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ABSTRACT

California has conducted on-site sound surveys of 36 different schools to determine the degree of noise, and thus disturbance, within the learning environment. This report provides the methodology and results of the survey, including descriptive charts and graphs illustrating typical desirable and undesirable sound levels. Results are presented for the following questions: What are the typical sound levels in open plan schools where few, if any, physical barriers exist between classes? Is it possible to obtain good sound control with open space planning? When do satisfactory acoustic performance levels stop and when do interference levels start? and What differences in architectural designs and finishes contribute to satisfactory or unsatisfactory acoustic performance? (GR)

School Sound Level Study

CALIFORNIA STATE DEPARTMENT OF EDUCATION
Bill Honig—Superintendent of Public Instruction
Sacramento, 1986

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Introduction

In the spring of 1975, the Bureau of School Facilities conducted a survey of sound levels in different kinds of spaces typically found in a variety of public schools throughout California. Prior to the survey most acoustic or sound control data familiar to the bureau dealt with sound control barriers between rooms or from the outside to the inside of a building. The designing of such barriers to meet given sound control needs is a relatively simple and well-known process.

In this study, however, the bureau wanted to find answers to the following questions:

1. What are the typical sound levels in open plan schools where few, if any, physical barriers exist between classes?
2. Is it possible to obtain good sound control with open space planning?
3. When do satisfactory acoustic performance levels stop? When do interference levels start?
4. What differences in architectural designs and finishes contribute to satisfactory or unsatisfactory acoustic performance?

On-site surveys were made and measurements taken by bureau staff members at 36 different schools throughout California. The staff used the A-scale of a General Radio Number 1565-B sound level meter. All measurements listed and sound levels given in this report of the study are intended to reflect typical active periods at each location. Unusual high and low measurements or unusual situations are not reflected in the report.

Results of the Survey

Some general patterns began to emerge after a number of on-site surveys had been made. Areas that seemed to the observers to be acoustically comfortable were determined to have a relatively uniform sound level, with an almost complete absence of high-impact noises generated by slamming doors or lockers; a relatively high ambient noise level; and no continuously high noises, such as those generated by internal combustion motors and grinders. Figure 1 illustrates examples of both desirable and undesirable sound nodules. The method for developing these nodules or "pictures" of sound is explained in the section entitled "Survey Process" and illustrated in figures 6 and 7. In general, areas that seemed comfortable acoustically developed uniform and compact sound nodules, and areas that seemed uncomfortable acoustically developed wide-ranging, nonuniform nodules. Sporadic high-impact noises were especially uncomfortable and distracting. Quality of sound was found to be as important as quantity of sound.

The questions asked in the survey and the answers given to those questions follow:

1. *What are the typical sound levels in open plan schools where few, if any, physical barriers exist between classes?*

   The typical or mean sound levels in carpeted open plan areas in both elementary and high schools are shown in Figure 2. They average about 63 decibels (dB), with a range from 52 dB to 73 dB. About 90 percent of generated noise falls within the 54 to 68 dB range.

   The point at which the sound level becomes uncomfortably high is arbitrary and subject to individual differences. The overall observation was that at about the 68 or 69 dB level, students obviously began to have trouble understanding what was being said and to be distracted by neighboring classes. Therefore, 70 dB, the closest round number, was selected as the arbitrary interference level base.

2. *Is it possible to obtain good sound control with open space planning?*

   Where activities are suitable for the use of carpeting as a flooring material, satisfactory sound control is relatively simple and economical to obtain. The carpet must be used in conjunction with other sound absorptive surfaces, such as an acoustic tile ceiling, however. Without carpet, effective sound control in open space classrooms is virtually impossible to achieve. The acoustic difference between a relatively thin glue-down type of carpet and a heavy broadloom carpet on a heavy pad is readily apparent.

3. *When do satisfactory acoustic performance levels stop? When do interference levels start?*

   Table 1 illustrates the answer to these questions. As previously noted, the interference level is based on the opinion of the surveyors, teachers, and students regarding the noise levels at the various schools.

Table 1
Decibel Levels

Quiet level Below 50 dB	*Satisfactory level* 50 to 70 dB
Interference level 70 to 90 dB	*Danger level* Above 90 dB

Regarding the quiet level, the State Department of Transportation considers 55 dB (residential areas) and 50 dB (schools) the points above which it will take corrective action for noise generated on freeways. This survey verifies the validity of the 50 dB level as being "very quiet." Outside noises of up to 50 dB cause virtually no interference with normal educational activity. It is actually less distractive if the sound level is never allowed to drop too low (i.e., below 50 dB).

Within the satisfactory level, noise levels from 50 to 70 dB between class groups engaged in similar activities caused no interference problems. For example, in an open pod arrangement of four to six mathematics classes in which each class had a separate teacher and all classes were in close general proximity to each other, noise levels ranging from 50 to 70 dB generated few noise interference problems for students and teachers.

Noise levels above 70 dB cause interference in a formal teaching–learning situation, but reasonably uniform noise levels up to 80 dB are tolerable in dining halls, gymnasiums, and multipurpose rooms where students are divided into very small groups.

Quality of sound, always important, becomes very important at levels over 70 dB. Band music, for example, is tolerable, even enjoyable, at levels up to 100 dB. Cal-OSHA considers the danger level to start at 90 dB. Table 2 shows exposure time at sound levels that will cause permanent hearing loss to nearly all persons.

Table 2
Cal-OSHA Criteria for Permanent Loss of Hearing

Maximum number of hours	*Sound level dBA*
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼	115

The highest sound level encountered in the survey, 102 dBA, was generated by a power lawn mower in a small, hard-surfaced motor test room. After 1½ hours of being subjected to noise of 102 dBA, permanent loss of hearing would be almost certain to result (see Table 1). Appliances such as grinders, power tools, computers, and data processing equipment that produce a very high and continuous noise level should be acoustically isolated.

4. *What differences in architectural designs and finishes contribute to satisfactory or unsatisfactory acoustic performance?*

The architectural designs and finishes that appear to contribute to satisfactory acoustic solutions in open plan classroom areas or pods include:

a. Installation of wall-to-wall carpet—the deeper the pile, the better. (Acoustics are improved by laying the carpet on a thick pad.)
b. Installation of full acoustic tile ceiling.
c. Installation of coffered ceiling with acoustic tile on the face of the coffers.
d. Installation of acoustic tile walls above 7 feet, 0 inches.
e. Installation of sound absorptive area dividers where necessary for visual partitioning.
f. Allowance of 40 to 45 square feet per pupil in open space classrooms rather than 35 square feet because corridors are usually not required and the corridor space should be made available for classroom space instead. (Simply removing the walls from standard size classrooms is insufficient. Additional square footage is necessary.)
g. Maintenance of ambient noise level at about 50 dB to act as a masking noise. (This level may be produced by sound from air conditioning and ventilating equipment or artificially.)
h. Implementation of suggestions found in Figure 12 and Figure 13.

The need for the faculty and staff to reduce generated sound levels through good teaching practices is also important. Other significant factors are student grouping, voice levels, and location of the teacher.

Where possible, adequate sound absorptive materials and acoustic consideration should be a part of the design for shop classrooms. Not providing adequate sound absorptive materials is an expensive mistake because poor sound control characteristics too often limit the use of these spaces. (See Figure 3 for good, bad, and typical examples of wood and metal shop nodules.)

Some situations approach the danger level (above 90 dB). Similarly, dining areas, multiuse rooms, and gymnasiums that typically have a hard floor have a special need for adequate sound absorptive materials on the walls and ceiling. See Figure 4 for examples of such sound nodules. It is possible to treat these spaces successfully acoustically at a nominal cost.

Note that even up to 40 typewriters in a classroom present no sound level problems where adequate acoustic treatment is provided, as shown in Figure 5.

Thus, a good sound environment may be developed in open plan schools by the use of quality absorptive materials. Savings that result by using the open plan include not having to use interior partitioning and doors, including expensive frames and hardware, and lower energy costs for heating and cooling that result from improved air circulation.

Survey Process

As previously noted, on-site surveys were made and measurements taken by bureau staff members at 36 different schools throughout California, and they used the A-scale of a General Radio Number 1565-B sound level meter. Because all measurements listed and sound levels given were intended to reflect typical active periods at each location, unusual high and low measurements or unusual situations were not discounted.

The unit measure for sound is the decibel. Good quality sound level meters have a choice of an A, B, or C scale. All dB listings in this report should be considered as dBA (decibels in the A-scale). (A description of the A-scale may be found in the section entitled "Description of the A-scale.") Some attempts by various authorities to relate sound intensities to familiar situations are shown in figures 8 through 11. Note that the intensity of sound is logarithmic relative to the decibel rating. Hence, 70 dB of sound is 10 times greater than 60 dB, 80 dB is 100 times greater than 60 dB, and so on. In the wood and metal shop examples in Figure 3, there is 100 times more noise (that to the ear would sound about four times louder) on the average in the noisiest shop measured than in the quietest shop measured. Apparently, effective sound control measures do make a difference.

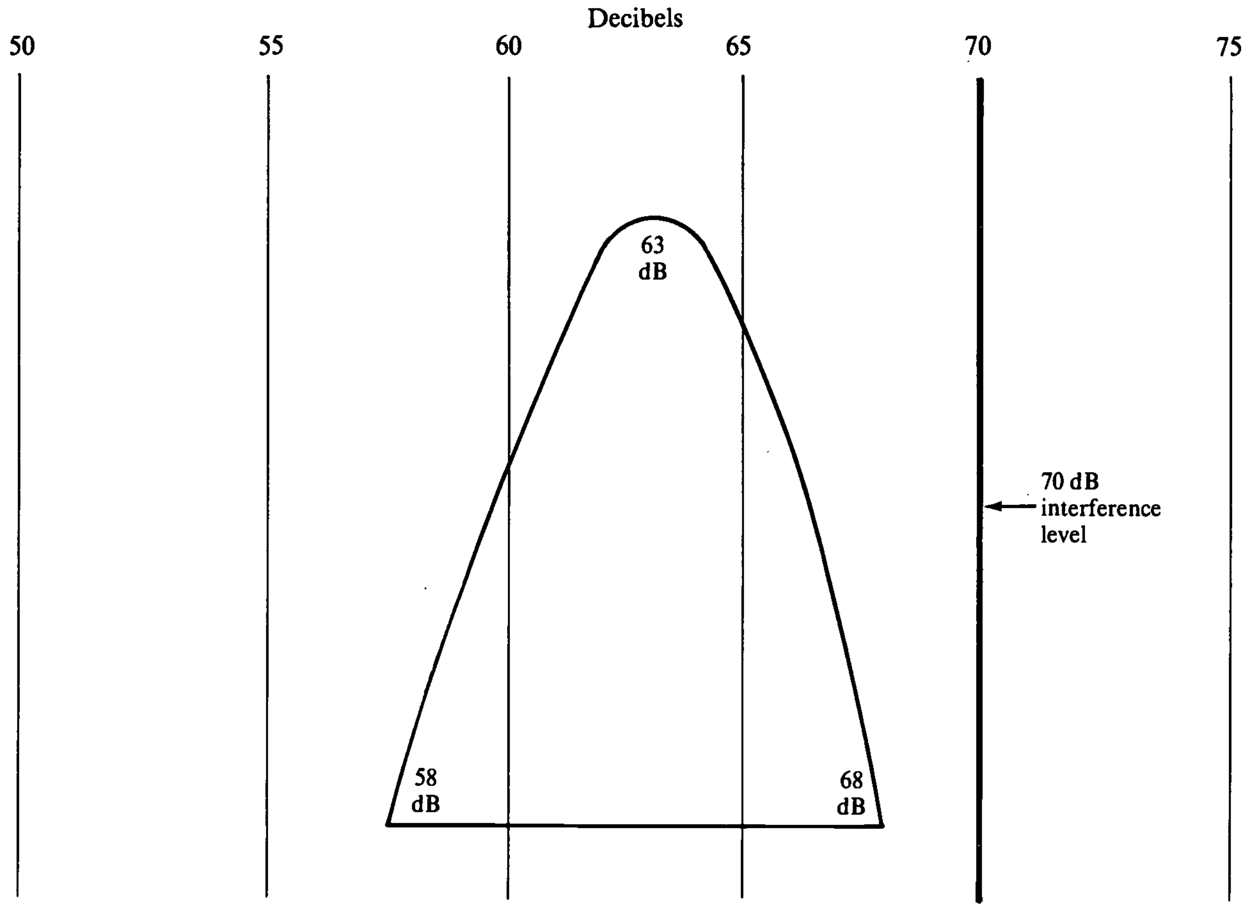
Typically, the level registering on the meter was read at five-second intervals for a period of about five minutes. The readings, as compiled on a sound level histogram (see Figure 6), result in a "picture" of incidences of sound at each possible level during the readings. These nodules of sound that are pictured may be compared with each other, and norms and means may be established.

Description of the A-scale

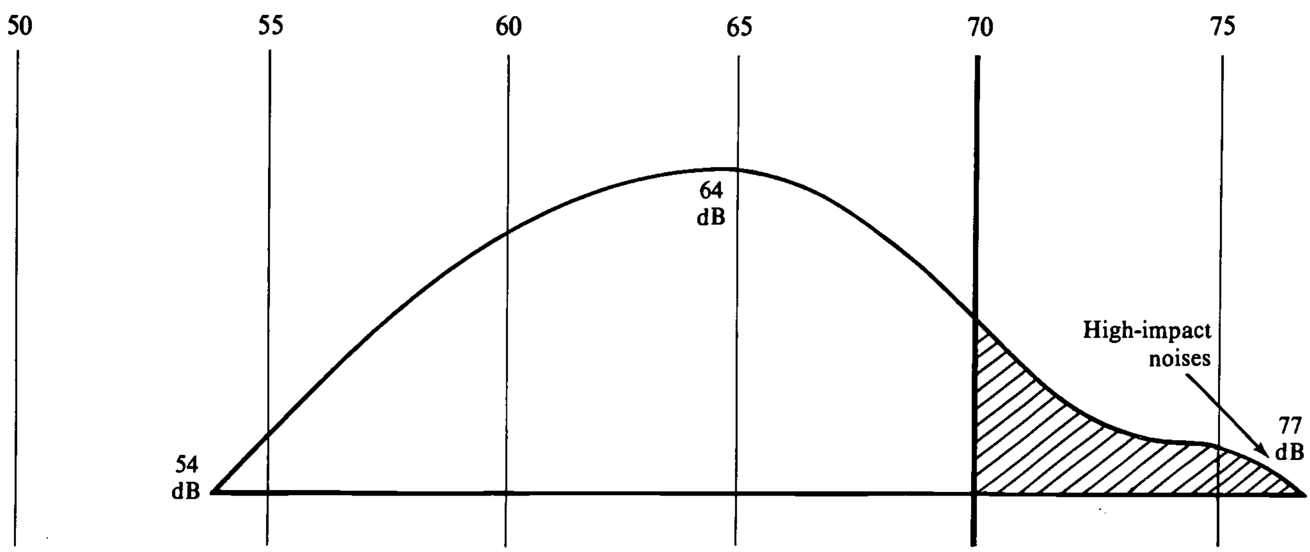
Findings of past studies indicate that when people make relative judgments of the loudness or annoyance or disturbance of a noise, their judgments correlate quite well with the A-scale sound levels of those noises. Other weighting networks have been used in these kinds of judgment tests. Some give poor correlation with judgments; and others, specially devised, may give slightly better correlation with the judgments of loudness, annoyance, or disturbance. The specially devised weighting networks were usually built around special problems or special applications, and those weightings do not appear to be sufficiently superior in their test results to justify construction, validation, certification, and use of sound meters having those special weightings for everyday use. The A-scale network has been in existence for over 30 years and has been incorporated in many U.S. sound level meters. Thus, it is an available instrument of relatively low cost and has been found to give reliable, reproducible correlation with many jury-type subjective judgments on the noisiness of many different types of noise.[1]

[1] *Fundamentals and Abatement of Highway Traffic Noise*. Prepared by Bolt, Beranek, and Newman, Inc. Washington, D.C.: U.S. Department of Transportation, 1973. Used by permission of the U.S. Department of Transportation.

Figure 1. Quality of sound



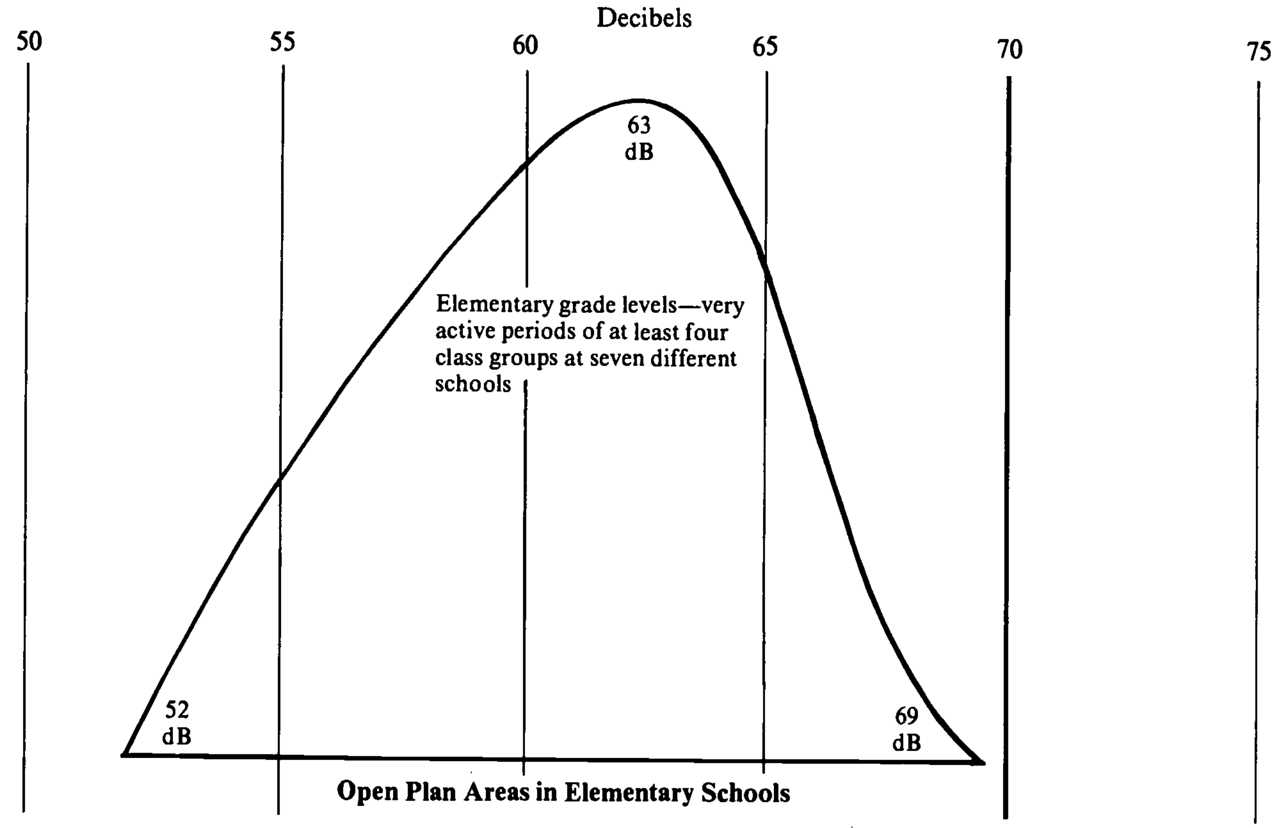
Desirable Sound Nodule
(uniform and compact)



Undesirable Sound Nodule
(nonuniform and wide-ranging)

Figure 2. Typical sound nodules

Satisfactory Examples of Open Plan Schools



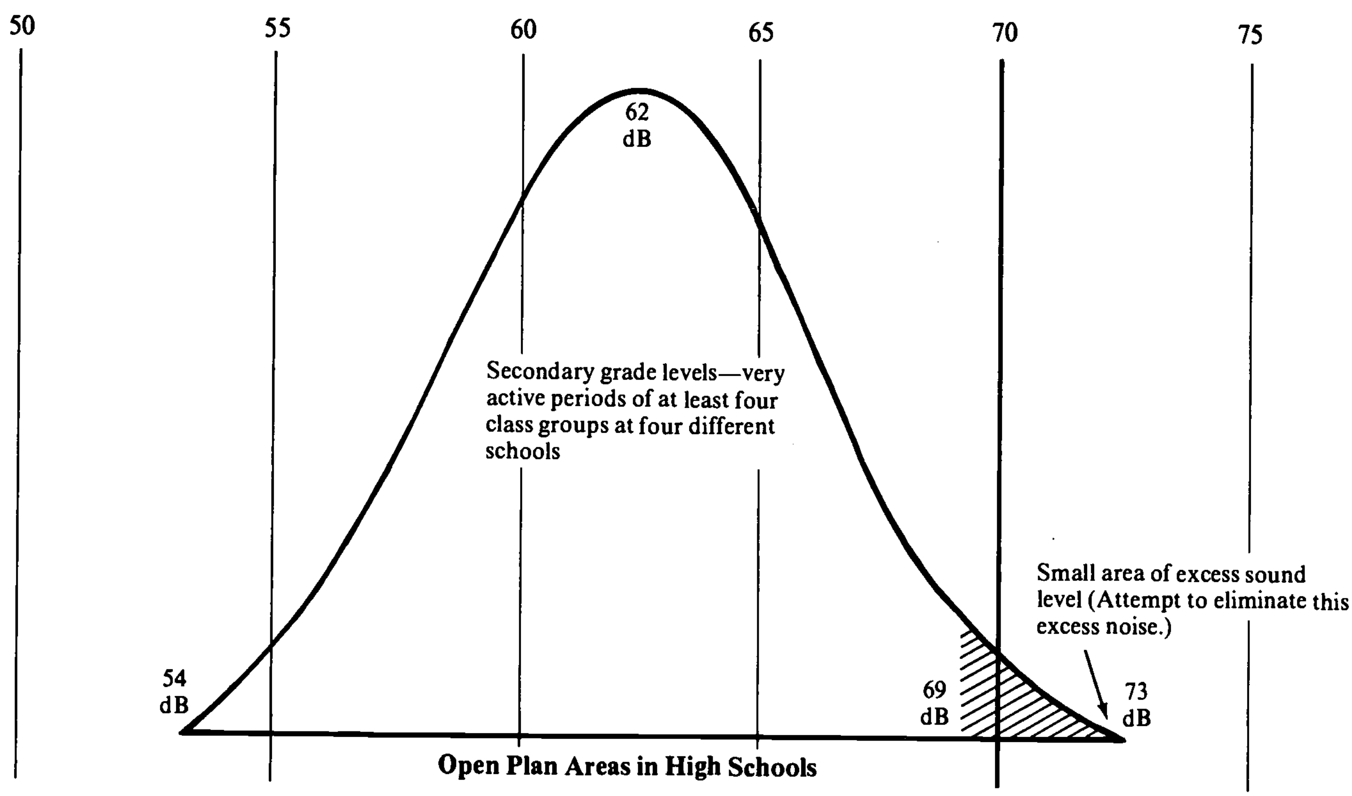


Figure 3. Wood and metal shop sound nodules

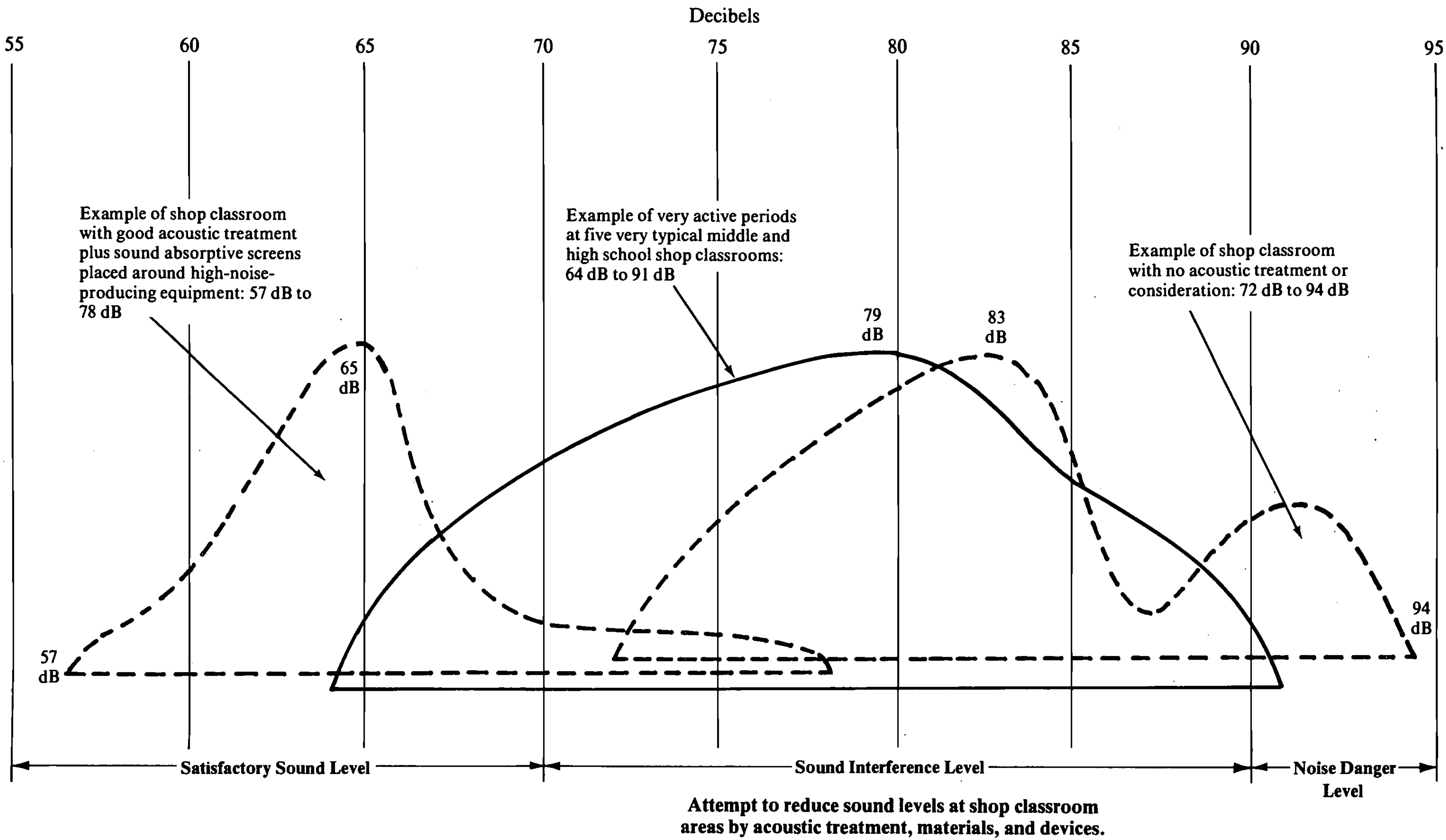


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Figure 4. Sound nodules

Hard Floor Multiuse Rooms and Gymnasiums at Nine Middle Schools and High Schools

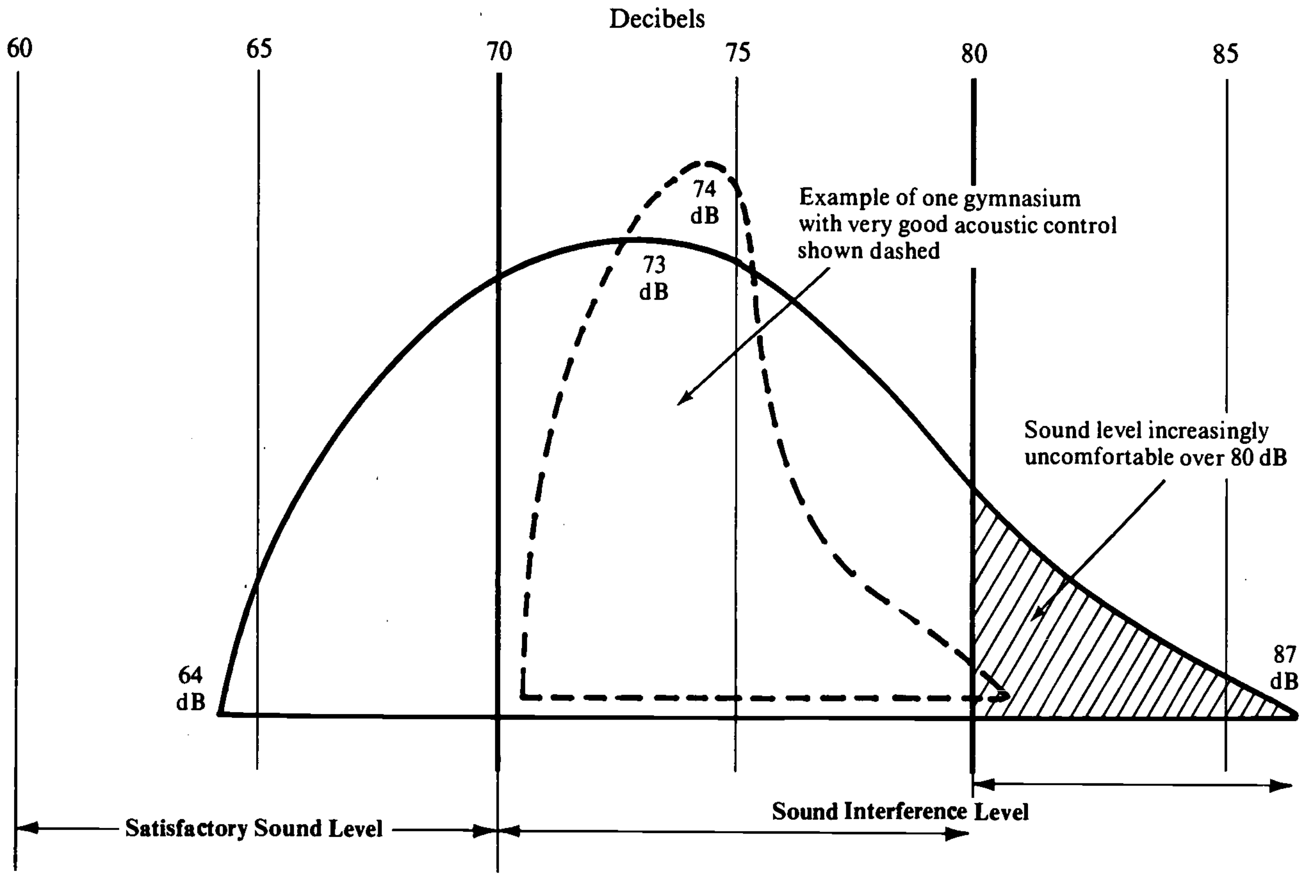


Figure 5. Typing areas that have carpet flooring and acoustic tile ceilings—four high schools

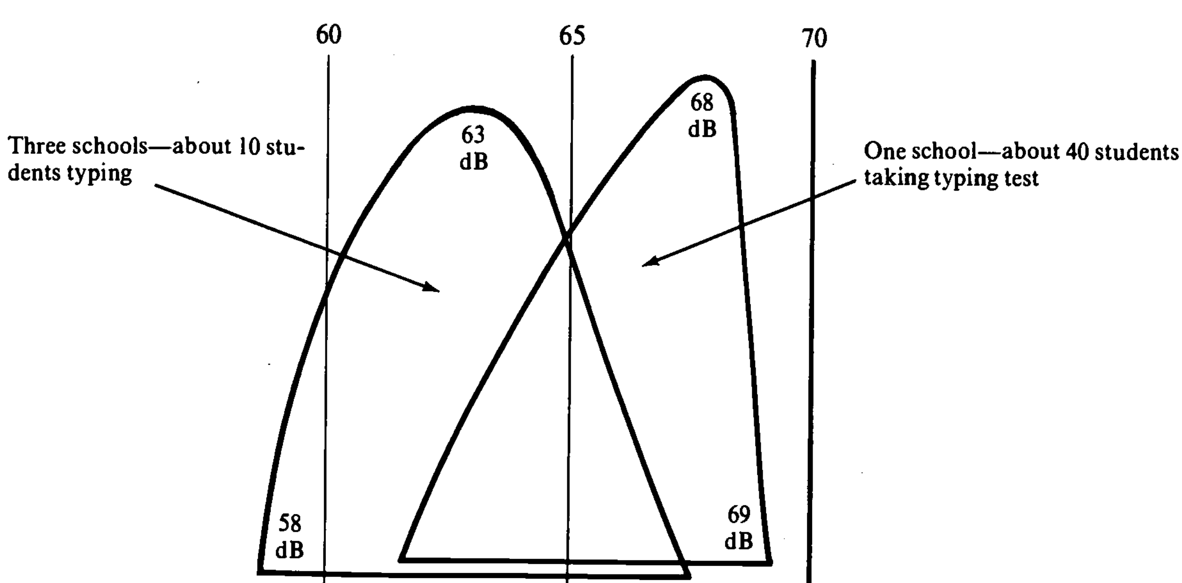


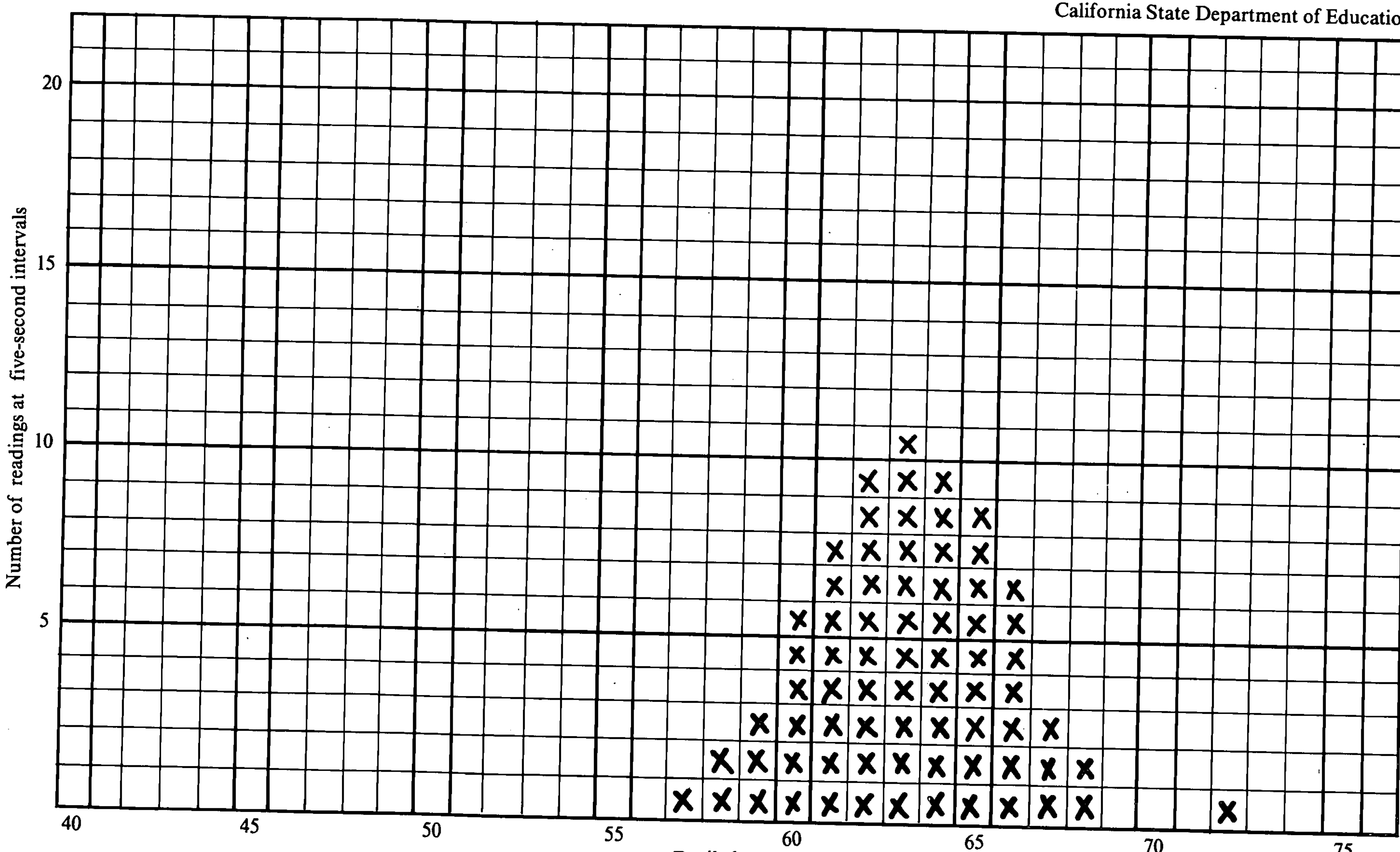
Figure 6. Sound level histogram

School: *ABC ELEMENTARY MIDDLEVILLE SCHOOL DISTRICT* Location of measurement: *CENTRAL POD - SIX ACTIVE CLASSROOMS, GRADES ONE THROUGH THREE*

Description: *CARPET FLOORING GLUED DOWN WITH NO PAD*
ACOUSTIC TILE CEILING AT 9 FEET, 6 INCHES
VINYL CLOTH ON GYPSUM BOARD WALLS

Date: *APRIL 1, 1975* By: *BURKE*

School Facilities Unit
California State Department of Education



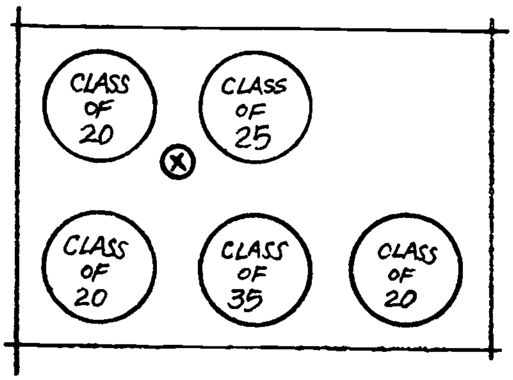
(Based on a form developed by Ultra Systems, Newport Beach, California. Used with permission.)

Figure 7. Ambient noise survey data sheet

Position: CENTRAL CITY HIGH, CLASSROOM POD E
Engineer: BOB JONES
Day of week: TUES.   Date: OCT. 20, 1975   Time, begin: 8:40 AM
Cal., begin: 9:00 AM

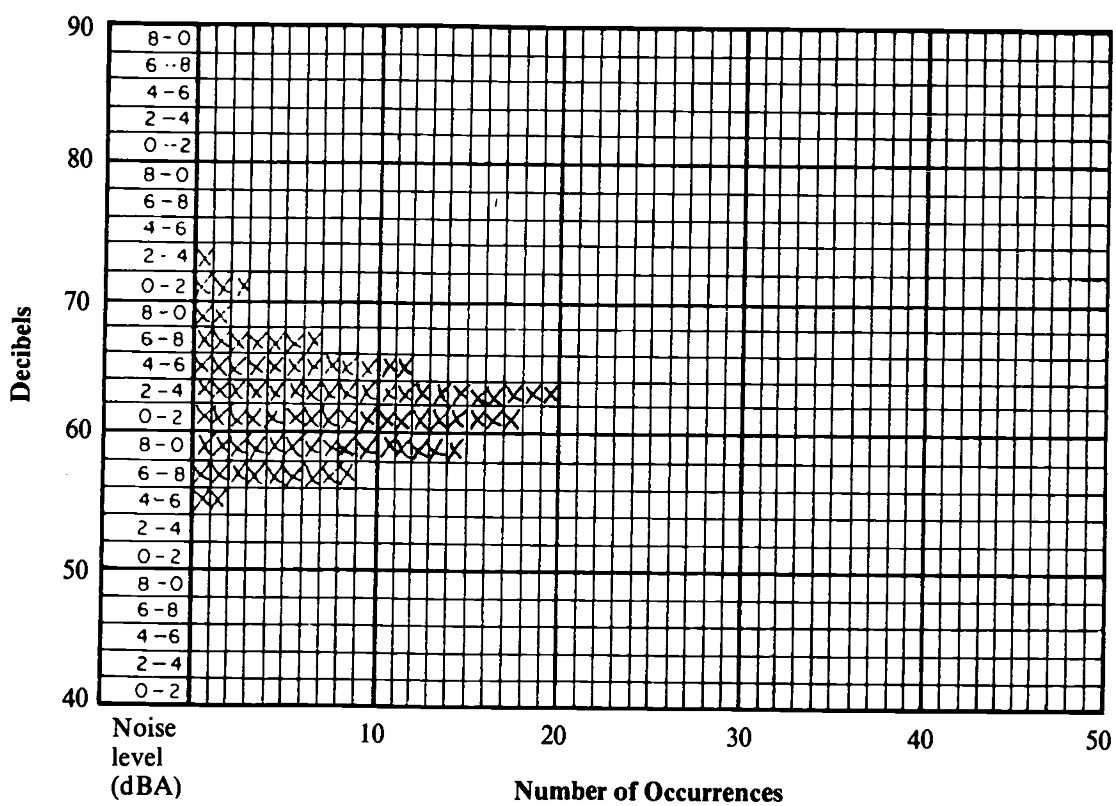
Job No. ______
Finish: ______
Finish: ______
Sky: ______
Wind: ______
dBA L_{10}: ______
Limits, dBA: ______

Notes and sketch:



PLAN: NO SCALE
⊗ = MEASUREMENT LOCATION

CARPET: FLOORING
CONCRETE BLOCK: WALLS
ACOUSTIC TILE: CEILING



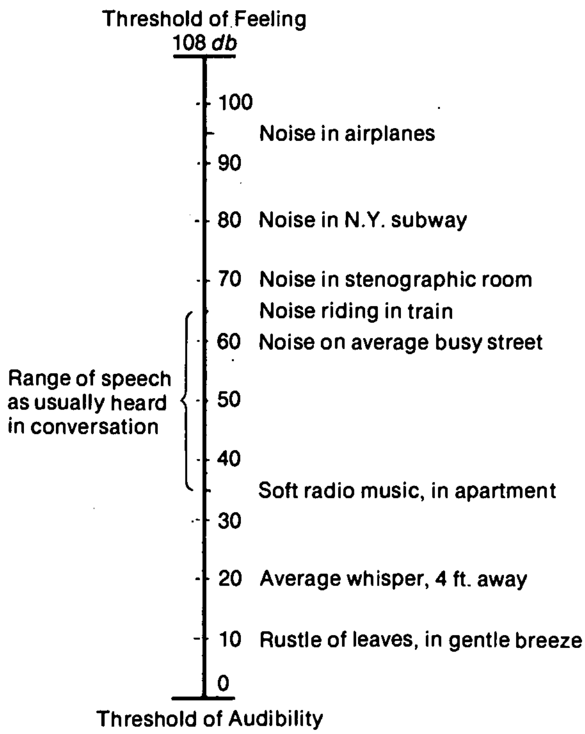


Figure 8. Examples of decibel ranges of various sounds

Source: Kidder, Frank E., and Harry Parker. *Architect and Builder's Handbook.* New York: John Wiley and Sons, Inc., 1931, p. 1869. Copyright, © 1884, 1892, 1897, 1904, by Frank E. Kidder; 1908, 1915, 1921, by Katherine E. Kidder; 1931, by Bradley P. Kidder. Reprinted by permission of John Wiley and Sons, Inc.

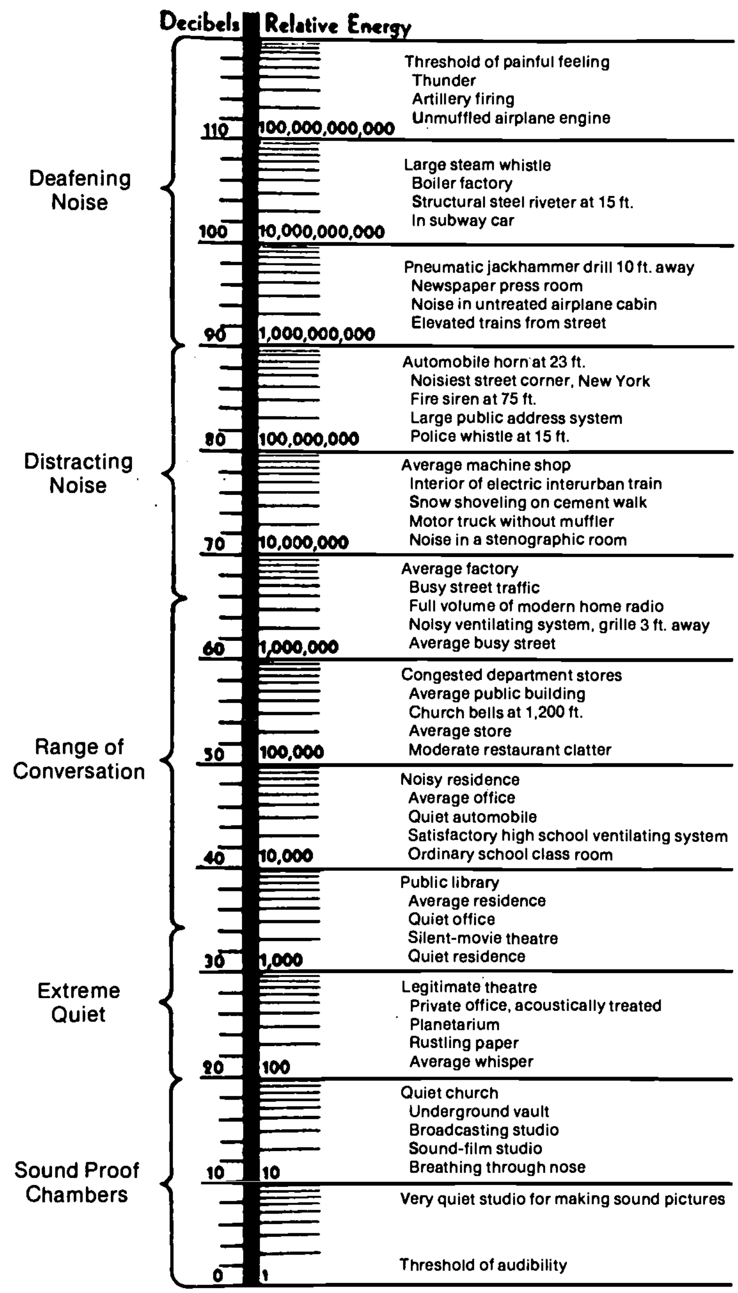


Figure 9. Examples of intensities of various sounds

Source: Graf, Don. *Don Graf's Data Sheets.* New York: Van Nostrand Reinhold Co., Inc., 1949, p. 687. Copyright, © 1944, 1949, Reinhold Publishing Corporation. Reprinted by permission of Van Nostrand Reinhold Co., Inc.

Figure 10. Relationship of sound intensity, level, and loudness and relationship of change in sound pressure level and change in apparent loudness

RELATIONSHIP OF SOUND INTENSITY, LEVEL, AND LOUDNESS

INTENSITY (RELATIVE ENERGY - UNITS)	SOUND PRESSURE LEVEL (DECIBELS)	LOUDNESS
100,000,000,000,000	140	Jet aircraft and artillery fire
10,000,000,000,000	130	Threshold of pain
1,000,000,000,000	120	Near elevated train
100,000,000,000	110	Inside propeller plane
10,000,000,000	100	
1,000,000,000	90	Full symphony or band
100,000,000	80	Inside auto at high speed
10,000,000	70	
1,000,000	60	Conversation, face to face
100,000	50	Inside general office
10,000	40	Inside private office
1,000	30	Inside bedroom
100	20	Inside empty theater
10	10	
1	0	Threshold of hearing

NOTE:

The decibel number represents a ratio (actually 10 x the logarithm) of the Intensity measured to a reference intensity roughly equivalent to the threshold of hearing.

SUBJECTIVE EFFECT OF CHANGE IN SOUND PRESSURE LEVEL

CHANGE IN SOUND PRESSURE LEVEL	CHANGE IN APPARENT LOUDNESS
3 dB	Just perceptible
5 dB	Clearly noticeable
10 dB	Twice as loud (or 1/2)
15 dB	Big change
20 dB	Much louder (or quieter)

Glenn A. Kahley; Vincent G. Kling and Associates; Philadelphia, Pennsylvania
Lyle F. Yerges, Consulting Engineer; Downers Grove, Illinois

5. ACOUSTICAL DESIGN

(A)

Choose materials, systems, and constructions to control sound transmission.

(B)

Design shapes, areas, volumes and surfaces to accomplish desirable interior accoustical conditions.

(C)

Economic factors:

"Build in" good acoustics.
Choose simplest construction meeting criteria.
Law of diminishing returns quickly limits benefits of increasing any variable (such as weight, thickness, etc.).
It is much cheaper to avoid noise problems in original design or in choice of equipment than to correct them later.

GENERAL NOTES:

Choose quiet, protected site; orient building with doors and windows facing away from noise sources.

Arrange building spaces with noisy equipment and noisy activities together, away from quiet spaces.

Choose quiet mechanical equipment.

Consider acoustical properties of all materials, systems and constructions before choosing any.

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