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# MODEL NOISE CONTROL PROVISIONS FOR BUILDING CODES AND IMPLEMENTATION MANUAL

August 1981


U.S. ENVIRONMENTAL PROTECTION AGENCY
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16. ABSTRACT A model municipal noise control code for buildings has been developed. Also included is an implementation manual for this code. The provisions of the code were developed with three objectives in mind. First, they attempt to minimize the adverse health and welfare effects of intruding noise without requiring the construction of economically unreasonable buildings. Proposed standards for the outdoor reduction of noise levels are achievable with existing materials and construction techniques. Secondly, enforcement for the review of plans and for the acceptance of completed buildings are described. Thirdly, this material should help jurisdictions develop a process of administration and enforcement that is compatible with existing building code procedures. The model provisions of the proposed building code contain performance standards. These standards are administered and enforced by review of plans and inspections during and after construction of buildings.

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# PREAMBLE

## INTRODUCTION

There is little question that noise has become an element of our environment that needs to be controlled. In a 1974 survey of housing in the United States, outdoor noise, including both street noise and noise from airplane traffic, was the most often mentioned undesirable condition in the vicinity of people's homes (U.S. Department of Commerce, 1976).

In fact, our living environment has become so noisy that government action to abate the noise can be said to rest on the elementary responsibility of government to preserve the public health and welfare, just as it protects us from harmful drugs and impure foods. One way to limit the noise to which we are exposed is through better building design and construction. Some government agencies have begun to require, or to encourage at the design and construction stages, the application of quantitative standards or guidelines for environmental noise and for privacy.

At the Federal level, the Department of Housing and Urban Development (HUD) has taken and is continuing to take action to study and, within its legal mandates, to set guidelines or standards to control building design and construction. The Federal Housing Administration (part of HUD) has developed standards designed to provide "...a high degree of acoustic and auditory privacy between living units and between living units and public and service spaces..." in housing projects that it insures or subsidizes (FHA, 1971). HUD has also provided interim standards that identify the limits of acceptable indoor and outdoor noise exposures and minimum acceptable sound

insulation between dwelling units for all HUD supported projects (HUD, 1971).

But Federal agencies, such as HUD or the Environmental Protection Agency (EPA), do not have the legal authority required to impose noise control standards on a majority of the new residential construction in the U.S. Therefore, action to implement noise control considerations at the design and construction stages must take place at the state or local level. Such state or local action is harmonious with the current popular preference for less Federal involvement and for more state and local solutions to identified problems.

Recognizing both the need for noise control design in residential buildings and the necessity to have this need met at the state or local level, EPA has exercised its authority under the Noise Control Act of 1972 (42 U.S.C. §4913) to prepare this *Model Noise Control Provisions for Building Codes (Model Provisions)* and the associated *Implementation Manual.*

This Preamble details the problems that the Model Provisions address, describes briefly the solutions to the problems, and tells how the Model Provisions and Implementation Manual were developed to solve these problems. The relationships between the Model Provisions and Implementation Manual are discussed, and finally, the Model Provisions are presented with descriptive comments.

The Problems

> "Managers and owners of apartments readily admit that market resistance is not only increasing as a result of excessive noise transmission, but also that lack of both acoustical privacy and noise control are the greatest drawbacks to apartment living..." (Finger, (1972).

Most of us have either lived in an apartment with inadequate sound isolation or have visited friends who live in such an apartment. We were made aware of the poor sound isolation in at least one of three ways: The apartment building either failed to shield us from the noise of the neighbors, did not adequately isolate us from outdoor noises, or assaulted us with the noise from the air conditioner, heating system, or other mechanical equipment. Some of us may even have complained to the building owner or to local government officials about the noisy conditions. But most of us probably did not complain, because we thought complaining would do no good, because we felt that our living conditions were temporary, or because noise was one of our lesser problems.

But whether we complain about it or not, this intrusive noise must still be thought of as having an adverse effect on the public health and welfare. The phrase "health and welfare" is defined as "complete physical, mental, and social well-being and not merely the absence of disease and infirmity." "Health and welfare" also includes personal comfort and well-being and the absence of mental anguish and annoyance (EPA, 1974).

Noise can adversely affect the community's health and welfare in many ways. Current studies of the effects of noise show that people repeatedly exposed to typical city noise levels exhibit increased inability to concentrate, impaired aptitude to perform

even simple tasks, and loss of sleep (Schultz, 1971). Noise can make conversation at normal voice levels impossible, thus seriously degrading the quality of life. "People who live in noisy places tend to adopt a lifestyle devoid of communication and social interaction. They stop talking, they change the content of the conversation, they talk only when absolutely necessary, and they frequently must repeat themselves." (EPA, 1978). More and more evidence suggests that there may even be a link between noise exposure and the development and aggravation of a number of heart disease problems.

> "We now have millions with heart disease, high blood pressure, and emotional illness who need protection from the additional stress of noise." Dr. Samuel Rosen, Mt. Sinai Hospital (EPA, 1978).

In any case, it is now generally agreed that something must be done about the noise. The movement involves the United Nations and Federal, state, and local governments, as well as science, industry, the legal profession, and citizens.

Four general avenues of noise abatement are available:

- Making *and enforcing* laws against unnecessary man-made noises, usually related to the use of machines
- Making *and enforcing* laws that limit the noise-making capability of the machines themselves
- Land use planning to separate unavoidable community noise sources from sensitive residential and recreational areas
- Attenuating the noise through the use of better building design and construciton.

The Model Noise Control Provisions are concerned primarily with the last approach: the design of buildings and their related structures to protect people from noise; and this process becomes the government's responsibility through the fashioning and enforcement of building codes.

*Noise Control Technology*

It is often thought that the chief obstacle to adequate noise control in dwellings is limited technology. This position is not unusual among acoustical engineers and consultants who face difficult problems almost daily and who are constantly aware of their own limitations. Moreover, this view is sometimes shared by government agencies concerned with providing people with suitable living facilities. This conclusion comes from practical and disappointing experience in various technical and building studies and experimental housing projects. HUD has recently suggested "two principal reasons why dwellings being built have inadequate noise exclusion capability:

(1) The state-of-the-art in architectural acoustics has not yet advanced to the stage where it is possible to design relatively lightweight structures with exceptionally good noise isolation properties.

(2) The best technological means presently known for soundproofing buildings increase cost appreciably."

However, it is possible that there are at least three other factors that significantly affect the noise control properties of buildings:

(1) Considerations other than acoustical requirements are given priority in determining the basic type of building structure, the method of assembly, and even the finish materials.

(2) Even if acoustical requirements *have* been considered early in the building design, and suitable noise control structures have been selected, a building structure that is acoustically adequate in itself can be inadequate when completed because the designer did not develop the architectural details with noise control in mind; "leaks" and "flanking transmission" bypass the intrinsic isolation that the structure could achieve.

Typical oversights of architectural detailing are as follows:

| Flanking Noise Paths | Noise Leaks |
|---|---|
| Unmuffled duct runs | Poor seal around duct penetrations |
| Outdoor sound path, window-to window | Poor mortar joints, porous masonry block |
| Hall sound path via openings under doors | Back-to-back wall cabinets or electrical outlets |
| Open lighting/ventilating troughs in floor-ceiling structure | Holes, gaps at wall, or floor penetrations |

Attention has been called to these matters frequently in the past. But something more forceful is required before the important acoustical details will be dealt with effectively from the architect's drawing board to the finished building.

(3) Even though the architect has chosen building constructions that acoustically are basically very good and has carefully described in his drawings and specifications all those construciton details that will avoid flanking transmission, the ultimate success of the building in providing adequate noise isolation depends directly on the work of men with no knowledge of acoustical problems: the contractor and the individual trades people.

*Existing Building Codes*

Noise control provisions are included in the building codes of many jurisdictions. Unfortunately, these provisions have not been very successful in preventing complaints form the tenants of the buildings to which the codes apply.

In part, the failure of existing code provisions is due to the fact that the masking effect of background noise is not taken into account in the codes; thus, a construction that would be entirely satisfactory in a noisy urban neighborhood would give rise to serious complaints in a quiet suburb.

Nevertheless, even when the architect *has* chosen appropriate building constructions that should satisfy the tenants at least most of the time, there are still complaints.

The answer to this apparent contradiction is not hard to find. If a reasonably good structure was selected in designing the building and, nevertheless, there are serious noise problems, then something must have gone wrong in the process of constructing the building .... something that the building code, as written, and that the normal practices of the enforcement agency were powerless to prevent. Either there were no noise control provisions in the code, the code specified the wrong accustical properties for the building, or the code was ineffectively enforced.

The Solutions

The Model Noise Control Provisions and the Implementation Manual have been written in an attempt to solve these major shortcomings of existing noise control provisions. Specifically, these two documents (together with the forthcoming Construction

Handbook) are designed to help jurisdictions achieve three important objectives.

First, they attempt to minimize the adverse health and welfare effects of intruding noise without requiring economically unreasonable buildings, from the construction viewpoint. Standards for adequate reduction of outdoor noise levels and of mechanical equipment noise levels are based on previous EPA work relating noise levels to health and welfare effects (EPA, 1974). These standards are achievable with existing materials and construction techniques. Standards for privacy are also achievable through current technology, but are based on the best available data relating tenant satisfaction to degree of privacy.

Second, the two documents describe enforcement procedures that should be used to obtain maximum compliance. The Model Provisions specify separately the enforcement procedures for the review of plans and for the acceptance of the completed buildings. Criteria and guidelines are given for judging the adequacy of the plans; and final post-construction tests are required to ensure that the completed building complies with the noise control requirements.

Finally, the Model Provisions and Implementation Manual should help the jurisdictions develop a process of administration and enforcement that is compatible with the existing building code procedures. The format of the Provisions is similar to that of the Uniform Building Code (UBC) (ICBO, 1976), and should fit easily into many existing building codes.

Like many building codes, the Model Provisions contain performance standards. These standards are administered and enforced by review of plans, inspection during construction, and inspection after construction prior to occupancy.

## Development of the Model Noise Control Provisions and Implementation Manual

The Model Provisions and the associated Implementation Manual were developed through a two-phase process. The first phase consisted of a review and evaluation of (1) the schemes used by U.S. and European national governments, (2) those used by U.S. state and local governments, and (3) those used in the major model building codes to specify and enforce acoustical requirements for buildings. This first phase led to the identification of basic factors that determine the feasibility and effectiveness of any scheme to control noise in buildings. The second phase, the complete development of the Model Provisions and Implementation Manual, then drew upon the strengths and attempted to avoid the weaknesses of these existing schemes. The following paragraphs summarize this two-phase process leading to the Model Provisions and the Implementation Manual.

### *Review and Summary of Existing Schemes*

#### European Practices

The most ambitious programs are those of Denmark, France, the Netherlands, Sweden, and West Germany. Much less active programs exist in Austria, Belgium, East Germany, and Switzerland. Almost all countries require the inspection of drawings before issuing a building permit, and most suggest or require approved types of construction known from experience or measurements to provide reasonable sound insulation. The majority of European countries also conduct at least some testing in finished buildings.

Beyond that, some of the enforcement methods are unique. Tending to emphasize the positive, France and the Netherlands have either developed nationally recognized rating schemes as

a means of exploiting the market advantage afforded by improved acoustical quality, or have provided greater financial support for improved acoustical performance in buildings. As a kind of complement to such action, West Germany and Denmark have sometimes required rent reductions because of poor acoustical performance.

The effects of comprehensive enforcement practices are impressive. The most dramatic improvements occurred in West Germany, where the average airborne sound insulation rating in government-financed buildings increased approximately 8 dB in the 18 years from 1950 to 1968. Over the same period, the average impact noise insulation rating increased approximately 20 dB. The most important factor in gaining these improvements was probably that payment of the final one-third of the construction funds is held up until compliance with code requirements is demonstrated by acoustical measurements in the completed building.

U.S. Federal Practices - HUD

Two sets of noise control requirements fall within the purview of HUD. One is the Minimum Property Standards of the Federal Housing Administration (FHA, 1971); the other is HUD Department Circular 1390.2, "Noise Abatement and Control: Departmental Policy, Implementation Responsibilities" (HUD, 1971). The former emphasizes noise insulation between dwelling units; the latter is concerned primarily with limiting the noise intruding into dwellings from outdoors.

A review of HUD's experiences in implementing its noise control policy yielded several general guidelines for the development of the Model Provisions and Implementation Manual. First, ease of administration is essential if the program is to be effective. Ease of administration can be achieved either by

making the Model Provisions consistent with the existing system of building code administration and enforcement, or by modifying the existing code system to ensure that the Model Provisions will be adopted and enforced. Second, the Model Provisions should have build-in flexibility so that communities with different problems can adapt the code to their specific needs. Finally, the Model Provisions should provide a systematic means for determining whether or not various noise control designs comply with the noise control requirements.

## State, Local, and Model Building Code Noise Control Practices in the United States of America

The noise control provisions of approximately 20 American building codes were examined to determine what requirements they generally include; and more than a dozen building code enforcement officials were interviewed in an attempt to learn about specific enforcement practices.

In general, all the codes contain similar provisions, and most are enforced with similar practices. Most have noise insulation provisions applicable to multifamily dwellings, including hotels and motels. These noise insulation provisions are given as performance requirements in terms of Sound Transmission Class (STC) ratings for airborne sound insulation and Impact Noise Ratings (INR) or Impact Isolation Class (IIC) for impact noise insulation. The performance requirements apply to party walls and floor-ceiling assemblies separating adjacent dwellings.

None of the codes, however, gave any justification for selection of the particular numbers that constituted the performance requirements. Although a few codes contain provisions that limit the level of outdoor noise intruding into dwelling

spaces, most do not. Most codes permit field testing of completed buildings at the building official's discretion, but such tests are almost never carried out.

Most jurisdictions enforce the noise control provisions primarily by reviewing plans of proposed buildings to determine that adequate noise control designs are used. Although most jurisdictions also inspect the buildings, both during construction and after construction prior to occupancy, almost none pay close attention to acoustically significant construction details during these inspections.

*Evaluation of Schemes*

The review of existing schemes led to identification of factors that can contribute to or diminish the feasibility and/or effectiveness of any scheme to control noise in buildings. By examining different schemes for the presence or absence of these factors, the feasibility and effectiveness of several possible noise control schemes were evaluated.

A scheme is *feasible* if people understand it, can comply with it, and can enforce it. Additionally, a scheme is considered feasible if it is easy to adopt, i.e., if it fits readily into a jurisdiction's existing system of administration and enforcement. A scheme is *effective* if its adoption and enforcement leads to the construction of buildings that actually achieve adequate noise control.

Factors that contribute to feasibility may reduce a scheme's effectiveness and vice versa. For exmaple, the following factors improve the chances that a scheme will be effective:

(1) Performance requirements are clearly stated;

(2) Performance requirements are applied not just to specific individual assemblies (walls, floor-ceiling) but to the building as a whole, i.e., attention to details of assembly, installation, and flanking paths is included;

(3) Materials necessary to provide required performance are known;

(4) Construction details necessary to provide required performance are known;

(5) Final tests of performance are mandatory;

(6) Limits are placed on noise that intrudes into dwelling units from outdoor noise sources and from mechanical equipment in the building;

(7) Numbers selected as performance requirements are based on reliable information about how people respond to intruding noise.

But some of these factors, for example (5), although necessary to ensure a scheme's effectiveness, greatly diminish its feasibility (ease of adoption) by increasing the difficulty of administering and enforcing the scheme.

*Final Development of the Model Noise Control Provisions*

The route taken in developing the Model Provisions, therefore, depended upon a balance struck between feasibility and effectiveness. EPA has decided, for two primary reasons, to develop Model Provisions that are aimed at high effectiveness. First, although high effectiveness may mean that the Model Provisions contain factors, such as a mandatory final test, that could discourage

adoption (reduce feasibility), EPA may be able to take action to counteract this reduction in feasibility. EPA could, for example, provide special funding for states or municipalities that adopt the Model Provisions. Such funding would be used to train and equip the officials who enforce the noise control provisions.

Second, any jurisdiction that adopts the Model Provisions will do so with the expectation that the provisions will provide an effective method for controlling noise in buildings. They would not bother to amend their laws or to adopt new laws if they thought that such efforts would be *feasible* but not *effective* in providing adequate acoustical quality.

Therefore, the Model Provisions have been designed primarily to be effective. They have provisions that control most types of noise likely to occur in buildings. They contain mandatory final tests for demonstration of compliance. The noise control requirements are based on how people respond to intruding noise and are designed to minimize the adverse effects intruding noise can have on health and welfare.

But feasibility has not been overlooked. Every effort has been made to develop Model Provisions that are understandable both by those who must comply with and those who must administer and enforce the noise control provisions.

### Energy Conservation

Currently, there is much interest in reducing or minimizing energy consumption. Implementation of the Model Provisions, specifically Section 3507, "Isolation from Noise Generated Outdoors," will help jurisdictions in their efforts to minimize building energy consumption. In two areas, the techniques used

to increase the noise reduction of building exterior walls are identical to the techniques of building energy conservation. These are:

(1) the doubling of barriers, as in double-glazing of windows or the addition of storm windows;

(2) the elimination of air leaks by the use of caulking and weather stripping.

To the extent that these methods are used, noise control and energy conservation go hand-in-hand.

The resultant energy savings can be quantified as dollars saved. Even when noise control means that a building must be air conditioned so that windows can be kept closed year-round, dollar savings result. For example, in an energy conservation study of public buildings, calculations showed that for 1100 schools examined, net energy consumption could be reduced on the average by $1500 per year per school by reducing air leaks and reducing thermal transmittance (u), even though energy was required to ventilate the buildings (FAA, 1977).

## GENERAL PROVISIONS

### Purpose

The Model Noise Control Provisions and Implementation Manual are designed to provide jurisdictions with the tools needed to minimize tha adverse effects on health and welfare of noise intruding into residential structures and schools. Three types of intrusive noise are addressed: noise from neighboring spaces that compromises privacy in multifamily dwellings and in school buildings; outdoor noise that intrudes into residential structures and schools; and noise from mechanical equipment located within residential structures and schools.

The Model Provisions contain the specific performance requirements and the administrative and enforcement procedures that both the enforcing agency and the public must know. The Implementation Manual contains information that will assist a jurisdiction in adoption and enforcement of the Model Provisions. The forth-coming Construction Handbook will provide examples of adequate designs.

### Method

The Model Noise Control Provisions are based primarily on *performance* standards, and thus conform with existing model building codes. These codes are generally *performance codes* rather than *specification codes* (Sanderson, 1969). Performance standards alone, however, cannot ensure that the completed building will have adequate noise isolation properties. In addition to knowing what performance standards must be met, the architect/designer must know which designs will provide this performance, and the builder, obviously, must construct the building in strict accordance with the selected design.

Consequently, in order to ensure that the required noise control is achieved in the completed building, the total system of administration and enforcement must provide (1) performance standards, (2) designs for structures that meet the performance standards, and (3) a method that encourages construction according to design. The Model Noise Control Provisions presented here and the associated Implementation Manual supply the performance standards and a method that encourages construction according to plan. A future EPA publication (the Construction Handbook) will supply details of typical adequate designs.

Ascertaining that the completed building contains all the noise control details specified in the plans is a difficult, and a somewhat unusual, problem. The problem of building a wall that will provide the designed sound isolation is different from building a wall that will provide the designed strength. The strength of a finished wall depends primarily on construction techniques that are familiar to most builders; serious flaws are usually obvious. Acoustical integrity, on the other hand, rests on small, seemingly unimportant and, in the finished building, unseen details. Whether or not a specific bead of caulking is properly applied or whether or not a plumbing penetration is sealed can have a significant effect on the noise isolation provided by the completed structure. If there is no way to check positively that these details are properly executed, and if there is no tradition of attention to unseen details, there is little incentive for construction personnel to give them the attention they require.

The Model Provisions include the only certain method for ensuring that the noise control details are properly executed: final performance tests prior to occupancy. Certainly, some

will object to using such tests — Who will do it? Who will pay for it? If a building fails a test, who is responsible for corrective action?

The Model Provisions address these problems. The jurisdiction decides who will do the tests before the Model Provisions are adopted; the Implementation Manual discusses the costs of testing. The Model Provisions make the building owner (permit applicant) responsible (just as he is ultimately responsible for compliance of all other aspects of the building code); but, as with other aspects of design, the owner may contractually pass the responsibility for compliance with the noise control performance standards to a qualified acoustical engineer/consultant.

Use of a performance test is necessary: it is the only way to ensure that the building is constructed according to plan. Initially there will be fear of failure and, certainly, some buildings may fail, but most will not. The Model Provisions require that the reasons for failure be located and remedied. Eventually, after all persons concerned have had some experience with construction of acoustically adequate structures, failures will be less and less frequent.

*The problem of adequate noise control is not a question of finding adequate designs and materials, but a question of constructing the building according to plan.*

Flexibility

Realizing that different jurisdictions have different noise control needs, flexibility has been built into the Model Noise Control Provisions. None of the sections dealing with noise control — Airborne Sound Isolation for Privacy, Impact Noise

Isolation, Mechanical Equipment Noise, Isolation from Noise Generated Outdoors – depends for its administration and enforcement upon any of the other noise control sections. Thus, jurisdictions can choose not to adopt one or another of these provisions. For example, in practice, some jurisdictions may not have outdoor noise levels high enough to cause problems, (the Implementation Manual tells how to estimate outdoor noise levels), and thus will not need the outdoor noise provision. However, most jurisdictions will probably wish to adopt the other three noise control provisions dealing with indoor noises.

### Format of the Model Noise Control Provisions

The basic numbering system, the subject division, and the terminology where applicable are derived from the UBC. But with minor revisions the Model Noise Control Provisions will fit into other model building codes, such as the Standard Building Code (SBCCI, 1976) or the Basic Building Code (BOCA, 1976).

### Enforcement Agency

The agency that administers and enforces the Model Provisions must have the legal authority to do so. The agency must have the authority to determine whether or not those people subject to the legal requirements are in compliance, to take action against those not in compliance, and to deal with cases where variances or exceptions from specific requirements are necessary.

For the purposes of administering and enforcing the Model Noise Control Provisions, the office of the building inspector, or some similar office, if it exists, will probably already have all the required legal mandates. Specifically, such an office is likely to have:

(1) authority to require submission of building plans and specifications;

(2) authority to require submission of computations or other data that demonstrate compliance of building plans with the code;

(3) authority to grant/deny building permits based on review of plans and specifications;

(4) authority and expertise needed to inspect buildings under construction;

(5) procedures for handling violations of building code provisions;

(6) an appeal board or board of adjustments to deal with disputes concerning code interpretations and to handle variances or exceptions.

Consequently, unlike an ordinance designed to contain all provisions necessary for its administration and enforcement, the Model Noise Control Provisions are designed to fit into existing building codes. They do not, therefore, contain separate provisions that establish powers and duties of the enforcement agency, that specify what administrative action should be taken against code violators, or that set up procedures for dealing with exceptions and variances.

Agencies other than the office of the building inspector could, however, play a valuable role in the administration and enforcement of the Model Provisions. Agencies such as a Health Department or a Department of Environmental Control may already have some expertise in noise measurement or control. Such participation by other agencies could range from reviewing the

acoustical aspects of plans to making the post-construction performance tests. Involvement of other agencies will depend heavily upon available expertise and funding and will have to be determined by each jurisdiction prior to implementation of the Model Provisions. Naturally, any agency involved in the administration and enforcement must be given the required legal authority; Health Department personnel, for example, must have the authority to enter buildings under construction if they are to make the performance tests.

# MODEL NOISE CONTROL PROVISIONS

## INTRODUCTION

The following material is designed to be inserted into an existing building code as a new or amended chapter, section, or article. Any material in the existing code, or in existing ordinances, that applies to noise control in buildings should be repealed.

Many of the Model Provisions sections are followed by explanatory *comments in italics*. These explanations are provided to assist a jurisdiction in the adoption, enforcement, and administration of the Model Noise Control Provisions. Although these explanations are *not* to be a part of the language inserted into the jurisdiction's building code, they should not be discarded. Since the explanations will be useful after the Model Provisions have been adopted, they should be made available to both administrative/enforcement staff and to the public who must comply with the provisions. For example, the explanations, together with the adopted provisions, might be published in pamphlet form for distribution to building permit applicants.

The general format and section numbering used here is similar to that of the UBC. Since the UBC has a chapter 35 devoted to noise control in buildings (Sound Transmission Control), the Model Provisions are written as Chapter 35 and replace UBC Chapter 35 in its entirety. The existing Chapter 35, Sound Transmission Control, should be repealed, and the new Chapter 35, Noise Control Requirements, adopted.

Section numbering is in accordance with the following format:

Section Title

Sec. 350x. (a)
(b)
(c) 1.
2.
3. A.
B.
C. (1)
(2)
(3) (A)
(B)
(C)

Chapter 35

NOISE CONTROL REQUIREMENTS

Purpose

Section 3501. The purpose of this chapter is to:

(a) Ensure adequate acoustical privacy in residential and educational buildings;

(b) Prevent the intrusion into residential and educational buildings of noise, generated outdoors or by mechanical equipment, that can have an adverse effect on health and welfare.

Scope

Section 3502. (a) General. This chapter specifies noise control requirements for Group R and Group E occupancies.

(b) Noise Generated Indoors. Group R occupancies containing two or more dwelling units or guest rooms, including hotels, apartment houses, lodging houses, and dwellings, shall comply with the requirements of Sections 3504 and 3505. All Group R occupancies shall comply with the requirements of Section 3506.

Group E occupancies, Division 1, including any building used for educational purposes through the 12th grade by 50 persons or more for more than 12 hours per week or four hours in any one day, shall comply with the requirements of Sections 3504 and 3506.

Section 3504 specifies minimum airborne sound isolation requirements that apply between any two private spaces and between any public space and any private space. Section 3505 gives minimum impact noise isolation requirements that apply between any two

dwelling spaces and between any public space and any dwelling space. Section 3506 specifies maximum permissible interior noise levels that result from the operation of mechanical equipment.

(c) Noise Generated Outdoors. All Group R occupancies and all Group E occupancies shall comply with the requirements of Section 3507. Section 3507 limits interior noise levels that result from outdoor noise sources by specifying minimum permissible sound level reductions provided by exterior shells of buildings.

*Comments*

*This chapter sets noise control standards for both residential (Group R occupancy) and educational (Group E occupancy) buildings, and this section specifies precisely which standards apply to which types of buildings. First, this section ensures that standards for acoustical privacy (Section 3504) and for impact noise (Section 3505) are applied to all residential-type buildings that are likely to have more than one family, or more than one person, living separately in independent living facilities for long or short periods of time. Thus, these standards apply to buildings such as hotels, motels, apartment houses, and townhouses constructed within a single structure, but not to detached single-family residences. Single-family residences are not included because not only could providing the sound isolation increase single-family house costs unacceptably, but also it is expected that families can deal in their own ways with the privacy needs of family members.*

*Second, this section ensures that standards for mechanical equipment noise are applied to all residential structures.*

*Third, this section ensures that standards for acoustical privacy and for mechanical equipment noise are applied to specific educational facilities. The impact noise standards are not applied to educational-use buildings because impact noise in these buildings is judged to be not generally a significant problem.*

*Finally, this section also ensures that all residential structures, including single-family dwellings, all buildings used for educational purposes through the 12th grade for more than 12 hours per week or four hours in any one day, and all buildings used for day-care purposes for more than six children, are isolated against the intrusion of excessive outdoor noise. Jurisdictions may wish to have the provisions of Section 3507 apply to other, or additional, occupancies, such as institutional or business occupancies.*

Definitions

Section 3503. The following definitions apply to terms only as they are used in this chapter.

ACOUSTICAL TERMINOLOGY: All acoustical terminology, not defined below, shall be that contained in ASTM C634-77 "Standard Definitions of Terms Relating to Environmental Acoustics."

ADJACENT spaces are rooms, hallways, stairways, etc., constructed so that part or all of a wall or floor/ceiling of one space forms part or all of a wall or floor/ceiling of another.

ANSI is the American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

ASHRAE is the American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., 345 East 47th Street, New York, NY 10017.

ASTM is the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

A-WEIGHTING NETWORK is an electrical circuit built into a sound level meter that has the frequency response characteristics specified in ANSI S1.4-1971, "Specification For Sound Level Meters."

A-WEIGHTED SOUND LEVEL is the sound level as measured on a sound level meter (or equivalent) having the A-weighting Network.

DAY-NIGHT SOUND LEVEL, abbreviated as DNL and symbolized as $L_{dn}$, is the equivalent A-weighted sound level during a 24-hour period with 10 decibels added to the equivalent A-weighted sound level during the nighttime hours (10:00 p.m. to 7:00 a.m.).

dB is the abbreviation for decibel.

DECIBEL is the unit of sound level. A sound level is the quantity measured by an instrument that satisfies the requirements of ANSI S1.4-1971, "Specification for Sound Level Meters."

DWELLING SPACE is a dwelling unit or a guest room.

ENGINEER/CONSULTANT is a qualified acoustical engineer/consultant.

EQUIVALENT A-WEIGHTED SOUND LEVEL is the A-weighted sound level that, if constant over a given time period, has the same sound energy as does a time-varying, A-weighted sound level over the same period.

EXTERIOR SHELL is all walls, floors, and roofs and all elements of these walls, floors, and roofs, such as doors, windows, vent openings, that, taken together, completely define the exterior boundaries of a building.

FOOD WASTE DISPOSER is an electrically powered device that is installed as part of the plumbing system and that reduces food waste to particle sizes that, with the aid of water, are discharged into the plumbing drainage system.

GUEST ROOM is any room or rooms used, or intended to be used, by one or more guests primarily for sleeping purposes.

INTERNATIONAL STANDARD is a standard published by ISO.

ISO is the International Organization for Standardization, Geneva. Copies of ISO publications (International Standards) may be obtained from ANSI.

MAJOR APPLIANCE means any or all of the following:

Clothes Dryer — an electrically powered machine for drying fabrics by evaporation through the use of various combinations of heat, air flow, and tumbling;

Clothes Washer — an electrically power machine for washing fabrics in water;

Dishwasher — an electrically powered device that uses water to wash and rinse dishware, glassware, cutlery, and most cooking utensils, and discharges waste water into the plumbing drainage system. A blower and heater may be used to dry the dishes.

Range Hood — a device designed to remove cooking-polluted air from the stove area, using one or more electrically powered fans or blowers.

MAJOR MECHANICAL EQUIPMENT is all mechanical equipment except major appliances and food waste disposers.

MECHANICAL EQUIPMENT is all machinery, including all components thereof, such as ducts, piping, and vent openings, which is usually operated at least once a week to provide sanitation, power, light, heat, cooling, ventilation, air-conditioning, refuse disposal, transporation, or similar service for a building, and which by design is a part of the building.

NORMALIZED SOUND LEVEL DIFFERENCE is the sound level difference adjusted to the expected acoustical conditions when the receiving room under test is normally furnished. The method for determining the normalized sound level difference is given in ASTM E597-77T, "Determining a Single-Number Rating of Airborne Sound Isolation in Multiunit Building Specifications."

OUTDOOR DAY-NIGHT SOUND LEVEL is the day-night sound level outside the exterior shell of a building generated by sources of noise outside the building.

PRIVATE SPACE is a dwelling unit, a guest room, or a teaching unit.

PUBLIC SPACE is an area of a building to which the public at large has access, or to which all or most tenants or occupants have access. Public space includes such areas as corridors, hallways, laundries, lobbies, lavatories, stairways, etc., serving more than one tenant.

QUALIFIED ACOUSTICAL ENGINEER/CONSULTANT is a person who shall have demonstrated his competence, to the satisfaction of the Building Official, in making noise measurements and in the analysis and design of noise control features for buildings.

SOUND LEVEL is defined under DECIBEL.

SOUND LEVEL DIFFERENCE is the difference between the average sound levels produced in two rooms by the operation of a test sound source in one of the rooms.

SOUND LEVEL METER is an instrument that complies with the requirements of ANSI S1.4-1971.

SOUND LEVEL REDUCTION is the difference, in decibels, between the outdoor equivalent A-weighted sound level and the corresponding equivalent A-weighted sound level inside a building.

STC or SOUND TRANSMISSION CLASS is a single-number rating of the airborne sound insulation of a specific partition (party wall or floor/ceiling construction), derived from sound transmission loss values in accordance with the procedures of ASTM E413-73, "Determination of Sound Transmission Class."

TEACHING UNIT is any space of a Group E occupancy that is used for instruction or study and is completely enclosed by walls, floors, ceilings, and components thereof.

*Comments*

*Guest Room: This definition is different from the UBC definition, which includes as guest rooms "[every] 100 square feet of superficial floor area in a dormitory...." Guest rooms so defined obviously could not be provided with the required airborne sound isolation.*

*Teaching Unit: This definition is intended to exclude open-plan classrooms from the airborne sound isolation requirements, but to include, generally, open-plan schools. In a single large room that has been divided with partial height partitions (i.e., "open-plan") so that several separate activities may be conducted simultaneously, it would not be possible to comply with the airborne sound isolation requirements if they were applied to the partial height partitions. However, it is conceivable that a school might have several large rooms each used in the open-plan fashion and other rooms used for instruction or study. Between these "completely enclosed" large rooms or between these rooms and other nonopen-plan rooms, the airborne sound isolation requirements apply.*

*Definitions that may be useful for understanding this chapter, but which are contained in the UBC are:*

*APARTMENT shall mean a dwelling unit as defined in this Code.*

*APARTMENT HOUSE is any building, or portion thereof, which is designed, built, rented, leased, let, or hired out to be occupied, or which is occupied as the home or residence of three or more families living independently of each other and doing their own cooking in the said building, and shall include flats and apartments.*

*DWELLING is any building or any portion thereof which is not an "Apartment House," "Lodging House," or a "Hotel" as defined in this Code, which contains one or two "Dwelling Units" or "Guest Rooms," used, intended, or designed to be built, used, rented, leased, let, or hired out to be occupied, or which are occupied for living purposes.*

*DWELLING UNIT is a single unit providing complete, independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking, and sanitation.*

*Group E Occupancies shall be:*

*Division 1. Any building used for educational purposes through the 12th grade by 50 or more persons for more than 12 hours per week or four hours in any one day.*

*Division 2. Any building used for educational purposes through the 12th grade by less than 50 persons for more than 12 hours per week or four hours in any one day.*

*Division 3. Any building used for day-care purposes for more than six children.*

*Group R, Division 1 Occupancies shall be:*

*Hotels and apartment houses.*

*Convents and monastries (each accommodating more than 10 persons).*

*Group R, Division 3 Occupancies shall be:*

*Dwellings and lodging houses.*

*HOTEL is any building containing six or more guest rooms intended or designed to be used, or which are used, rented or hired out to be occupied, or which are occupied for sleeping purposes by guests.*

*LODGING HOUSE is any building or portion thereof, containing not more than five guest rooms which are used by not more than five guests where rent is paid in money, goods, labor, or otherwise. A lodging house shall comply with all the requirements of this Code for dwellings.*

*MOTEL shall mean hotel as defined in this Code.*

*OWNER is any person, agent, firm, or corporation having a legal or equitable interest in the property.*

*STAIRWAY. Two or more risers shall constitute a stairway.*

Airborne Sound Isolation for Privacy

Section 3504. (a) Performance Requirements. All Group R occupancies and Group E occupancies to which this section applies [identified in Section 3502 (b)] shall be designed and constructed to provide normalized sound level differences (sound isolation) at least equal to the values in Table No. 35-A. The requirements of Table No. 35-A apply to projects where outdoor noise levels equal or exceed a day-night sound level of 60 dB. For projects where the outdoor day-night sound level is less than 60 dB, the corrections of Table No. 35-B shall be *added* to the normalized sound level differences and design requirements of Table No. 35-A. Outdoor day-night sound levels for use with Table No. 35-B shall be determined in accordance with computation procedures described in the Implementation Manual.

TABLE NO. 35-A. AIRBORNE SOUND ISOLATION REQUIREMENTS: NORMALIZED SOUND LEVEL DIFFERENCE AND ASSOCIATED DESIGN REQUIREMENTS

| | Private Space to Private Space | Public Space to Private Space |
|---|---|---|
| Normalized Sound Level Difference | 45 dB | 40 dB |
| Design Requirements (STC) | 50 | 45 |
| Typical Adequate Constructions | See Construction Handbook | See Construction Handbook |

TABLE NO. 35-B. ADJUSTMENTS TO TABLE NO. 35-A AS DETERMINED BY OUTDOOR DAY-NIGHT SOUND LEVEL

| If Outdoor Day-Night Sound Level Is: | | Add the Following to All Numbers In Table No. 35-A |
|---|---|---|
| Equal to or Greater Than | But Less Than | |
| 60 dB | -- | 0 dB |
| 55 dB | 60 dB | 5 dB |
| 50 dB | 55 dB | 10 dB |
| -- | 50 dB | 15 dB |

*Comments*

*These performance requirements ensure that dwelling-to-dwelling and classroom-to-classroom acoustical privacy is achieved.*

*The numbers in Table No. 35-A, adjusted as necessary by values in Table No. 35-B, represent minimum performance standards. In general, the principle is to reduce any noise produced by neighbors in an adjacent apartment (condominium, town house, hotel room, etc.) so that the noise is barely noticeable, if noticeable at all. When these performance standards are met, conversational speech, for example, should be reduced to a barely audible, unintelligible level.*

*Why do the requirements of Table No. 35-A have to be adjusted upward (more isolation) when outdoor noise levels are low? Privacy is not only a measure of how little noise passes from one apartment (condominium, classroom, etc.) to the next, but rather a measure of how little one can hear of the noise that passes from apartment to apartment. Thus, background noise — for example, intruding noise produced by outdoor noise sources — helps make neighbor noise more difficult to hear by covering it up or "masking" it, and therefore it can increase privacy.*

*In fairly noisy areas, such as locations in cities or densely populated suburbs, or in locations near major transportation arteries, the background noise levels will be high, and the noise of neighbors in an adjacent apartment would be more difficult to hear than in a rural setting. Consequently, if the same degree of privacy is to be achieved in quiet as well as in noisy locations within a jurisdiction, more sound isolation will be required of the interdwelling partition in the quiet locations, and the acoustical performance requirements must be adjusted, depending upon the level of the expected background*

noise. Table No. 35-B provides these adjustments as a function of outdoor day-night sound level, and the Implementation Manual (see Step 4, Sec. C.3 of the Manual) provides a method for computing this outdoor day-night sound level.

The method for computing outdoor day-night sound levels takes into account local population density and major street traffic noise sources. Additionally, the method recognizes that outdoor day-night sound levels may be different for different units in the same building. For example, dwelling units facing a highway will experience higher noise levels than would units on the opposite side of the building, facing away from the highway. The method requires adjustments of computed outdoor day-night sound levels for such typical situations.

Noise measurements are not to be used to determine outdoor day-night sound levels for use with Table No. 35-B. Some types of outdoor noise, such as that produced by aircraft or by train passages, cannot be relied upon to mask the noise from an adjacent apartment. Such noise sources do not produce the continuous background noise levels needed for masking. Since it can be very difficult to eliminate the influence of these outdoor sources from noise measurement, the resulting measured levels would not represent the true levels of background masking noise, but would tend to overstate the background noise levels.

(b) Review of Plans. Building noise control design will be considered adequate for purposes of issuance of the building permit if the plans and specifications filed by a permit applicant show that the design of interior walls and floors is in conformance with the STC values of Table No. 35-A, as adjusted by Table No. 35-B, and follows in principle the construction detail guidelines of ASTM E497-73T, "Installation of Fixed Partitions of Light Frame Type for the Purpose of Conserving their Sound Insulation Efficiency."

*Comments*

*Acoustical* isolation *between spaces is the difference, in decibels, between the sound level observed in the noise-source room of a structure and that observed in the listener's or receiver's room. The purpose of this section is to achieve adequate* isolation *between spaces, and this required isolation is given by the normalized sound level differences in Table No. 35-A.*

*On the other hand, acoustical* insulation *refers to the noise-reducing property of a single partition or of a part of a partition, such as a door. The acoustical insulation provided by a partition or by a door, window, etc., is usually determined by testing that individual partition, door, etc., when it is mounted between specially designed noise-source and receiver rooms in a laboratory. Thus manufacturers of partitions or partition components can test their products and provide the prospective purchaser with the measured values of acoustical* insulation.

*Consequently, for designing buildings, values of the acoustical insulation of components are readily available to the architect. The plans, therefore, are approved on the basis of the values of the acoustical* insulation. *The requirements*

*for this insulation are given by the STC ratings (see Definitions, Section 3503) in Table No. 35-A.*

*The Building Official will, therefore, approve plans on the basis of STC ratings. Buildings designed according to the STC ratings of Table No. 35-A will, if constructed according to the plans, provide the associated normalized sound level differences given in the table. The Construction Handbook contains acceptable wall designs and associated STC ratings.*

(c) Acceptance. 1. The building owner shall have the completed building tested for compliance with the normalized sound level difference requirements of this section. Tests shall be made in accordance with ASTM E597-77T, "Determining a Single-Number Rating of Airborne Sound Isolation in Multiunit Building Specifications," and shall be made by a qualified acoustical engineer/ consultant.

2. Testing. A. Initial Measurements. When the first dwelling units, teaching units, or guest rooms are completed in conformance with the test specimen requirements of ASTM E597-77T, measurements shall begin.

(1) Measurements shall be made between adjacent rooms from one private space or public space to an adjacent private space. Measurements shall be made in both the horizontal direction (through walls) and in the vertical direction (through floor-ceilings). Subject to the provisions of (2) and (3) below, a minimum of three examples of each are to be measured in the following space-to-space categories:

(A) private space to private space - horizontal;

(B) private space to private space - vertical;

(C) public space to private space.

(2) The number of examples measured in each space-to-space category shall equal at least ten percent of the total number of dwelling units and guest rooms or teaching units in the building.

(3) If the building contains more than one space-to-space separation construction type (e.g., staggered studs with single layers of gypsum board; concrete block covered with plaster, etc.) in any of the three space-to-space categories, then for each such

category, at least one of each space-to-space separation construction type shall be included in the measurements.

(4) Measurements shall be made from private space or from public space to an adjacent bedroom, if one exists, in the adjacent private space. Otherwise, measurements shall be made from any room in the private or public space to any room in the adjacent private space, as long as the selected rooms are themselves adjacent.

(5) If a measurement yields a normalized sound level difference lower than the value required by Table No. 35-A, as adjusted by Table No. 35-B, the airborne sound isolation is inadequate.

(6) If any of the measurements made on a given space-to-space construction type demonstrate inadequate airborne sound isolation, the Building Official shall require that the building owner have further testing done and remedial action taken in accordance with Section 3508.

B. Additional Measurements. As more dwelling units, teaching units, and guest rooms are completed and conform to the test specimen requirements of ASTM E597-77T, the Building Official may require that more measurements be made. If a significant number of these measurements demonstrate inadequate airborne sound isolation, the Building Official may require that the building owner have further testing done and remedial action taken in accordance with Section 3508.

*Comments*

*Testing for compliance with the airborne sound isolation requirements consists, basically, of making a standard noise in*

*one room and measuring how loud the corresponding transmitted noise is in an adjacent room. The concept behind this acceptance testing is to measure a small, but typical, sample of the most important adjacent spaces.*

*Measure a minimum of three pairs of dwelling units, teaching units, or guest rooms that are horizontally adjacent; three pairs of dwelling units, teaching units, or guest rooms that are vertically adjacent; and three dwelling units, teaching units, or guest rooms that are vertically or horizontally adjacent to public spaces. The total number of pairs measured in each space-to-space category must equal at least ten percent of the number of units in the building. Thus, if there are 30 or less dwelling units and guest rooms, or teaching units in the building, measure three pairs of dwelling units, etc. in the horizontal direction, three pairs of dwelling units, etc. in the vertical direction, and three public-space-to-private-space pairs. If there are more than 30 units, select more pairs for testing until the number of pairs tested in each category equals or exceeds ten percent of the number of units.*

*For some projects, more than one construction type may be used to separate the spaces. For example, dwelling units in one apartment house may be separated horizontally in some cases by brick walls, in other cases by wood frame and plaster walls. In such an apartment house, at least one brick separation and one frame and plaster separation must be measured. If three measurements must be made of horizontal separations between dwelling units [space-to-space category (A)], then either two brick and one frame and plaster or one brick and two frame and plaster separations will be measured.*

*If any of the dwelling units and/or guest rooms have bedrooms that are located next to the adjacent private or public space, these dwelling units or guest rooms should be the ones selected for testing, and the measurements should be conducted between that bedroom and the adjacent private or public space. Since selection of units for testing can be rather involved, the Implementation Manual provides a flow chart for testing in space-to-space categories (A) or (B), (see Step 12, Section C.3 of the Manual).*

*The concept of the initial acceptance testing, (c) 2.A., is to measure the first units completed so that if inadequate airborne sound isolation is discovered, the problem can be located and corrected before all units are finished.* If, however, all units are simultaneously completed, the testing requirements of (c) 2.A. still apply; that is, the minimum examples in each space-to-space category must still be measured. These compliance tests must be mandatory if the airborne sound isolation requirements are to be effective.*

*Note that these mandatory tests are stated as minimum requirements; the Building Official is free to require more measurements to satisfy himself that the building complies with the code's noise control requirements.*

*After these initial mandatory tests are completed for a given project, and remedial action, if necessary, is taken in accordance with Section 3508, the Building Official is intentionally given freedom to decide how much further testing is*

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*To be "completed", units must conform to the test specimen requirements of ASTM-E597-77T. Basically, these requirements impose minimum aging periods for materials such as adhesives, plaster, concrete, mortar, etc., that must cure or dry.

*required. Based on the results of the initial measurements performed on a building, and after he has gained experience in administering these provisions, the Building Official should be able to make informed judgments as to the necessity for further tests. He will know which builders, architects, engineers, or consultants can be relied upon to produce consistently adequate buildings and which produce work of varying quality. The initial tests, however, are always mandatory.*

*This section is written so that the building owner pays for the acoustical testing. Some jurisdictions, however, may wish to have the Building Official or his office carry out the measurements specified in ASTM E597-77T, "Determining a Single-Number Rating of Airborne Sound Isolation in Multiunit Building Specifications," and to have the test paid for by permit fees.* This test has been intentionally designed to use relatively inexpensive equipment and to require only a modest amount of training and technical expertise. It can be done quickly. Consequently, some jurisdictions may see an advantage in having the testing capability in-house, if not in the office of building inspection, perhaps in an agency such as a Department of Health or a Department of Environmental Control that already has some expertise in noise measurement.*

Impact Noise Isolation

Section 3505. All Group R occupancies to which this section applies shall be designed and constructed to minimize transmission of impact noise from dwelling space to dwelling space and from public space to dwelling space. Designs will be considered

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*Note that standards referenced in the code, such as ASTM E597-77T, are summarized in Appendix D of the Implementation Manual.

adequate if they conform with typical designs provided in the Implementation Manual.

*Comments*

*This approach to the control of impact noise differs from what, in the past, has been thought to be good model building code practice. Current practice suggests that a model code provision with respect to impact noise should contain quantitative (numerical) performance standards, supplemented by references to approved test procedures, calculation procedures, and building material ratings.*

*This section to control impact noise is a specification-type provision, rather than a performance requirement, because the state-of-the-art of impact noise measurement simply cannot support reliable performance standards. Existing methods for testing and rating the impact noise isolation performance of materials and designs produce performance numbers that bear almost no relation to people's subjective judgment of impact noise (Schultz, 1974). This lack of reliable performance standards, however, does not mean that adequate designs do not exist; they exist, but we cannot rate them, numerically, in a way that corresponds to people's subjective judgment.*

*Consequently, this section does not specify a performance standard, but rather it references approved designs. Designs provided in the Implementation Manual and in the forthcoming Construction Handbook will form the foundation for approval.*

Mechanical Equipment Noise

Section 3506. (a) Performance Requirements. 1. All Group R occupancies to which this section applies shall be designed and

constructed so that, in any dwelling unit or guest room, when measured to accordance with the procedures described in (c) below, the A-weighted sound level produced by the operation of:

A. Major mechanical equipment does not exceed 45 dB;

B. Any major appliance does not exceed 70 dB;

C. Any food waste disposer does not exceed 88 dB.

2. All Group E. occupancies to which this section applies shall be designed and constructed so that in any teaching unit the A-weighted sound level produced by the operation of major mechanical equipment does not exceed 45 dB when measured in accordance with the procedures described in (c) below.

(b) Review of Plans. The permit applicant shall submit acoustical analyses, prepared by a qualified acoustical engineer/consultant, of major mechanical equipment/major appliance/food waste disposer noise when plans and specifications are submitted for review. The analyses shall demonstrate that interior noise levels produced by the mechanical equipment/major appliances/food waste disposers described in the plans and specifications will be controlled to the levels specified in this section. Any elements of design assumed for the analyses to provide noise control shall be incorporated into the plans and specifications.

(1) Analyses of major mechanical equipment noise shall follow the basic procedures described in Chapter 6, "Sound Control Fundamentals" of *ASHRAE Handbook of Fundamentals* and in Chapter 35, "Sound and Vibration Control" of *ASHRAE Handbook & Product Directory*.

(2) Analyses of major appliance noise and of food waste disposer noise shall be based on sound power levels, when available, measured in accordance with either International Standard 3743,

"Acoustics-Determination of sound power levels of noise sources – Engineering methods for special reverberation test rooms," or Draft International Standard 3744, "Acoustics-Determination of sound power levels of noise sources – Engineering methods for free-field conditions over a reflecting plane."

(c) Acceptance. The building owner shall have mechanical equipment tested for compliance with the requirements of this section. 1. Major Mechanical Equipment. After all major mechanical equipment has been installed and is operable, and dwelling units, guest rooms, or teaching units are completed except for furnishings, A-weighted sound levels produced by operation of the major mechanical equipment shall be measured in accordance with the space averaging procedures of ASTM E597-77T, Sections 8.3.1 and 8.3.2.

2. Major Appliances. After all major appliances are installed and operable in a dwelling unit, and the unit is completed, except for furnishings, the A-weighted sound levels produced by operation of each major appliance shall be measured in the room where the major appliance is located in accordance with the space averaging procedures of ASTM E597-77T, Sections 8.3.1 and 8.3.2.

3. Food Waste Disposers. After all food waste disposers are installed and operable in a dwelling unit, and the dwelling unit is completed except for furnishings, the A-weighted sound level produced by operation of each food waste disposer shall be measured. Sound levels shall be measured at a location five feet above the floor and three feet from a food waste disposer.

4. If any measured A-weighted sound level exceeds the A-weighted levels specified by this section, the Building Official shall require that the building owner have further testing done and remedial action taken in accordance with Section 3508.

*Comments*

*The definition of mechanical equipment is intentionally broad. There are so many different types of equipment installed in modern buildings (ranging, for example, from garbage disposals, kitchen and bathroom ventilating fans, window air conditioners, fan coil units, and other equipment installed in individual dwelling units, teaching units, and guest rooms, to large compressors, fans, circulating pumps, trash compactors, elevators, and other equipment centrally located in equipment or service rooms) that the Model Provisions could not possibly deal separately with each.*

*Rather, the provisions have separated mechanical equipment into three basic categories, one that is very broad and two that are very specific. The two specific categories, "major appliances" and "food waste disposers," have been used because the equipment they include is often installed within a dwelling unit and is operated only for short periods of time, at the operator's convenience. On the other hand, the broad category of "major mechanical equipment" tends to include automatic equipment that operates for long periods throughout the day. Thus, maximum permissible levels differ, the maximum levels for the equipment that operates all day being lower than the maximum levels for the equipment that operates for short periods.*

*The maximum A-weighted sound level specified for major mechanical equipment is based on the sound level identified by EPA "below which no adverse effects on public health and welfare occur due to interference with speech or other activity" (EPA, 1974, p. 22). This maximum permitted level also corresponds to the level found by a HUD study to cause negligible or only slight interference with conversation and listening.*

*The levels specified for major appliances and for food waste disposers are based on data published in the EPA report, "Noise from Construction Equipment and Operations, Building Equipment, and Home Appliances," NTID 300.1. Approximately 90% of the measured values in that report fall below the maximum permitted levels. Thus, this requirement is intended to prevent installation of any of the 10% noisiest equipment in each category.*

*Acceptance, as is the case in Section 3504, must be based on a post-construction acoustical measurement. Although it is possible to select mechanical equipment and to design its installation so that the code provisions are met, only a final measurement can assure that the completed building complies with the code.*

Isolation from Noise Generated Outdoors

Section 3507. (a) Performance Requirements. All Group R occupancies and Group E occupancies shall be designed and constructed so that the exterior shell provides sound level reductions at least equal to the values in Table No. 35-C.

The sound level reduction requirements for a project depend upon the outdoor day-night sound level at the project. Table No. 35-C gives sound level reduction requirements for projects where outdoor day-night sound levels equal or exceed 60 dB. Outdoor day-night sound levels will be determined in accordance with procedures described in the Implementation Manual. There are no exterior shell requirements for projects where outdoor day-night sound levels are less than 60 dB.

TABLE NO. 35-C. REQUIREMENTS FOR ISOLATION FROM OUTDOOR NOISE: SOUND LEVEL REDUCTIONS PROVIDED BY EXTERIOR SHELL AS DETERMINED BY OUTDOOR DAY-NIGHT SOUND LEVEL

| If Outdoor Day-Night Sound Level Is: | | Then Sound Level Reduction Provided by Exterior Shell Shall Be: |
|---|---|---|
| Equal to or Greater Than | But Less Than | |
| 60 dB | 65 dB | 20 dB |
| 65 dB | 70 dB | 25 dB |
| 70 dB | 75 dB | 30 dB |
| 75 dB | 80 dB | 35 dB |
| 80 dB | Construction is prohibited | |

(b) Special Provision. For Group R occupancies and Group E occupancies designed to provide the sound level reductions specified by this section, the ventilation requirements of this building code shall be satisfied by a means that, when used to provide ventilation, does not reduce the sound level reduction below the applicable value required by Table No. 35-C.

(c) Review of Plans. Exterior shell design will be considered adequate for purposes of issuance of the building permit if plans and specifications filed by a permit applicant show that the design is in conformance with the guidelines of the Construction Handbook. The permit applicant shall also submit information that demonstrates how the outdoor day-night sound levels were determined.

(d) Acceptance. 1. The building owner shall have the completed building tested for compliance with the sound level reduction requirements of this section. After construction is completed, the sound level reduction shall be measured in accordance with the procedures of Draft International Standard 140/V, "Acoustics-Measurement of sound insulation in buildings and of building elements – Part V: Field measurement of airborne sound reduction of facade elements and facades." The sound level reduction shall be measured using the procedures described for determining the "standardized level difference," except that all measurements shall be made using only the A-weighted network.

2. If the measured sound level reduction is less than that required by this section, the Building Official shall require that the building owner have further testing done and remedial action taken in accordance with Section 3508.

*Comments*

*The EPA has identified a day-night sound level of 45 dB as the indoor level "below which no effects on public health and welfare occur due to interference with speech or other activity." (EPA, 1974, p. 22). Also, people indoors do not start to raise their voices above normal conversational levels until the day-night average sound level exceeds 50 dB (Pearsons, 1976). The performance standards of this section are designed to ensure that indoor day-night sound levels caused by outdoor noise sources do not exceed 45 dB.*

*Determination of outdoor day-night sound levels must be based on the local population density, and on the presence of major road, railroad, or aircraft noise sources. The Implementation Manual gives methods for determining outdoor noise levels (see Step 1, Section C.3 of the Manual).*

*The noise control performance of even the best exterior shell design will be compromised by opening a window. Since open windows are often, by design, the primary means of ventilation, the Special Provision requires that methods of ventilation must not compromise the noise control design. Practically, this requirement means that in noisy areas, windows must be kept closed, mechanical ventilation must be installed, and any openings to the outside must be provided with suitable sound traps. Some jurisdictions may currently have provisions that prohibit the use of mechanical ventilation in rooms used for sleeping purposes. In these jurisdictions, requirements for the substitution of mechanical ventilation for open window area must be established.*

Responsibility for Remedial Action

Section 3508. (a) When, in accordance with a section of this chapter, the Building Official requires the building owner to have further testing done and remedial action taken, the building owner shall retain a qualified acoustical engineer/consultant.

(b) The engineer/ consultant shall devise and conduct tests to determine why the acceptance measurements produced results that did not comply with the requirements of the section.

(c) If the tests demonstrate that the building was constructed in accordance with the approved plans and specifications and that noncompliance is due to inadequate design, the building owner shall submit to the Building Offical a report from the engineer/consultant that documents the tests and the conclusions.

(d) If the tests reveal that the building was not constructed in accordance with the approved plans and specifications, the building owner shall take either of the following actions:

1. Correct the building so that when completed it is constructed in accordance with the approved plans and specifications, and complies with the performance requirements specified by the section.

2. Have the engineer/consultant design noise control features for the building, that, when implemented, will result in compliance with the requirements of the section.

The building owner shall have these noise control features implemented and shall remeasure the building to demonstrate that as corrected it complies. The building owner shall submit to the Building Official a report from the engineer/consultant that documents the final measurements and results.

(e) No occupancy permit shall be granted until the building owner has complied with the requirements of this section.

*Comments*

*This section clearly places the responsibility for determining reasons for noncompliance with the building owner. There are two possible reasons for noncompliance: either the approved design was inadequate or the building was not constructed as designed. In case of the former, the building owner does not need to take action. In case of the latter, the building owner can choose one of two courses. Either he corrects the building so that it is built as designed and complies with the requirements of the code, or he simply corrects the building so that it complies with requirements.*

## IMPLEMENTATION MANUAL

The Implementation Manual focuses on the process of using the Model Noise Control Provisions in an adopting jurisdiction. It considers staffing the noise control function. It considers the costs of the MNCP. And, it considers administration of the noise control function. The Implementation Manual addresses separately the issues of each part of the process.

### A. Staffing the Noise Control Function

The MNCP will be incorporated into an existing code. Thus, although it involves new knowledge, new administrative mechanisms and specialized enforcement, these will supplement activities that exist because of the basic building code. This first part of the Implementation Manual examines staffing requirements in terms of skills required, comparisons with present staff, size of staff required and required special training.

#### 1. Skills required

The basic staff skills required by the MNCP include: (1) document review for noise control design, (2) inspection during construction and (3) review of acoustical test data. A jurisdiction might also decide to make acoustic measurements as part of an enforcement program. If the jurisdiction decides to take this approach, then special skills will be required in using acoustic instrumentation and testing acoustic performance.

*a. Document Review for Noise Control Design*

The Building Official will receive drawings, specifications and certifications of conformance with the MNCP. The certifications

will include documentation of sound isolation for privacy (MNCP 3504), impact noise isolation (MNCP 3505), control of mechanical equipment noise (MNCP 3506) and isolation from noise generated outdoors (MNCP 3507).

Review of drawings, specifications and certificates of conformance with codes is a normal task for building departments. Specific knowledge about noise control details will be required if the MNCP is adopted. Reviewers must know what makes details work and what makes them fail. The knowledge is rather basic - e.g., that noise leaks lead to noise problems as surely as water leaks lead to water problems. However, it is a separate area of knowledge.

Review of sound isolation for privacy includes review of designs for party walls, review of designs for wall/ceiling systems and review of details for penetrations of these constructions (MNCP 3504). If the designs have been developed with the aid of an acoustical/engineer consultant, this will be indicated on the submitted documents.

Review of impact noise insulation will consist of determining whether acceptable construction details have been incorporated in the drawings (MNCP 3505).

Design for adequate control of mechanical equipment noise will generally be the combined responsibility of the project's mechanical engineers and a qualified acoustical engineer/consultant. Section 3506 of the MNCP required that an acoustical analysis of mechanical system noise control be submitted with the design documents and that the documents incorporate any elements of noise control design incorporated in the acoustical analysis.

The acoustic design requirements for the building exterior shell (MNCP 3507) are determined by the noise environment at the site. The noise control staff must review the site noise analysis presented by the permit applicant to determine what analysis method was used, whether the results appear consistent with sites in similar locations and whether the results call for special exterior wall construction (MNCP 3507).

*b. Inspection During Construction*

Inspection during construction requires the Building Official to read the drawings and specifications as well as to have knowledge of potential problem areas in noise control. Building Officials will be experienced in working with drawings and specifications. Nonetheless, they may be unfamiliar with acoustic details. Required skills include experience with acoustic details in actual construction projects. The permittee bears responsibility to build in accordance with the approved contract documents. However, site inspection during construction can reveal potential future problems, such as failure to provide sealant between plates and floors.

*c. Review of Acoustical Test Data*

Acoustic test data must be submitted by the permittee in accordance with the requirements of the MNCP for airborne sound isolation (Sec. 3504), for mechanical equipment noise (Sec. 3506) and for isolation from noise generated outdoors (Sec. 3507). The building code staff should have adequate knowledge of the appropriate standards to be sure that the test data reflect proper test procedures. For example, were the tests conducted in the right spaces? Was the correct equipment used? and, was a sufficient number of samples tested?

*d. Making Acoustic Measurements*

If a jurisdiction decides to use measurements as part of an enforcement program, skills will be required in use of acoustic instrumentation. The instruments used will depend on the extent of involvement the jurisdiction desires. Basic instrumentation will include noise generators, sound level meters and calibration devices. A jurisdiction may also elect to use portable systems to monitor outside noise. None of these instruments is difficult to use. However, proper procedures must be followed in the use of the instruments if the results are to be accurate.

2. Comparison with probable present staff

In the previous section required noise control skills were identified. The focus was on skills uniquely related to noise control. It is highly unlikely that these skills would be present in a department that has had no previous concern with noise control. Skills in acoustic measurement will also be absent. However, review of contract documents, inspection of buildings under construction and review of test reports all are part of code enforcement. One or more existing staff members could be upgraded through training so that they can perform the noise control function. Alternatively, staff could be added as required to achieve the new function. The new staff could be hired with the required skills or upgraded through training.

3. Size of staff required

There is no fixed rule for determining the size of staff required. The size of staff will vary according to the number

of buildings under construction. For example, a small town with few multi-family buildings will need no additional staff. A larger, growing city with a high proportion of multi-family projects, or one that is adding schools, hotels or motels will need to add staff.

The city of San Diego, California is an example of a growing city (the 1973 population was 697,000 and between 1970 and 1975 the population grew 11%) which enforces the provisions of the California Noise Insulation Standards. The Noise Abatement and Control Office has a staff of 5 people who work full time on noise. The staff consists of:

1 Administrator

1 Assistant Administrator (professional)

1 Field Investigator (nonprofessional)

1 Stenographer - secretary

1 Clerk-typist.

This 5-man staff is part of a 100- to 135-person department. Thus, noise control represents 4 to 5 percent of the total department. This same group enforces the San Diego noise ordinance. Thus, they do not devote all their efforts to building noise control.

Jurisdiction staff needs will differ. Nonetheless, there are three levels of activity that will be involved: administration project monitoring (inspector) and record keeping (administrative assistant). Job descriptions related to those three levels of activity will be of utility to adopting jurisdictions.

Title: Administrator – Noise Abatement and Control (Building Department)

This person has overall responsibility for enforcement of the noise control provisions of the Building Code.

Specific responsibilities of this person include:

1. interpreting noise control provisions,
2. proposing changes in noise control provisions,
3. establishing procedures for monitoring compliance wiht noise control provisions,
4. recommending approval of Building Permit application for building projects with designs that comply with noise control provisions,
5. recommending approval of occupancy permit for completed buildings that comply with noise control provisions, and
6. establishing and administrating programs to supply information about the noise control provisions to government, the building professions, building owners and the general public.

This person may have to supervise a staff carrying out the above responsibilities.

This person requires a thorough understanding of laws, policies and procedures related to noise control in buildings and some understanding of the principles of noise control. Some formal training in building technology would be helpful.

Title: Inspector

There may be one or more people in this position. The position is responsible for monitoring compliance with the noise control provisions of the Building Code following the procedures established by the Administrator.

Specific responsibilities of this position include:

1. reviewing drawings, specifications and consultants' reports to determine if building designs meet the requirements of the code,
2. inspecting work-in-progress to ascertain if building is being constructed in accordance with the approved design,
3. reviewing reports and performance testing on buildings.

This position requires a thorough understanding of building construction techniques as they relate to noise control and intimate familiarity with noise control provisions of the code. An associate degree in building construction of the equivalent acquired through experience is required.

Title: Administrative Assistant

This person performs secretarial duties of the Administrator and staff and is also responsible for the efficient, courteous operation of the office.

Specific responsibilities of this person include:

1. organizing and maintaining files and reference materials,
2. logging in requests for document review and establishing check lists to make certain that actions are processed in an efficient manner,
3. responding to requests for application forms and other information in a timely, courteous manner, and
4. typing letters, forms, etc. for the Administrator and staff.

Requires a well organized, reasonably aggressive person with excellent typing skills and the ability to establish good rapport in telephone conversations and direct conversations.

4. Required specialized training

Review of drawings, specifications, and certificates of conformance with code elements is a normal task. However, training will be required to familiarize staff members with issues critical to the performance of noise control details. A number of federal programs provide training. Such a course might be developed to assist jurisdictions adopting the MNCP. The training should also include "laboratory" demonstrations of details that are functioning and other, apparently identical details that are not functioning. The laboratory training would impart skills required for site inspection and also would emphasize the extent that acoustic performance depends on careful construction.

Review of site noise analysis is an area where training would be required. In some jurisdictions, California and Maryland for instance, state law may require site noise analyses even now. That responsibility may reside in the building department, in the planning department or in an environmental department. If there is no capability to deal with site noise analyses, training will be required. (Section C.3 of this report describes the process of site noise analyses.)

A training program lasting two or three days could provide basic awareness of code enforcement for noise control. This course could include basic noise control, demonstration of noise measurements and demonstration of proper construction techniques.

B. Costs Related to the Model Noise Control Provisions

Costs of the code fall into two areas: costs of enforcement and costs of compliance. Costs of enforcement fall upon the adopting jurisdiction. They then become costs of general government or part of the cost of a building permit. Costs of compliance fall upon the building owner. We now look in more detail at these costs.

The costs of enforcement will be primarily costs of staffing unless a jurisdiction decides to include measurement of performance in its enforcement program. As noted earlier, the level of staffing and associated costs depend on the level of construction activity and the size of the jurisdiction. San Diego's very comprehensive enforcement program, that includes measurement of outdoor noise levels and indoor noise levels, is staffed by a department that is only 4 to 5 percent of the Building Department and also enforces the local noise ordinance. A less comprehensive program would involve a smaller staff. A smaller jurisdiction might find that enforcement equivalent to San Diego's would cost more per building.

Costs of compliance again fall into two categories: costs of design and costs of construction. We draw upon the California experience for this information. Increased design costs result from the requirement to have a qualified acoustical consultant review the project, estimate the outside noise level and recommend construction types for exterior walls and roof construction as well as for party walls and interior noise control. The cost of consulting is minimized if the design architect knows noise control methods and details, and increases if the architect is unfamiliar with noise control. For small multi-unit housing projects the minimum cost, in 1978, is in the vicinity of $500.

For a large multi-unit project (more than 20 units) with repetition of a limited number of construction types, consulting costs during design are in the range from $750 to $1,250 irrespective of the size of the project.

Costs of construction will change because of changes in construction type, because of emphasis on quality of construction, and also because of the need to measure performance after construction. Costs due to changes in construction are the most difficult to estimate. For the most part, the party wall design will not change, but the need for quality control during construction will increase. Also, if a building is in a noisy area, exterior roof and wall construction may need to be upgraded relative to normal construction. The building industry is becoming increasingly sensitive to conservation of energy. In many areas of the country buildings must incorporate high degrees of insulation. Because walls that insulate well against noise intrusion also insulate well thermally, both qualities of buildings can be achieved by a single change in design. It is thus difficult to say whether changes in noise control requirements, alone would change the cost of construction.

Performance testing is a new requirement and a new cost. There is the possibility that two types of tests may be required in a building: (1) testing to determine whether construction meets the code requirements, and (2) testing when remedial work is required before a building meets the code requirements. Level reduction tests to determine compliance with the code can be made at a rate of 8 to 12 per day in one project. The cost of testing should be in the range of $300 to $400 per day or a per test cost of $25 to $40, approximately. If the test results show that the test samples meet the design requirements there would be no

additional tests involved. When the requirements are not met, tests will be required and costs will be incurred to find the problems and remedy them. Diagnostic measurements and remedial construction would add costs for measurements, for analysis, and for upgrading construction. Failures will fall into two general categories:

- Inadequate isolation from wall or floor/ceiling construction;
- Excessive mechanical system noise.

Problem solving will require careful analysis. The rates for on-site measurements and recommendations will tend to cost $300 to $400 per day, plus any travel costs. Remedial work will generally involve bringing construction up to the design standards of the construction documents. This may involve adding layers of wallboard that were initially omitted or sealing around penetrations that were overlooked. The numbers of problems that will occur cannot be predicted with a high degree of certainty. No good statistics exist. Each architect and contractor will learn from experience. The time required to achieve a low failure rate will vary widely depending on the individual learning curve.

## C. Administration of the Model Noise Control Provisions

The fundamental responsibility of the Building Department is enforcement of the code. However, administration and compliance can be simplified if the Building Department provides information on the code to interested parties. This discussion of code administration considers three aspects of the process: (1) providing information, (2) setting fees, and (3) enforcement.

### 1. Providing information to interested parties

The Building Department can take a number of administrative actions that simplify enforcement of the code and simplify compliance with the code: preparing procedural check lists for applicants, listing qualified noise control consultants, and preparing material to demonstrate the code to the public, to building trades, and to governmental groups. If applicable for a particular jurisdiction, the actions can include preparation of information on noise levels in various parts of the jurisdiction. These actions are examined in the following paragraphs.

#### *a. Listing of Complying Construction System*

Jurisdictions that have noise control provisions in their codes have achieved administrative simplicity by listing and illustrating assemblies that, when properly constructed, meet the noise control requirements of the code. Other assemblies than those shown in the listing may be used if detail drawings and test results are submitted as part of the permit application process. This process of listing complying constructions is recommended for any jurisdiction that implements the MNCP. The City of San Diego, California has a very effective way of providing this information. They have a two-sided sheet which

incorporates structural details, plumbing details, and electrical details (see Fig C.1). The sheet includes general notes explaining test procedures and other aspects of code compliance. The sheet is to be incorporated into the architectural documentation for a project. Each detail includes all materials for the specific construction. In addition, intersections of floor/ceiling constructions and party-walls are shown, as well as all caulking details. In short, the details shown are those that, if built properly, allow a building to provide adequate privacy.

The sheet of construction types should include all party-wall constructions normally used in the adopting jurisdiction. An applicant may wish to use a construction method that is innovative. Any construction that meets the other code provisions, such as fire resistance, and has been measured and certified by a qualified testing laboratory as meeting the code,* should be accepted for use. Treatment of floor/ceiling assemblies, plumbing and electrical details to avoid acoustic leaks common to all construction should be part of non-standard wall or floor details too.

The inspector's role in providing detail drawings is to simplify the job of code administration. He will not certify the noise control performance of constructions. Measurement and certification is the job of testing laboratories. The EPA's *Construction Handbook* will list the performance data for most typical constructions, show details, and pinpoint aspects that

*The appropriate measurement procedure is based on ASTM E 413-73.

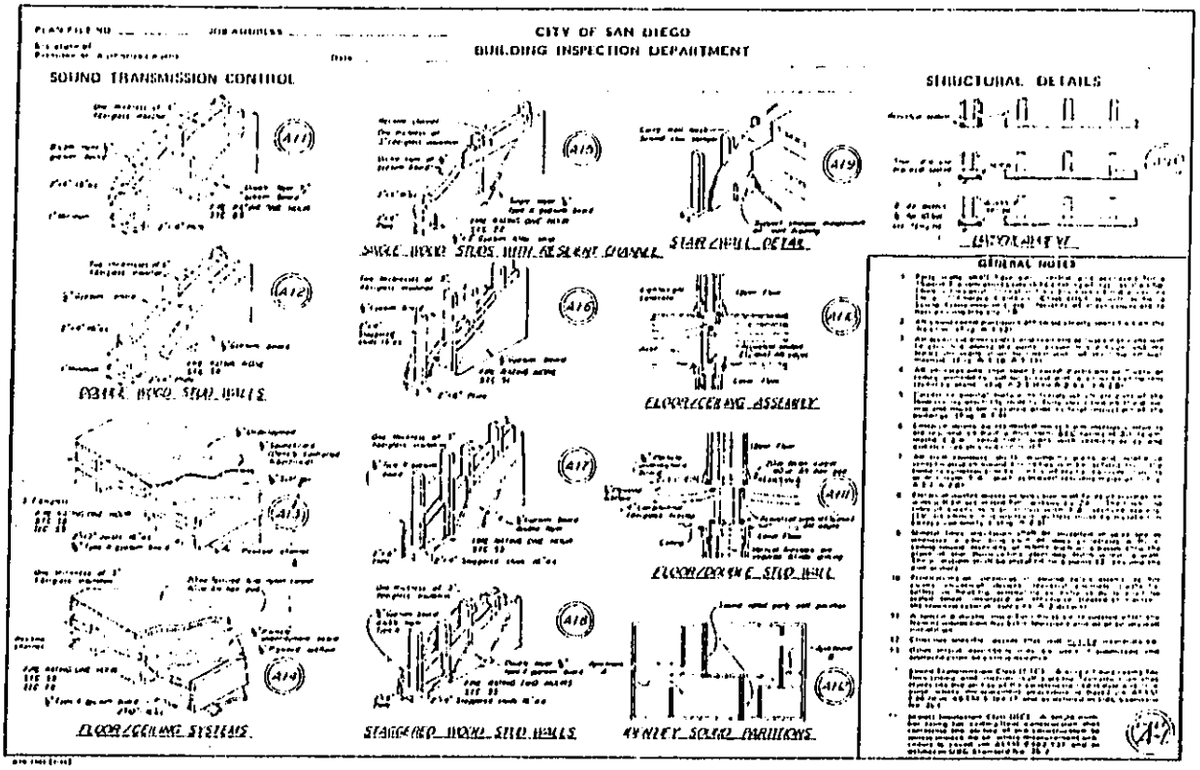



FIG. C.1. SAMPLE OF INFORMATION ON ACCEPTABLE CONSTRUCTION.

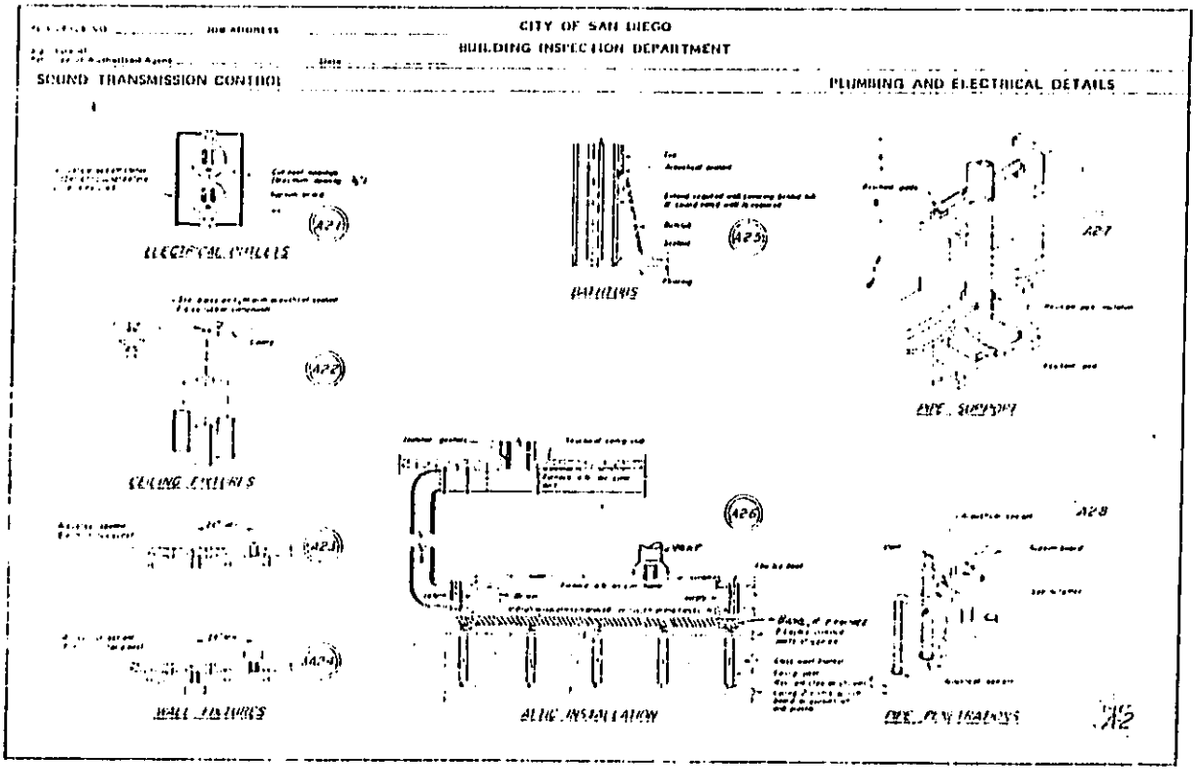

CITY OF SAN DIEGO
BUILDING INSPECTION DEPARTMENT
SOUND TRANSMISSION CONTROL
PLUMBING AND ELECTRICAL DETAILS

FIG. C.1. *(Cont.)*

can cause acoustical leaks. Detail sheets such as the one in Fig.C.1 can be prepared based on details in the *Construction Handbook*.

*b. Listing of Qualified Consultants*

Applicants may ask a building inspector which consultants can prepare acoustical analyses. The inspector would not act as an agent for any consultants or guarantee the work of a consultant. However, as an aid to inspectors who are reviewing the work of a consultant, the building office will want to have information on qualified individuals and firms. The building office should tell potential consultants to provide staff resumes and histories of job experience. Consultants would then submit the information. After review of the submittals the building office should notify consultants whether or not they will be listed. The list of qualified consultants can be then be prepared. On the list should be a notice that the list is provided for information, that the data were provided by the consultants, that the listing constitutes neither an endorsement nor a guarantee, and that other individuals or firms may be qualified to do the work. As additional firms qualify for listing the list can be changed or supplements can be prepared.

*c. Preparation of Check Lists for Applicants*

The application process is simplified for applicants and administrators alike if applicants are fully informed about the process. Check lists for use of applicants can improve this interaction. Work sheets or check lists should be prepared for analysis of noise at the project site, for reviewing completeness of applications, and for contract documents. Figure C.2 is an example of such a work sheet. Applicants should be given copies

Use to Determine Outdoor Day-Night Noise Levels for MNCP Sections 3504 and 3507

Step A. Identify noise sources influencing site and check appropriate boxes.

Step B. Calculate levels from all sources identified in Step A, using procedures in Implementation Manual Sec. C.3, Step 1, and enter in appropriate box.

Step C. Sum contributions using the method in Appendix A.

| Possible Source: | Is the source present? No | Is the source present? Yes | If present, enter levels (Ldn in dB) | |
|---|---|---|---|---|
| General Community Activity (always present) | | ☐ | ☐ | ☐ |
| Major Highway | | | | |
| Cars | ☐ | ☐ | ☐ | ☐ |
| Trucks | ☐ | ☐ | ☐ | ☐ |
| Aircraft | ☐ | ☐ | ☐ | ☐ |
| Railroad | ☐ | ☐ | ☐ | ☐ |
| Rail Rapid Transit | ☐ | ☐ | ☐ | ☐ |
| Decibel Sum | | | For MNCP 3507 ☐ | For MNCP 3504 ☐ |

FIG. C.2. SITE NOISE WORKSHEET

of the work sheets, check lists, and any explanatory material when they request building permit application forms. Completed work sheets and check lists should be required as part of the building permit application. This procedure will help the building inspector accomplish his work.

*d. Education and Demonstration*

Enforcement of a new code element requires education of permit applicants, contractors, architects, tenants, and government officials. The goal of education is to make sure the code element is understood. The most important point is that the noise control provisions are the way to achieve the performance that has been paid for all along. That is, the basic designs will not change by the MNCP, but adherance to the designs will be increased and the result will be improved acoustic performance.

Jurisdictions adopting the noise control provisions can use EPA prepared descriptions of the provisions for basic education. They focus on the purpose of the provisions, the benefits of achieving good performance, and the fundamental simplicity of achieving it.

Each audience will have specific concerns. Governmental officials will want to know the public benefits and any public costs. The fundamental benefit is privacy — privacy from intruding speech and privacy from other intruding sounds. Costs involved for government would be due to any increased staff. As we have seen earlier, for San Diego (a city of 697,000) administration of the "Sound Control" portions of the building code, the California Noise Insulation Standards, and the local noise ordinance involves a staff of 5 which is 4 to 5 percent of the Building Inspection Department.

Tenants will want to know how the code will improve their living environment. They can be told that the MNCP was developed with the goal of providing buildings that assure privacy. They can be told that privacy results when the correct design is built well. They can be told that normally loud speech will be inaudible and that shouted speech will be barely audible and not understandable. They can also be told that normal walking will not be heard.

Building owners (permit applicants) will want to know their responsibilities under the code, the benefits, and the costs. The owners are responsible for code compliance. They delegate certain responsibilities to the architect and to the builder. However, the ultimate responsibility is the owner's. Achieving compliance requires that care be taken during construction to build normal types of construction the way they are designed. The unique aspect of the code is that it requires that acoustic performance be tested. Although unique for noise control code elements in the U.S., performance testing is used to assure that other building systems work. For example, plumbing must be tested for freedom from leaks at high pressure in order to be acceptable. Under this code element, the owner and his agents are required to confirm that the building "works" acoustically before an occupancy permit can be issued. The benefits to the owner are very real — usable spaces. For example, all units of an apartment house can provide tenants with good living environments. There is no excuse for having apartment buildings in which neighbors overhear normally loud conversations in adjoining apartments or where noise from television sets is disturbing to neighbors. The MNCP contains the elements required to prevent these problems.

The information for all of these groups can be presented in one or more brochures. Federal support may be available for such information programs.

Similarly, demonstration programs can show builders that no exotic construction skills are required. Caulking of sills, sealing around electrical outlets and methods of sealing other penetrations can be demonstrated easily. The acoustic effects of treatment can also be demonstrated easily and at the same time as the methods of caulking and sealing are demonstrated. For example, cracks around convenience outlets can be sealed during a demonstration of performance testing. Observers will hear the noise reduction that can be achieved by such simple, but essential measures.

*e. Community Noise Data*

The noise control provisions (MNCP 3504,3507) require that information be known about the outside noise environment at a site. In most instances, the applicant will have a consultant prepare the information using the procedures discussed in Sec. C.3. In some jurisdictions information may be available about noise levels near airports, near highways, or near sites of heavy industries. The extent that data are available will vary among jurisdictions. The proprietors of major airports will tend to have noise data for some periods. State highway departments may have noise data for major highways. A building department can simplify administration of the noise control provisions by maintaining a map showing known data.

2. Preparation of fee structure

Whether or not the addition of a noise control element influences the fees charged by a Building Department depends on the staff changes required and the fee setting policy of the individual jurisdiction. Fee structures range from those based on square footage in a building, irrespective of the building type, to those based on the estimated level-of-effort for the Building Department. It is typical to try to have the Building Department operate long-term on a break-even basis. Thus, the fees would be adjusted to reflect actual costs. If the MNCP increase costs 3 to 5 percent for a given level of construction, for example, the fees should then rise 3 to 5 percent for that level of construction.

3. Enforcement

The steps to be followed in the enforcement of the Model Noise Control Provisions are illustrated graphically on Fig. C.3. Thirteen steps are indicated in time sequence: the order in which they most conveniently can be taken. The first eight steps are to be taken by the Applicant in preparing material for submission to the Building Official. The Building Official, in turn, then proceeds through the last five steps in processing and responding to the application as well as in inspecting the building.

Each of the thirteen steps on Fig. C.3 is described in detail below.

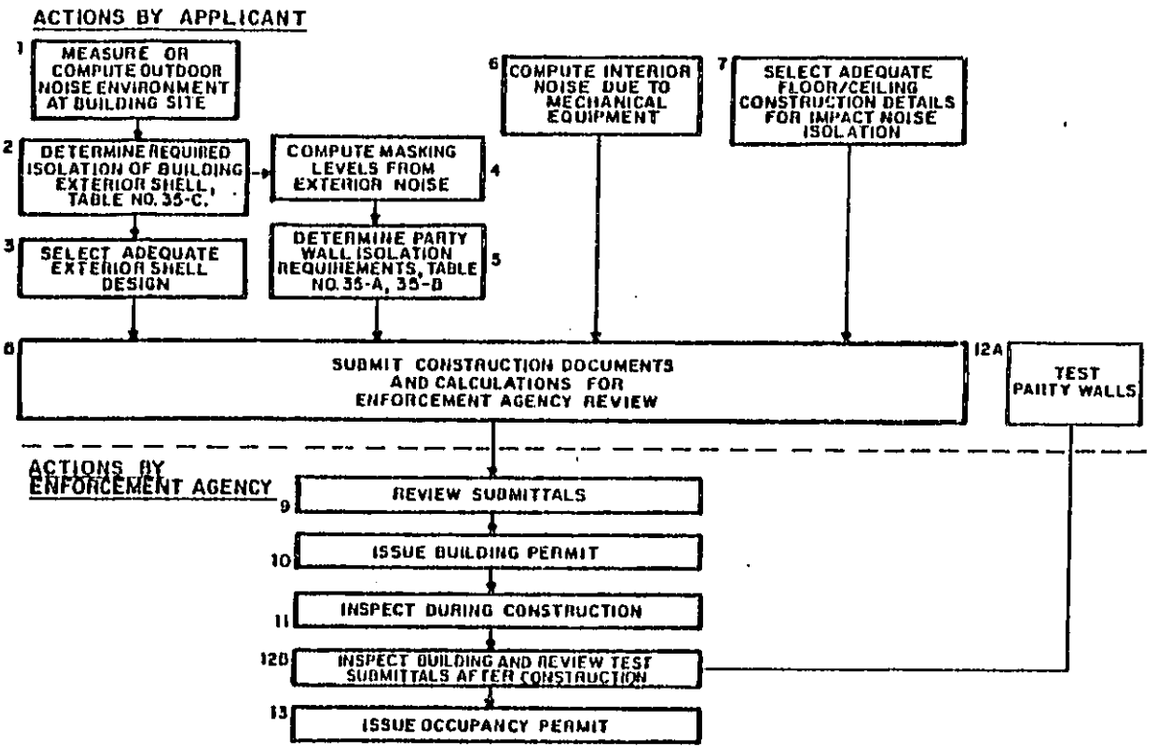



FIG. C.3. STEPS TO BE FOLLOWED IN ENFORCEMENT OF THE MODEL NOISE CONTROL PROVISIONS.

*1. Determination of Outdoor Day-Night Sound Levels at the Site*

For purposes of designing the exterior shell, the Applicant must determine the outdoor Day-Night sound levels at the site that could potentially intrude upon activities within his proposed building. Noise levels must be examined for two periods:

- The present noise level at the site.
- Future noise levels at the site, over the next twenty years. (The building must be designed for future levels if future noise levels will be higher than those existing at the site at present.)

A building will have a long life of use. Thus, the design should account for future site conditions as well as present conditions. For example, if a quiet nearby street is to be replaced by a major highway, the future utility of the building will be best protected if future noise levels are considered in the design. Twenty years is the normal planning horizon for projects such as highways and airport expansion plans. Thus, although a building can be expected to have a longer useful life than twenty years, only a twenty year future can be considered here.

*Present noise levels* at the site can be calculated from data known about noisy activities that contribute to the site. In some instances, present levels can be measured directly. The sources of interest include local street activity, other neighborhood activities, highways, railroad, rail rapid transit, aircraft and industrial noise. The calculation procedures are discussed in the following paragraph.

To calculate the noise levels at a site, all sources of noise at the site should be listed, their contribution to site noise determined and the overall level obtained by summing the individual contributions. This process is illustrated by the worksheet of Fig. C.2. There is a calculation procedure for determining the contribution from each source. The procedures are as follows:

- General Community Activity: Levels from Table C.1
- Highway Activity: From graphs of Figs. C.4 and C.5
- Railroad/Rail Rapid Transit Activity: Levels from graph of Fig. C.6
- Aircraft: Levels provided by airport proprietor or according to the procedures of EPA Report 550/9-77-450, "Calculation of Day-Night Levels ($L_{dn}$) Resulting from Civil Aircraft Operations."

The contributions of all sources should be summed as described in Appendix A.

Under some circumstances the present levels can be determined by direct measurement. Measurements are allowed only when it is reasonable to expect that the noise environment on a day selected at random will adequately reflect the average noise environment at the site on other days of the year. Aircraft activities seldom are regular enough from day to day to fulfill this requirement. Measurements should be made using an environmental noise measuring system capable of accumulating noise data for at least 24 hours and calculating $L_{dn}$ for each 24-hour period.

TABLE C.1. General Community Activity

| Thousands People/sq mi | $L_{dn}$ (outdoors) |
|---|---|
| 1 | 52 |
| 2 | 55 |
| 3 | 56.8 |
| 4 | 58 |
| 5 | 59 |
| 7 | 60.5 |
| 10 | 62 |
| 20 | 65 |
| 30 | 66.8 |
| 40 | 68 |
| 50 | 69 |
| 70 | 70.5 |
| 100 | 72 |

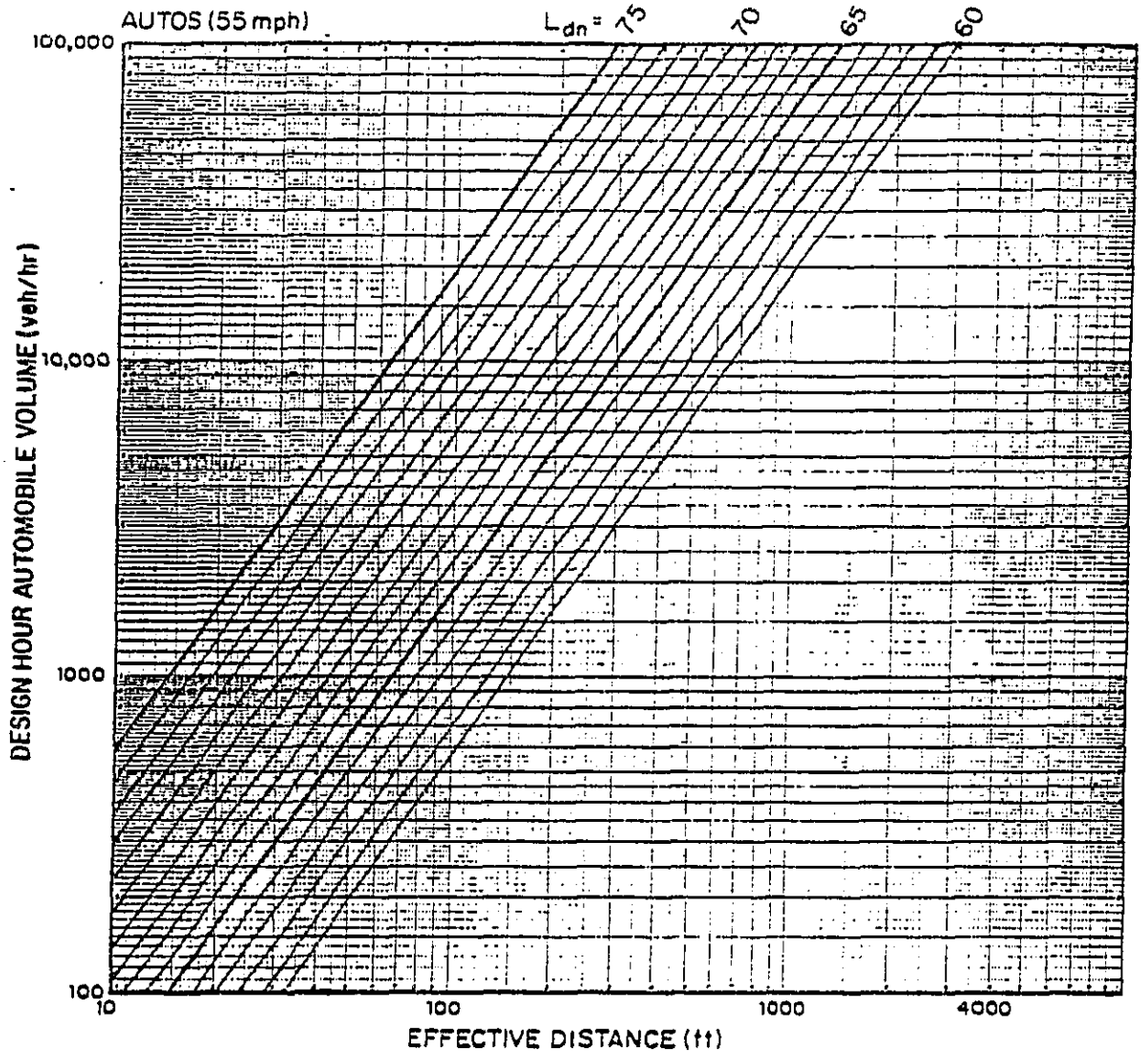



FIG. C.4. GRAPH FOR ESTIMATING DAY-NIGHT AVERAGE SOUND LEVEL ($L_{dn}$) FOR AUTOMOBILE TRAFFIC.

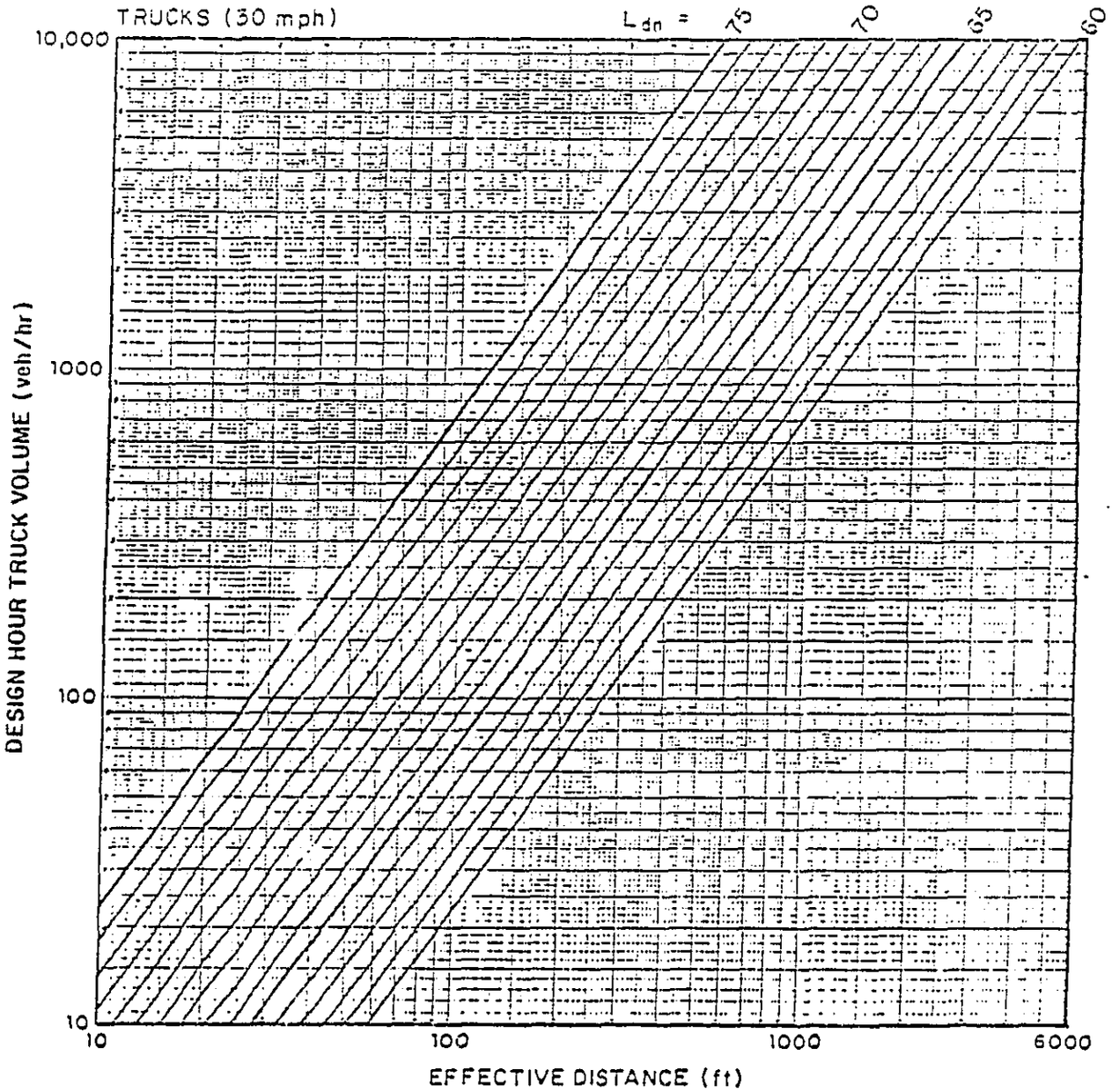



FIG. C.5. GRAPH FOR ESTIMATING DAY-NIGHT AVERAGE SOUND LEVEL ($L_{dn}$) FOR TRUCK TRAFFIC.

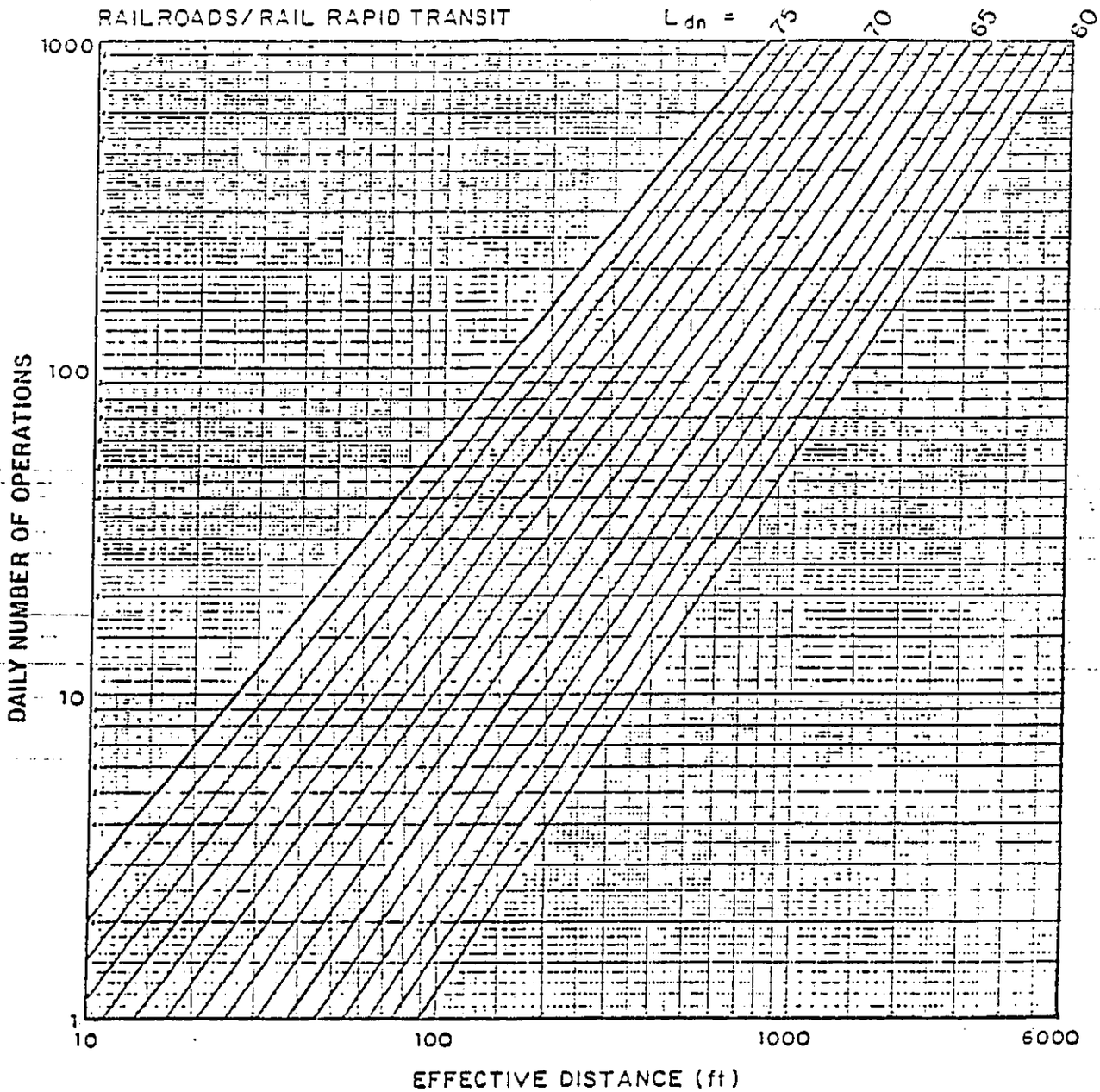



FIG. C.6. GRAPH FOR ESTIMATING DAY-NIGHT AVERAGE SOUND LEVEL ($L_{dn}$) FOR RAILROAD TRAFFIC (INCLUDING RAIL RAPID TRANSIT).

*Future noise levels* at the site must be estimated based upon known plans for changes in noise sources that will influence the site. The levels should be estimated for the period 20 years hence. Check with the local planning office for zoning changes, the highway department for new highways, the airport and the transit authorities. The procedures described above for present noise levels can be used to estimate the future noise levels likely to occur as a result of such changes.

The "Outdoor Day-Night Sound Level" for design of the building exterior shell noise should be selected as the greater of the two noise levels determined above: either the present level or the future level.

2. *Determining Sound Isolation Requirements for the Building Exterior Shell*

On the basis of the design noise level for outdoor intrusive noise (from Step 1), the sound isolation requirement for exterior building shell can be determined from Table No. 35-C of the MNCP.

3. *Selection of Exterior Shell Design*

The Applicant should select an exterior shell structure adequate to provide the sound isolation requirements determined in Step 2. Acceptable documentation shall be presented to demonstrate that the selected structure is adequate. Acceptable documentation includes:

a. Actual measured data acquired by the Applicant on similar structures in accordance with standard procedures such as:

- American Society for Testing and Materials E413-73, "Determination of Sound Transmission Class"
- Draft International Standards ISO/DIS 140/V, "Field Measurements of Airborne Sound Insulation of Facade Elements and Facades."

b. Data published in the literature for similar structures. Suitable references include:

- National Bureau of Standards Building Science Series Publication 77, "Acoustical and Thermal Performance of Exterior Residential Walls, Doors and Windows"
- *The Construction Handbook*, a handbook prepared by the EPA indicating typical construction details known to be suitable to meet the isolation requirements of the MNCP.

Note that for building exterior shells with windows and doors, the effective sound isolation value will often be determined, essentially, by the sound isolation values of the windows and/or doors. The sound isolation value of the wall structure itself will be of little significance. This is particularly true of masonry structures. The value submitted for compliance with the MNCP must be determined for the wall *with* all doors and windows.

The Applicant is responsible for selecting an acceptable exterior shell structure, for documenting its adequacy to the

Building Official and for assuring that in the final building, the selected structure does meet the prescribed sound isolation requirements.

*4. Compute Outdoor Day-Night Sound Level That Provides "Masking"*

As discussed in comments to MNCP 3504(a), sounds which cover up or "mask" potentially intrusive noise from neighbors can improve privacy. This masking sound should be continuous and should not be so loud that it is annoying. Masking noise is contributed by noise sources that are continuously present: general community activity and automobile traffic on major highways. The level of masking sound is calculated in this step from information developed during Step 1. The procedure is illustrated by Fig. C.2. Levels should be calculated for the present and for the future (20-year) conditions.

*5. Party-Wall Sound-Isolation Requirements and Party-Wall Design Selection*

Based upon the *lower* of the two outdoor Day-Night sound levels determined in Step 4, the Applicant shall determine the isolation requirements of party walls in accordance with Table No. 35-A and 35-B of the MNCP. Wall designs suitable to satisfy these requirements shall be used, and acceptable documentation supporting their use shall be prepared for presentation to the Building Official.

Acceptable documentation includes:

a. Actual measured data acquired by the Applicant on similar structures in accordance with standard procedures such as:

- American Society for Testing and Materials E413-73, "Standard Classification for Determination of Sound Transmission Class."

b. Data published in the literature for similar stuctures suitable reference include:

- National Bureau of Standards Building Science Series Publication 77, "Acoustical and Thermal Performance of Exterior Residental Walls, Doors and Windows"
- *The Construction Handbook*, a handbook prepared by the EPA indicating typical construction details known to be suitable to meet the isolation requirements of the MNCP.

The Applicant is responsible for selecting acceptable interior wall designs, for documenting their adequacy to the Building Official, and for assuring that in the final building, the selected structure does meet the proscribed sound privacy requirements.

*6. Computation of Mechanical Equipment Sound Levels*

The Applicant shall present an analysis by a qualified acoustical engineer/consultant showing the interior noise level due to the operation of building mechanical equipment. This computation shall be done by applying the methods of Chapter 8 of the *Handbook of Fundamentals* of the American Society of Heating Refrigeration and Air Conditioning Engineers, or similar approved method. Values computed in terms of NC levels should be corrected as follows:

Continuous A-weighted sound level = NC level + 5 dB.

The Applicant is responsible for assuring that the interior noise level due to building mechanical equipment shall not exceed the limits of Sec. 3506 of the MNCP.

*7. Selection of Construction for Impact Noise Isolation*

For multi-level structures having more than one dwelling unit, the Applicant shall select floor/ceiling constructions that provide adequate impact-noise isolation. Drawings and acceptable documentation supporting this selection shall be prepared for submittal to the Building Official for review. A source of information on designs to provide acceptable impact-noise isolation is:

> *The Construction Handbook*, a handbook prepared by the EPA indicating typical construction details known to be suitable to meet the impact isolation requirements of the MNCP.

Figure C.7 illustrates acceptable construction types.

The selection of acceptable impact-noise-isolation structural details shall be specified on the building plans.

*8. Submission to Enforcement Agency*

The Applicant shall submit to the Building Official:

- Drawings and specifications for the proposed building
- Copies of (or references to readily available) documentation as required to support the design choices of Steps 3, 5, 6 and 7.

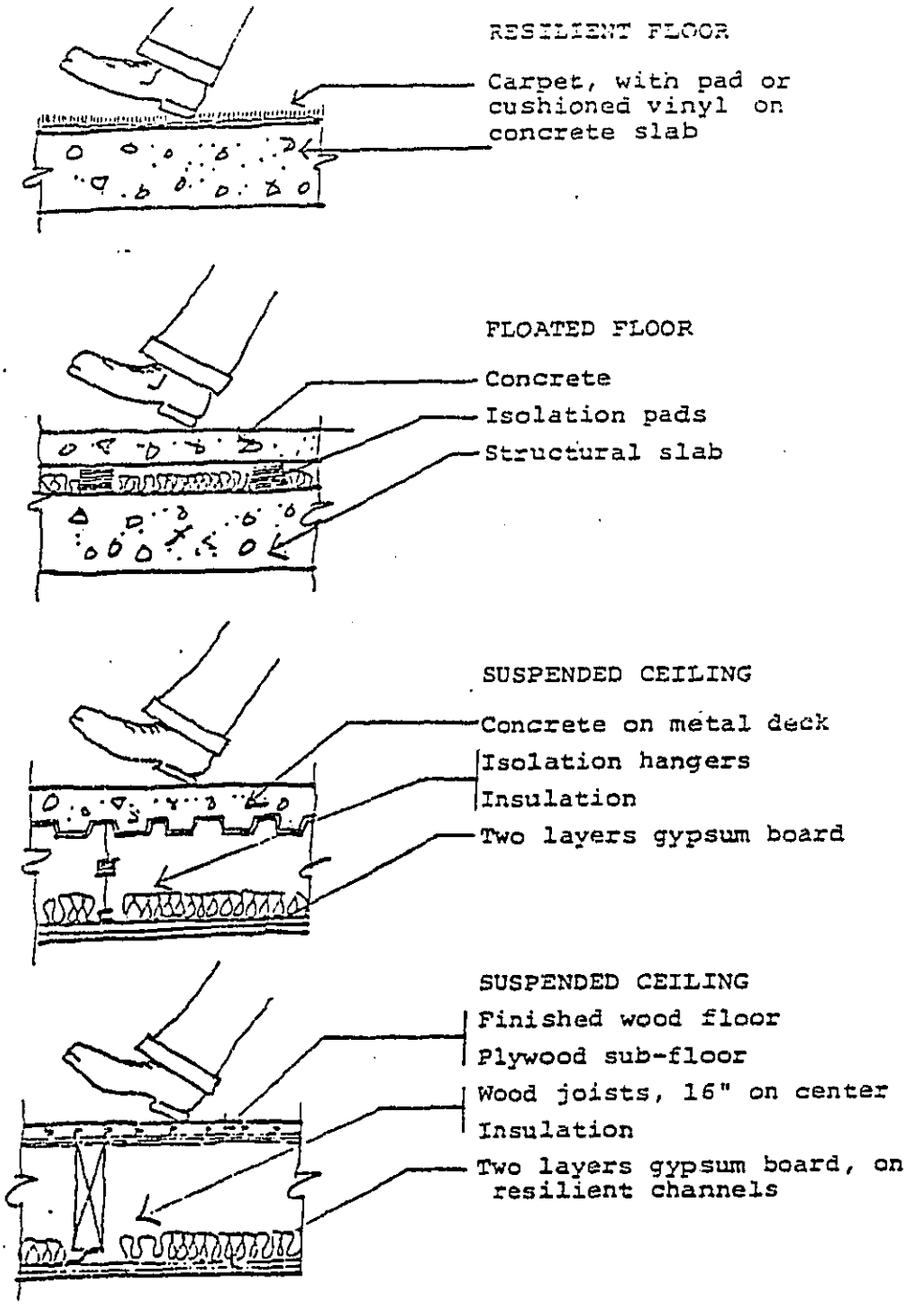



FIG. C.7. ACCEPTABLE CONSTRUCTIONS TO REDUCE IMPACT NOISE.

- Copies of measurements or computations for Steps 1 and 4. Include "Worksheet for Outdoor Day-Night Sound Levels" (Fig. C.2).
- Certification of compliance with the requirements of applicable sections of the MNCP, and a proposed Compliance Monitoring Program to assure that critical structures are built to approved drawings.
- Other documents as required by the Building Official.

*9. Review of Submitted Material by the Building Official*

The Building Official will review the material submitted by the Applicant for completeness, and for compliance with the provisions of the MNCP. If information is missing, or if any elements of the design are found not to be in compliance with the MNCP, the Applicant shall be requested to supply additional information and/or make design changes until compliance is assured.

If, in the opinion of the Building Official, compliance with the MNCP is assured, a building permit will be issued (Step 10). If compliance is lacking, the building permit will be withheld until suitable design changes are made.

*10. Issuance of Building Permit*

Where indicated as a result of Step 9, the Building Official will issue a building permit for any building design that complies with the MNCP.

*11. Inspection During Construction*

The Building Official shall inspect the building during construction to verify compliance with the approved drawings. In general, the inspection should be made before the interior walls are covered, but after all rough electrical, plumbing and HVAC work has been completed. At this inspection, verify:

- That basic wall, ceiling and floor structures are in accordance with approved drawings.
- That potential acoustic flanking paths, such as through air ducts or back-to-back duplex outlets, have been avoided.
- That structural isolation through resiliently suspended ceilings and double walls has not been compromised by utility penetrations, unplanned structural ties, construction debris, etc.

If construction errors are noted, approval to cover the interior walls shall be withheld until corrective action is taken by the Applicant. Additional inspections may be necessary to verify that remedial work has been properly completed.

*12. Final Inspection and Testing*

Following the completion of construction, the Building Official shall inspect the building for compliance with the provisions of the MNCP. This final inspection shall be in two parts:

a. Visual inspection of sealing, surface and finishing materials to determine that they are in compliance with the approved construction plans.

b. Review of reports of party-wall compliance tests submitted by the Applicant in accordance with Sec. 3504 of the MNCP.

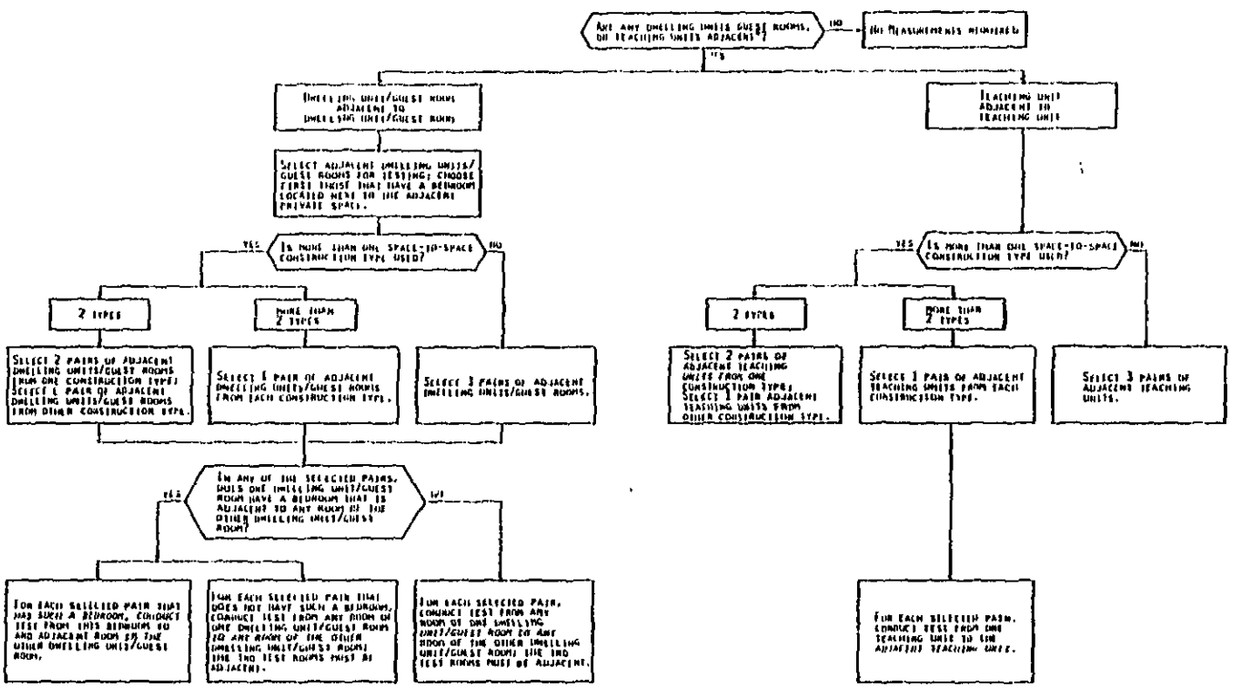
The tests are to be made by a qualified acoustical engineer/ consultant. The number and locations of tests are specified by MNCP Sec. 3504. The testing process is illustrated by the flow chart of Fig. C.8.

If the final inspection or the performance tests indicate the building is not in compliance with the provisions of the MNCP, then the Applicant shall be instructed in accordance with MNCP Sec. 3508 to rework and retest the building structure until compliance is achieved. No occupancy permit shall be issued until the building is found to be in compliance.

Responsibility for bringing noncomplying structures into compliance rests with the Applicant. Consequently, the Applicant may wish to protect himself by contractually assigning the responsibility for compliance to a qualified architect, engineer or consultant. These contractual arrangements would be made prior to design so that the responsible architect, etc., could develop the plans, inspect the construction, and generally follow the project to insure that the completed structure complies.

*13. Occupancy Permit*

Following successful completion of Step 12, including any remedial work and retesting required, the Building Official may grant an occupancy permit for the building.




*TWO SPACES ARE ADJACENT IF ANY PORTION OF A WALL OR FLOOR/CEILING IN ONE FORMS PART OF A WALL OR FLOOR/CEILING OF THE OTHER.

FIG. C.8. FLOW CHART FOR TESTING OF AIRBORNE SOUND ISOLATION FOR PRIVACY SPACE-TO-SPACE CATEGORY (A) PRIVATE SPACE TO PRIVATE SPACE.

## REFERENCES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## APPENDIX A: ADDITION OF DECIBELS

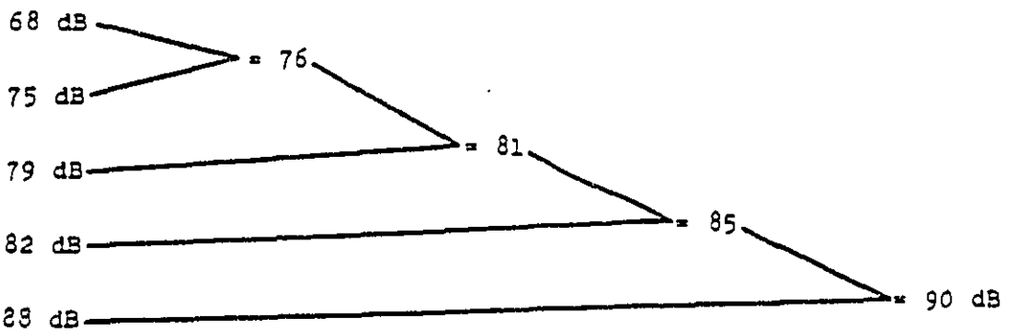
Since decibels are logarithmic values it is not proper to add them by normal algebraic addition. For example, 63 dB plus 63 dB *does not* equal 126 dB but only 66 dB.

A very simple, but adequate schedule for adding decibels is as follows:

| When two decibel values differ by: | Add the following amount to the higher value: |
|---|---|
| 0 or 1 dB | 3 dB |
| 2 or 3 dB | 2 dB |
| 4 to 9 dB | 1 dB |
| 10 dB or more | 0 dB |

When there are several decibel levels to be added, they should be added two at a time, starting with the lower valued levels and continuing the addition procedure of two at a time until only one value remains.

To illustrate, suppose it is desired to add the following five sound levels, using the above summation procedure:



The simplified addition rules above involve rounding off to some sums to the nearest whole number, resulting in the possibility of a small error. In general, the above procedure will yield sums accurate to the nearest 1 dB.

## APPENDIX B SUMMARIES OF STANDARDS CITED IN THE MODEL NOISE CONTROL PROVISIONS

The standards and draft standards cited in the MNCP are copyrighted documents and may not be reproduced here. This Appendix includes the full names of the standards and draft standards as well as summaries of their contents.

### ANSI S1.4-1971

Specification for Sound Level Meters

*Summary*

This standard states the minimum performance requirements for four types of sound level meters. It also establishes calibration requirements.

### ASTM/ANSI C 634-77

Standard Definitions of Terms Relating to Environmental Acoustics

*Summary*

This standard includes definitions of terms relating to environmental acoustics including building noise control.

### ASTM E 413-73

Standard Classification for Determination of Sound Transmission Class

*Summary*

This standard describes the method for calculating the Sound Transmission Class of a party wall or floor/ceiling construction. Included in the standard are both graphic and tabular methods.

ASTM E 497-73T

Tentative Recommended Practice for Installation of Fixed Partitions of Light Frame Type for the Purpose of Conserving Their Sound Insulation Efficiency

*Summary*

This standard describes measures intended to prevent situations or conditions that will cause light frame walls to provide less acoustic protection than they are capable of providing. Conditions discussed include flanking, leaks, short-circuits and miscellaneous conditions. Twenty figures illustrate problems and corrective actions.

ASTM E 597-77T

Tentative Recommended Practice for Determining a Single-Number Rating of Airborne Sound Isolation in Multi-Unit Building Specifications

*Summary*

This document describes a procedure for determining the A-weighted sound level difference between two neighboring rooms in a building. The document specifies the conditions of the test specimen, the procedure, a standard sound source, reporting, precision and accuracy. In the section on procedure, descriptions are included for calibration, measurement, adjustments for background noise and measuring the absorption of the receiving room.

ISO 3743

Acoustics – Determination of Sound Power Levels of Noise Sources – Engineering Methods for Special Reverberation Test Rooms

*Summary*

This standard specifies methods for determining the approximate sound power levels of small devices that produce noise. Measurements are carried out in a specially designed reverberation test room.

DRAFT INTERNATIONAL STANDARD ISO/DIS 140/V

Acoustics – Measurement of Sound Insulation in Buildings and of Building Elements – Part V: Field Measurements of Airborne Sound Insulation of Facade Elements and Facades

*Summary*

This document describes two methods for measuring the sound insulation of facades. One method uses traffic noise as the noise source. The second method uses a loudspeaker outside the building as the noise source. Both methods use a single microphone position outside the building and multiple microphone positions inside the building.

DRAFT INTERNATIONAL STANDARD ISO/DIS 3744

Acoustics – Determination of Sound Power Levels of Noise Sources – Engineering Methods for Free Field Conditions Over a Reflecting Plane

*Summary*

This standard specifies methods for determining the approximate sound power level of devices that produce noise. The size of the device is limited only by the test environment which is described in the standard. The test environment is outdoors or indoors in a large space.