 Adhere to the following Occupational Safety and Health Act of 1970 (OSHA) noise exposure limits (see Federal Register, Part 1910, Paragraph 95).

Exposure Time (Hr/Day)	Maximum Sound Level [dB(A)]
8	90
4	95
2	100
1	105
1/2	110
<1/4 or less	115
Impact Noise Limit	140-dB peak sound pressure level

8.02 Central office equipment shall not produce sound levels above the following limits when measured 3 feet from the surface of the noise source at a 4-foot elevation.

	Equipment	Sound Level [dB(A)]
Indoor	Engines	85
	All other	75
Outdoor	All equipment	90

8.03 Areas of the equipment building shall be designed to the following limits [refer to Fig. 4 for national consensus Noise Criteria (NC) curves].

Type of Space	Sound Level NC Curve	Sound Level dB(A)
Lobbies, general secretarial offices, engineering rooms and other rooms (to obtain good listening conditions).	50	56
Office-type equipment operating in administrative areas, computer facilities (rooms to obtain acceptable speech and telephone communication).	60	65
Telephone equipment rooms.	70	75
Areas where speech or telephone communication is not required, but where there must be no risk of hearing damage.	75	80

8.04 Use partial enclosures and sound-reducing techniques to provide space with the required sound levels.

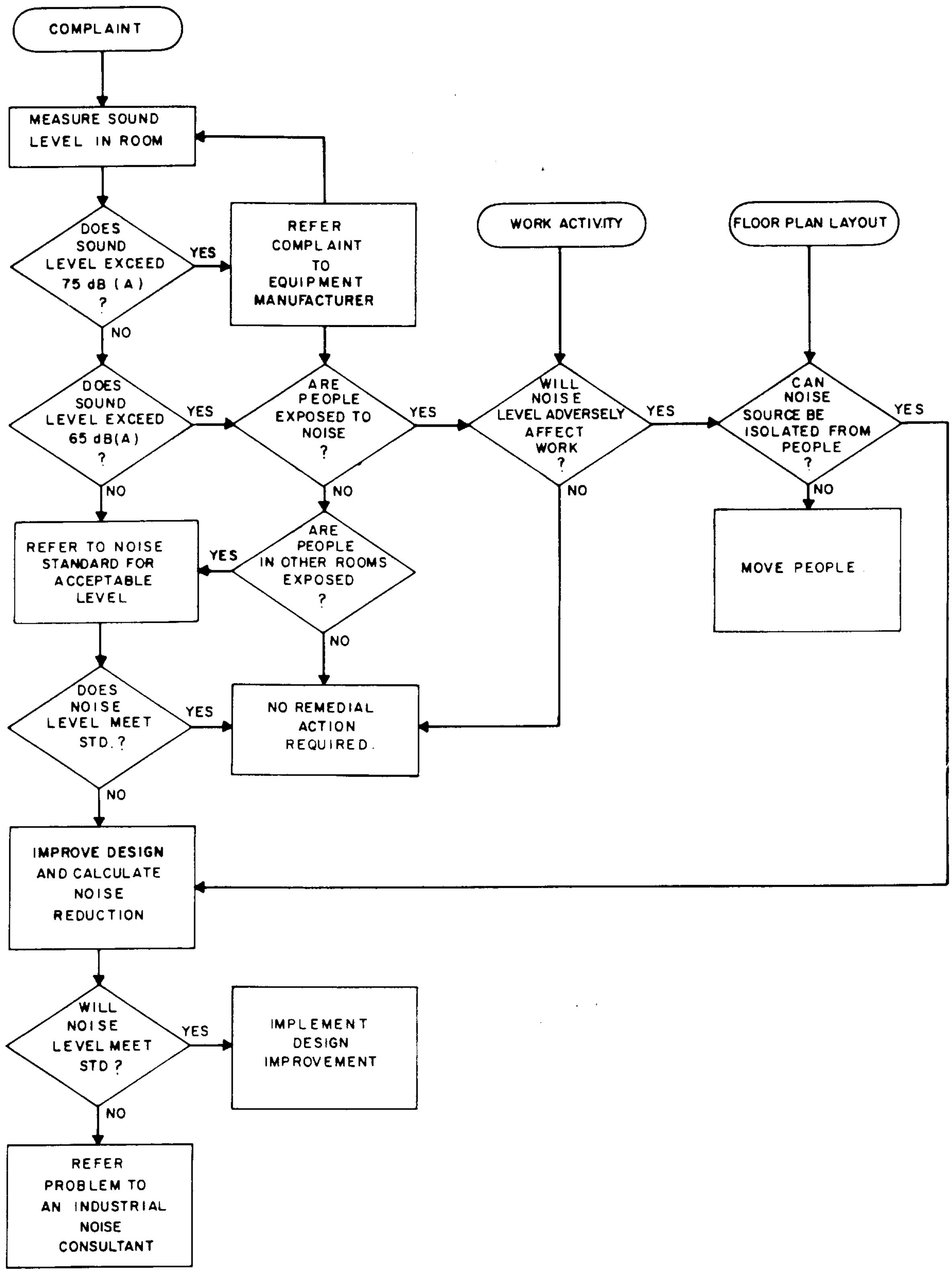


Fig. 9—Procedure for Investigating Complaints of Noise in Telephone Buildings