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SOUND CONTROL PROVISIONS WITHIN BUILDING CODES

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prepared by

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Richard L. Katz

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INTRODUCTION

Noise - from the same Latin root as nausea!

Many of today's problems, and the solutions to these problems, have brought to us yet another dilemma, that of environmental noise pollution. Because of economical factors taking precedence over environmental factors, noise has grown to disturbing proportions. Much of the blame can be pointed to increasing population, industrialization, and sociological changes. However, technological "advances" must bear the greatest responsibility. As these advances were made, the price paid has been the increasing amount of noise pollution. Growing at an increasing rate, noise pollution will soon reach the crisis proportions as air and water pollution if the public doesn't take the time to react.

This report is primarily concerned with a mostly overlooked, but nevertheless, important aspect of community noise control, comprehensive noise control provisions within building codes. It is not the intention of this report to concern itself deeply with general community noise abatement programs or industrial noises. To do so is beyond the scope of this work.

The main purpose for the establishment of building codes is to insure the safety, health, and welfare of a building's occupants. The World Health Organization states that, "...health is a state of complete physical, mental, and social well-being and not merely an absence of disease and infirmity."[1] Noise can cause the disturbance of sleep, rest, and relaxation; be annoying; interrupt the thinking processes; and sometimes even cause physical damage to the ears. Physical or mental illness may be caused by exposure to even subtle, unwanted sounds.[2] Unlike air and water pollution, noise cannot be seen, and most of the time, the ordinary citizen is not fully conscious of its effects upon him.

Many of today's architects, builders, and engineers realize that the progress made in the construction industry concerning the use of lightweight materials, flexibility of buildings, and economics, have resulted in entirely unsatisfactory acoustical conditions inside the completed building. Every aspect of design should be considered for proper noise control including structure, types of materials used, types of construction, mechanical equipment and systems, and methods of construction. An "after-the-fact" attitude concerning noise control is improper.

The purpose of this report is to review the status of current and future noise control provisions within the various domestic governmental levels, and at the national level internationally. In many cases, direct comparisons are made. This report will also deal with some of the effects of unwanted sound upon people and some of the causes of complaints from occupants in multifamily dwellings experiencing insufficient noise control.

SECTION TWO

PSYCHOLOGICAL AND PHYSIOLOGICAL EFFECTS OF NOISE ON MAN

The purpose of this section is to point out some of the basic psychological and physiological effects of noise upon man and to provide insight as to why noise control through the use of building codes is important. It is beyond the scope of this report to explain in detail these effects (there is extensive reference material concerning the matter).

Noise, by definition, is unwanted sound. The psychological reaction to noise depends not only on the physical make-up of the noise, but also on the susceptibility of the individual hearing it who is conditioned by many variable factors within himself (including his conscious perception of it). The determinants of human sensitivity to noise are extremely complex. They include, but are not limited to, educational level, interests in machinery, types of activity interrupted by the noise, attitudes towards noise sources, and personality.[1] Besides personal attitudes towards noise, it has been reported that sensitivity to noise is usually low during periods of physical labor and exertion, while over-fatigue, annoyance, and sickness increase it.[2] Also, due to the hearing characteristics of the ear, noises of high frequency nature (e.g. high speed centrifical compressors) tend to be more annoying than noises of low frequency nature (such as electrical hum at 120Hz). Furthermore, devices that produce discrete frequencies (such as pure tones) are more annoying than those that produce random noise. However, noise can annoy due to continued exposure resulting in the irritation of the auditor(s). There are even some relatively quiet sounds which can be annoying to the auditor, no matter how quiet they are. These may include a crying baby, dripping tap water, conversations heard indistinctly from another room, flushed water heard in a living room filled with guests, etc.

The pervasiveness of noise makes it a problem of special concern. Noise cannot be just shut out, one cannot just close his ears. Noise interrupts the thinking process, interdisposes itself in conversations, and prevents deep sleep. It has been well established that people require rest and relaxation at regular intervals in order to maintain good mental and physical health.[3] It has been becoming increasingly evident that the need for noise control is a very important factor of life in our type of society.

Objective data concerning the effects of noise on rest and sleep is either very scarce or non-existant.[4] It has been determined that night-time sounds are more disturbing than daytime sounds.[5] According to one study, it was found that older people find it harder to fall asleep and awaken more easily than young people.[7] Other than that, researchers have little clear knowledge concerning the true effects of noise upon sleep.[8] Some authors have tried to indicate that noise, by preventing complete and deep sleep, is responsible for making it impossible to recuperate physical and mental energy expended during the day's activities.[9] On the other hand, others have tried to show that noise in itself cannot be harmful so long as secondary factors do not prevent the individual from becoming naturally accustomed to the noise.

Many researchers concerned with noise are convinced that even though some noises are not intense enough to cause permanent hearing damage, they should not be dismissed simply as nuisances. In some instances, auditory stimulation can affect the other senses. These intersensory effects may occur as part of normal phychological and physiological functions.[10] However, noise can produce general phychological distress adding to the overall stress of life thereby possibly contributing to the incidence of non-auditory diseases.[11] Even moderate noises make the pupils of the eyes dilate (which may explain why surgeons, and others who do close work, are so bothered by noises). Moderate noises also cause small blood vessels in the body to constrict and impede blood flow (vasoconstrictive reflex) which is the body's automatic response to noise stress.[12] It has been conjectured (without any conclusive evidence) that this vasoconstrictive reflex may negatively influence the activity of various glands, e.g., the digestive glands, with the possibility of metabolic disturbances. There are presently millions in the United States who have heart disease, high blood pressure, and emotional illness who need protection from the additional stress of noise.[13]

The ideal acoustical environment is one which enhances the quality of life by eliminating disturbing noises. Noise pollution is definitely a health hazard and should be controlled through the use of building code requirements.

SECTION THREE

NOISE REGULATION: COMPARISONS OF DOMESTIC BUILDING CODE PROVISIONS

BHBC = Beverly Hills, California Building Code, Section 1314, "Sound Transmission Through Separation Walls and Floors" Adopted through Ordinance No. 71-0-1405, 1971

HMO = Weston, R. T., "A Model Ordinance to Control Noise Through Building Code Performance Standards", Harvard Journal on Legislation, Vol. 9, 1971-1972, pages 66-114.

HUD = U. S. Department of Housing and Urban Development, "A Guide to Airborne, Impact, and Structure Borne Noise-Control In Multifamily Dwellings", September 1969.

NCBC = Newark, California Building Code, Section 2.5, "Sound Isolation Control", 1971.

NIBC = Northbrook, Illinois Building Code, Chapter 3, Article V, "Sound Insulation Requirements", November 1970 (Adopted through Ordinance No. 70-71.)

NYCBC = New York City Building Code, Chapter 26, Sec. 1208.0, 1970.

SSBC = Southern Standard Building Code, Appendix "E", "Recommended Guide for Sound Isolation in Multi-Family Dwellings", 1969.

UBC = Uniform Building Code (International Conference of Building Officials) Appendix Chapter 35, "Sound Transmission Control", 1973.

GENERAL:

The NYCBC indicates in its introduction that its section on noise control in multiple dwellings concerns requirements for airborne sound insulation for interior walls, partitions, floor-ceiling assemblies, and mechanical equipment in spaces or buildings in its type J occupancies (i.e. shelter and sleeping accomodations on the day to day, week to week, month to month basis; one- or two-family units; convents; and rectories). It also indicates that provisions are provided for airborne sound control for exterior mechanical equipment noises from any type occupancy as well as impact noise isolation requirements for floor-ceiling constructions. The UBC expresses the same thing for its groups H and I occupancies (hotels, motels, apartment houses, convents, monasteries, dwellings, or lodging houses). The NIBC indicates approximately the same; its sound control provisions are for all hotels, motels, and all dwelling units regulated by its codes except for single-family dwellings. The SSBC indicates that provisions are made for airborne sound control, but no mention is made of impact noise control. The HMO is more general in nature not specifically mentioning airborne or impact noise control, but expresses the fact that provisions are made to insure minimum acceptable acoustical environments (according to the HMO standards).

The U. S. Department of Housing and Urban Development (HUD) of the Federal Housing Administration (FHA) has developed a comprehensive report on noise control entitled, "A Guide to Airborne, Impact, and Structure Borne Noise-Control in Multifamily Dwellings". Within this report is a brief explanation of some of the general principles of sound transmission. There is also a comprehensive discussion pertaining to specific noise problems and their solutions (including illustrations). Of most importance, there is a complete section on FHA recommended criteria for noise control in dwelling units and the development of these criteria. This recommended criteria is required for approval of all HUD projects. Sections of the report are devoted to data and sound transmission class (STC) ratings of wall constructions and floor-ceiling assemblies, as well as impact insulation class (IIC) ratings for floor-ceiling assemblies. HUD indicates that the overall objectives of its sound control recommendations are to provide direction toward the attainment of acoustical privacy and the control of noise in multifamily dwellings.

Only the SSBC [Appendix E(c)] and the NYCBC [C26-1208.1(b)] requires that all construction used for noise control is also to maintain performance characteristics (e.g. structural stability, fire resistance, etc.) required elsewhere in their respective codes. The UBC, BHBC, NCBC, HMO, AND HUD do not specify this.

RATING NOISE INSULATION:

AIRBORNE NOISE INSULATION:

The NYCBC, SSBC, UBC, BHBC, NCBC, AND HUD have adopted the Sound Transmission Class (STC) rating system which was developed by the ASTM. This single-figure rating is derived by comparing test measurements of the partition in question with a standard shaped curve.

HUD states the following about its use of the sound transmission class (STC) ratings system (as well as the single-figure impact noise reduction (INR) system):

> "The plan used by the FHA [HUD] is fundamentally a gradation of single-figure ratings, based upon reference contours. This system affords the greatest opportunity for relating recommendations or requirements to a variety of conditions, such as: ambient background noise usable for masking purposes which imply urban, suburban, or rural locations; minimal, average, or high income housing; and for specific wall or floor-ceiling functions within buildings. In addition, ease of revision of recommendations or requirements is inherent in this system without

disrupting the basic scheme for classifying structures as to their acoustical properties."[1]

The STC reference curve consists of a line segment increasing 15 dB in the 125-400 Hz interval, a line segment increasing 5 dB in the 400-1250 Hz interval, and then a horizontal line segment in the 1250-4000 Hz. interval (see Fig. 1). This reference contour takes into consideration the sensitivity of the human ear, that is, being able to hear the higher frequencies more easily than the lower frequencies. Therefore, the curve is designed as a function of frequency. To determine the STC rating of the test specimen, sound transmission losses are measured in 16 contiguous 1/3 octave bands centered on 125 to 4000 Hz. The results of the test are plotted on a graph and then compared to the standard STC contour which is "shifted" vertically until certain conditions are fulfilled. The total transmission loss below the standard contour (total adverse deviation) is not to exceed 32 dB (an average of 2 dB for each 1/3 octave band). Also, the adverse deviation in any one band is not to exceed 8 dB. When the standard contour is adjusted to the highest possible value (in integral decibels) while maintaining these two conditions, the STC rating is determined by the sound transmission loss (STL) corresponding to the intersection of the standard STC contour and the 500 Hz ordinate. STC ratings relate the sound insulating properties of a structure as a function of frequency more effectively than did earlier arithmetic average sound transmission loss values.

HUD states that airborne sound insulation measurements should be conducted in accordance with the current methods of test which are endorsed and published by the major standardization committees and associations such as the American Society for Testing and Materials (ASTM), the United States of America Standards Institute (USASI) [now the American National Standards Institute (ANSI)], and the International Organization for Standardization (ISO).

The author of the HMO, R. T. Weston, expresses the opinion that the STC rating system has certain advantages, these being that the STC rating system is flexible allowing for both poor and good insulating assemblies to be rated by the same system; also, STC ratings for many common constructions are published and readily available making for convenience in architectural design. A deficiency in a 1/3 octave band reading, provided that it does not exceed 8 dB, is not subjectively noticeable, therefore not unduly penalizing the construction's rating. However, he points out that the standard STC curve was derived for domestic (and some commercial) noise spectra. Low frequency components, such as traffic and machine noises, if prominent, make STC ratings ineffective. Since STC ratings are based upon individual construction elements, various flanking sound transmission paths are not taken into account. Therefore, the HMO adopts a "new" airborne noise insulation standard, the Normalized Noise Insulation Class (NNIC), which takes into account airborne sound isolation "between rooms" instead of basing the system solely upon the performance "of a partition."

The HMO discussion introducing the model ordinance explains that the NNIC is designed to account for primary paths and flanking transmission of noise by instituting a single performance test for the entire completed construction thereby assuring acoustical privacy and protection in the actual use of the building.

HMO uses the equation:

$$NR = \overline{L}_1 - \overline{L}_2,$$

where:

NR = noise reduction
$\overline{L}_1$ = average sound pressure level in room 1, the source room
$\overline{L}_2$ = average sound pressure level in room 2, the receiving room.

Noise reduction is measured by establishing a sound field in the source room of sufficient intensity so that the sound transmitted into the receiving room can be measured over any ambient noise level present. The average sound pressure levels ($\overline{L}$) for each room are measured in the sixteen 1/3 octave bands (with frequencies centered on 125 to 4000 Hz).

In the HMO, the NR value is normalized to account for acoustically absorptive material in the receiving room. Each frequency band is normalized in terms of reverberation time as if the receiving room contained a typical amount of absorption (e.g. furnishings).

Therefore,

$$NNR = NR + 10 \log_{10} (T/T_o),$$

where:

NNR = normalized noise reduction
NR = measured noise reduction
T = measured reverberation time in the receiving room
T_o = reference reverberation time of 0.5 seconds.

The normalized noise isolation class (NNIC) is derived by comparing NNR values plotted as a function of frequency to a NNIC chart (see fig. 2). The comparison is identical in manner as the method of comparison in determining STC ratings. The single number NNIC value is the highest NNR value at 500 Hz which fulfills essentially the same requirements of that of STC ratings; that is, the sum of the individual adverse deviations (those values below the prescribed values) for the row shall not exceed 32 dB (an average of 2 dB per column), and no individual test frequency deficiency shall exceed 8 dB.

The HMO NNIC reference curve and the STC reference curve are virtually the same. The only substantial difference is that the NNIC reference curve relates to normalized noise reduction values whereas the STC reference curve relates to sound transmission loss. The main difference between the NNIC system and the STC system is that the NNIC system depends on post-construction field measurements whereas the STC is determined from standardized laboratory procedures.

IMPACT NOISE INSULATION

The NYCBC and BUBC have adopted the Impact Noise Rating (INR) system developed by the U.S. Federal House Authority (FHA bulletin no. 750, "Impact Noise Control in Multifamily Dwellings" of January 1963). Impact noise isolation is evaluated using an International Organization for Standardization (ISO) standard tapping machine from which impact sound pressure levels are determined in the room directly below the test floor in 1/3 octave bands from 100 to 3150 Hz. The curve derived from the measurements is compared with the standard INR curve (see fig. 4a). The amount in dB that measured curve has to "shift" vertically to comply in all frequency could be rated plus, or minus, x dB; plus being to shift up, and minus being to "shift" down. The greater the positive INR, the better the impact sound reduction of the partition in question. (see fig. 4b)

Both the UBC Standard 35-2 and HUD have adopted the Impact Insulation Class (IIC) rating system. This system was developed to establish somewhat of a parallelism with the more familiar STC rating system of airborne sound control. Another reason, according to a HUD discussion, the IIC was developed to avoid dealing with "negative insulation values" of the INR system. The IIC system rates floor-ceiling assemblies with positive numbers, the larger the number, the greater the insulation.

Hud indicated that impact sound pressure levels should be measured in accordance with current methods of testing which are endorsed by the major standardization organizations. However, the only formal document in current use concerning this matter is the ISO recommendation R-140, "Field and Laboratory Measurements of Airborne and Impact Sound Transmission", ISO/R140-1960(E). It is also the preferred method at the National Bureau of Standards and has also been under consideration by the ASTM.

In this method, like the INR method, a "standard" tapping machine (as specified in ISO/R140) is used on the floor-ceiling assembly and measurements of the resultant impact sound pressure levels are measured in 16 contiguous 1/3-octave bands with frequencies centered in the 100-3150 Hz range and averaged over time and space. These measurements are made at six stationary microphone positions or with a slowly moving microphone in the receiving room with the tapping machine placed successively in at least three specified locations on the floor above. Results of the measurements are reported as impact sound pressure levels (ISPL) and are normalized to a reference room absorption of $A_o = 10m^2$ or 107.6 sabins.

After the ISPL are normalized, they are compared to the IIC standard contour. Like STC ratings, the curve of the results is "shifted" vertically until certain conditions are met: a single unfavorable deviation (an ISPL value which lies above the curve) may not exceed 8 dB, and the sum of the unfavorable deviations may not be greater than 32 dB. The single figure IIC rating for the specimen in question is the value of the ordinate scale on the right (IIC) corresponding to the ISPL value at 500 Hz, of the lowest contour for which the above conditions are fulfilled. (see fig. 3b)

The IIC contour is constructed as follows: a horizontal line segment in the interval 100-315 Hz; a middle line segment decreasing 5 dB in the interval 315 to 1000 Hz; followed by a high frequency line segment decreasing 15 dB in the interval of 1000 to 3150 Hz (see fig. 3a).

On the average, the IIC rating is approximately 51 points higher (algebraic addition) than the INR rating used in FHA No. 750 However, the spread between the two rating systems may be as much as ±2 points, thereby making an "across the board" adjustment to all INR ratings inappropriate.

Impact sound pressure levels normalized to $A_o = 10m^2$ are plotted, to the nearest whole dB, on graph paper on which the ordinate scale is 2mm/dB and the abscissa scale is 50mm/decade.

In order to produce sound levels in the receiving room that are sufficiently above background noise to give valid readings, the ISO standard tapping machine produces sound levels that are much greater than those produced by footsteps. Floors with the same subjective detectability of footfall noise may differ by as much as 14 INR units. It is the opinion of the HMO author that for these reasons, the tapping machine method is unacceptable for use in building code specifications. The HMO author also expresses the opinion that adoption of the INR or IIC methods of rating impact sound insulation into building codes makes little economical, political, or acoustical sense. Therefore, impact sound insulation is rated indirectly by the HMO NNIC rating system for airborne sound insulation.

The SSBC has no provisions for impact sound insulation requirements or methods of testing for proper impact sound insulation.

FIELD TESTING AND MEASUREMENT:

AIRBORNE SOUND:

Appendix Chapter 35 of the UBC and the NIBC indicate that field testing shall be done under the supervision of an experienced professional acoustician who fowards the test results to the building officials. Along the same lines, the HMO indicates that field testing should be undertaken by the building code administrator or by an inspection service which has a reputation for quality and reliability. UBC has no provisions for the actual testing of STC ratings but states that if testing is required, the UBC Standard No. 35-3, "Airborne Sound Insulation Field Tests" is to be used. This standard is based upon the recommended practice E336-67T of the American Society of Testing and Materials. In the UBC, all sound transmitted from the source room to the receiving room is considered to be transmitted through the test partition. The UBC standard defines certain words, abbreviations, and their derivatives, and then indicates that the test specimen must be tested "as is" with no alterations before or after the field test. Aging periods for specimens with curing times are discussed also. UBC Standard No. 35-3 refers one to UBC Standard No. 35-1, "Sound Field Test Procedure." Standard No. 35-1 determines that the sound transmission loss (noise reduction) of the test partition will be derived from measurements in the two rooms involved according to the formula:

$$FTL = \overline{L}_1 - \overline{L}_2 \text{ (dB)}$$

where:

FTL = transmission loss (in dB) of the test partition (the prefix F is added to indicate field measurement)

$\overline{L}_1$ = average sound pressure level in room 1, the source room

$\overline{L}_2$ = average sound pressure level in room 2, the receiving room.

FTL is also defined in UBC Standard No. 35-1 as:

$$FTL - 10 \log_{10} (W_1/W_2)$$

where:

W_1 = sound power (sound energy per second) incident directly upon the partition on the source side

W_2 = sound power radiated directly from the quiet side of the partition into the receiving room.

The HMO uses virtually the same equation:

$$NR = \overline{L}_1 - \overline{L}_2$$

where:

NR = noise reduction (according to ASTM designation C634-69 ¶4.6).

However, the HMO indicates that acoustical field testing of noise reduction should be indicated as the normalized noise reduction (NNR) so as to take into account the absorption of the receiving room. In order to use the NNR, the reverberation time of the receiving room must be know. (Determination of reverberation time is discussed as a function of frequency and measured in the same 1/3-octave band widths as the NR values so that the normalized noise reduction can be calculated. In the HMO, normalized noise reduction is defined as:

$$NNR = NR + 10 \log_{10} (T/T_0)$$

where:

NNR = normalized noise reduction
NR = measured noise reduction
T = measured reverberation time in the receiving room
T_o = reference reverberation time of 0.5 seconds.

No formal requirements for field testing is written into the HMO. However, in a discussion introducing the HMO, the author suggests that some sort of "go-no-go" field test standards be put into practice. One suggestion is that a standard sound source should be placed in the sending room producing a standard sound spectrum. Sound level readings would be taken using a sound level meter, on the A-weighted scale. "All-pass" readings (instead of multiple band frequency readings) would be taken at several points in both the source room and the receiving room. The space-averaged A-levels would be determined and then the "A-weighted noise reduction" (the difference between the two readings) of the construction between the two rooms (including flanking transmission) would be calculated. If the calculations showed sufficient noise reduction, the construction would be presumed to be satisfactory.

The NYCBC reference standard RS 12-2 indicates that field testing for STC ratings are to be done in accordance with ASTM E90-61T (omitting paragraphs 3(b), 3(c), 3(d), and 3(f); or Albert London's "Methods of Determining Sound Transmission Loss in the Field" which is in the Journal of Research of the National Bureau of Standards. The NYCBC states that installed equipment must not fail by more than 2 dB in any octave band, and that the installed partition (or floor-ceiling assembly) must not fail by more than 2 points to meet the code's STC requirements. (The HUD report indicates that field tested STC ratings may be as much as 4 to 5 points, on the average, lower than laboratory STC ratings.) The HMO is somewhat like the NYCBC in that it requires construction not to fail by more than 2 rating points to meet its normalized noise isolation class (NNIC) standards for airborne sound insulation. Neither Appendix Chapter 35 of the UBC nor UBC Standard No. 35-3 indicates that field test measurements are necessary for a partition to comply with UBC airborne sound insulation requirements.

The NIBC (Art. V. sec. 3.12(b)) and NCBC (sec. 2.5(e)) state that field airborne sound transmission test procedures are to be conducted in accordance to the applicable portions of ASTM E90 and its related appendix. The BHBC requires much the same thing by stating that airborne sound control field testing and measurement be conducted in accordance with the latest standards set forth by the ASTM. None of these three codes designate what field test results are necessary for a partition to comply with their airborne sound insulation requirements.

The SSBC has no provisions for airborne sound insulation field testing.

IMPACT NOISE:

The NYCBC has no specific provisions for field testing floor-ceiling constructions for impact noise reduction. NYCBC has no specific testing procedures but indicates that the floor-ceiling system, if measured in the field, is not in conformance with the code if it exceeds the NYCBC INR requirements by more than two points.

The UBC states that impact sound insulation field tests, if required, shall be accordance with UBC Standard No. 35-2. This standard is based upon the U.S. Department of Housing and Urban Development (HUD) Publication FT/TS24, "Guide to Noise Control in Multifamily Dwellings."

Both, the UBC standard and the HMO, define the average sound pressure level as:

$$\overline{L} = 10 \log_{10} \frac{P_1^2 + P_2^2 + \ldots P_n^2}{(n)P_o^2} \text{ (dB)}$$

where:

$P_1, P_{2\ldots}P_n$ = r.m.s. sound pressure at n different positions in room

P_o = reference sound pressure

According to UBC standard No. 35-2, the normalized impact sound pressure level is measured in a specific frequency band in the receiving room and is defined as:

$$L_n = \overline{L} - 10 \log_{10}(A_o/A)$$

where:

$\overline{L}$ = average sound pressure level in the receiving room produced by the standard tapping machine

A = measured absorption in the receiving room

A_o = reference absorption ($10 m^2$ or 107.6 sabins)

UBC Standard No. 35-2 carefully describes, in complete detail, the standard tapping machine and also explains the methods of measuring transmissions as well as the determination of the average sound pressure levels. Also within this standard are directions for providing a statement of results.

The HMO, unlike the UBC, has no specific guidelines for field testing procedures, but does state that any necessary testing may be undertaken by the administrator or by an inspection service which has a reputation for quality and reliability. The requirements for conforming construction are much like those of the NYCBC. The construction in question must not exceed the normalized noise isolation class (NNIC) standards by more than 2 rating points between the two spaces being measured. (After some discussion in his text, the author of the HMO expresses the opinion that neither the IIC nor the INR system is appropriate for building code usage.)

In a general discussion, the HUD report indicates that there is no standard method of field measurement of impact sound insulation in the United States. (The United States voted against the I.S.O. recommendation R-717, "Rating of Sound Insulation for Dwellings".) However, HUD indicates that impact sound pressure level measurements should be performed in accordance with the current methods of test which are endorsed by the major standardization organizations. The I.S.O. Recommendation R-140, "Field and Laboratory Measurements of Airborne and Impact Sound Transmission", ISO/R140-1960 (E), of the International Organization for Standardization, has been used internationally to enable objective measurements of sound transmissions. HUD recommends the following method currently in use at the National Bureau of Standards (which has been under consideration by the ASTM).

In this method, a "standard" tapping machine (as specified in ISO/R140) is used on the floor-ceiling assembly and measurements of the resultant sound pressure levels produced in a reverberant room directly below are made. Sound pressure levels are measured in 16 continguous 1/3-octave bands with center frequencies in the 100-3150 Hz range and averaged over time and space. These measurements are made at six stationary microphone positions or with a slowly moving microphone in the receiving room with the tapping machine placed successively in at least three specified locations on the floor. Results of the measurements are reported as impact sound pressure levels (ISPL) and are normalized to a reference room absorption of $A_o = 10m^2$ or 107.6 sabins.

The NCBC [sec. 2.5(f)], BHBC [sec. 1314], and the NIBC [Art. V, sec. 3.12(a)] require that impact noise field testing be done in accordance with international standard I.S.O. recommendation R 140, "Field and Laboratory Measurements of Airborne and Impact Sound Transmission." The SSBC has no provisions for field testing floor-ceiling constructions for impact noise reduction.

ACOUSTICAL ISOLATION OF DWELLINGS:

AIRBORNE NOISE:

The NYCBC [C26-1208.2(a)(1)] requires that, as of January 1, 1972, walls, partitions, floor-ceiling constructions that separate a dwelling unit from public spaces (e.g. stairs, hallways, lobbies, garages, etc.), or from another dwelling unit, are to have a minimum sound transmission class (STC) rating of 50 for airborne noise. Dwelling unit entrance doors are required to have an STC rating of at least 35. The STC ratings are to be obtained from, or determined by, NYCBC reference standard RS 12-2.

The SSBC and NCBC provide that the above described partitions, walls, and floor-ceiling systems are to have a minimum STC rating of 45 with no mention of entrance door requirements. STC ratings are to be tested in accordance with the latest revisions of ASTM E90-61T, so says the SSBC. The NCBC requires that STC ratings be tested in accordance with ASTM E90 and its appendix.

The BHBC is very much like the SSBC and NCBC except that a minimum STC of 48 is required. The BHBC specifies that the above described separation walls must extend through the ceiling to the floor above.

The UBC requires that all separating walls and floor-ceiling assemblies are to meet a minimum STC rating of 50 (45 is field tested) as defined by UBC Standard No. 35-1, "Laboratory Determination of Airborne Sound Transmission Class." However, this standard is based upon specification E90-70, E413-70T, and E90-61T of the American Society for Testing and Materials. Dwelling unit entrance doors with seals are required to maintain an STC rating of at least 30. [Sec. 3501(b)]

The HMO breaks down its airborne noise control recommendations into different building types: multiple unit dwellings (including both apartment buildings and mixed dwelling-commercial structures); Single Unit Dwellings; Commercial, Industrial, and Profession Buildings; Schools; and Hospitals.

For multiple unit dwellings, the HMO recommends a normalized noise isolation class (NNIC) minimum rating of 50 between one dwelling unit and another (or public area including hallways, lobbies, stairways, etc.; or service spaces including mechanical equipment rooms and shafts, elevator shafts, garages, etc.; or commercial spaces including industrial, recreational, and professional spaces). Also recommended is a minimum NNIC rating of 45 between a bedroom (with its doors closed) and other rooms of the same dwelling unit. Between a room (other than a bedroom) and other rooms of the same dwelling unit, it is recommended that there should be a minimum NNIC rating of 40 [Sec. XX02.1].

For single unit dwellings, the HMO recommendations of interspace NNIC requirements within the unit are the same described above [Sec. XX02.3].

For commercial, industrial, and professional buildings, HMO recommends that between spaces or rooms occupied by an establishment and another space occupied by a different establishment (or mechanical space or shaft), there is to be a minimum NNIC rating of 50 [Sec. XX02.3].

Schools and buildings used primarily for educational purposes, according to the HMO, should have an NNIC rating of at least 45 between any two occupied spaces (including classrooms, gymnasiums, libraries, offices, cafeteria, etc.). [Sec. XX02.4].

Between bed-patient care rooms (e.g. wards, semi-wards, semi-private, private) of hospitals (or buildings used primarily for in-patient health care, but not limited to hospitals, infirmaries, sanitariums, etc.), the HMO recommends that there be a minimum NNIC rating of 45. Between bed-patient care rooms and other types of spaces (e.g. pharmacy, lobbies, kitchens, surgical prep rooms, etc.), it is recommended that there be a minimum NNIC rating of 50 [Sec. XX02.5]

The author of the HMO stresses the point that the recommended NNIC ratings in the model ordinance used for noise control criteria are subject to modification to allow for varied noise environments (e.g. urban, sub-urban) and different economic conditions. HUD acknowledges these variables and other factors in developing its STC recommendations. Some of these factors are: possible characteristics of intruding noises; sound insulation performances of walls and floor-ceiling assemblies, particularly as integrated systems in a building complex; the types and intensity of noises subjectively acceptable to the majority of occupants; and the effects of background noise and its use as a masking agent. Taking into account these variables and factors, HUD defines three grades (Grade I, Grade II, and Grade III) of acoustical environments and situations.

HUD used an empirical approach to develop its STC criteria for noise control. Using average data collected from an extensive literature survery as well as unpublished results from National Bureau of Standards investigations into the matter, HUD approximated subjectively acceptable levels from anticipated noise levels (NC curves adjusted to 1/2-octave band levels) within various spaces of a dwelling unit. By subtracting these assumed acceptable levels from anticipated noise levels intruding upon the spaces (adjusted to 1/2-octave band levels), HUD obtained the sound pressure level differences required tc reduce the anticipated noise levels to the assumed acceptable levels. HUD does acknowledge that sound insulation criteria depend upon sound absorption of the space and partition area. Even though HUD assumes that the measured sound transmission loss (STL) values of partitions are represented directly by the values of given sound transmission class (STC) contours, HUD recognizes that this is seldom the case and suggests that this is a reasonable approximation for establishing a criterion with a single-figure rating.

Grade I is applicable primarily in suburban and peripheral suburban residential areas in which exterior nighttime noise levels would be approximately 35-40 dB(A). The interior noise environment might be characterized by noise criteria values of NC20-25. This grade is also applicable to certain cases such as dwelling units above the eighth floor, and the better class ("luxury") buildings, regardless of location. The STC values recommended in this grade are usually higher than those on Grade II or Grade III. (See table 1).

Grade II is mostly urban and suburban areas considered to have an "average" noise environment in which the nighttime exterior noise levels may be about 40-45 dB(A) and the permissible interior noise environment should not exceed NC 25-30. HUD indicates that emphasis should be placed on Grade II since it represents the largest percentage of multifamily dwellings. (See table 1).

Grade III is applicable in some urban areas considered to be "noisy." Nighttime exterior noise levels may be as high as 55 dB(A) or higher. The recommended interior noise environment should not exceed the NC 35 characteristic. The criteria for noise control in this class are usally lower than Grades I or II. (See table 1).

Other types of buildings (i.e. commercial, industrial, recreational, schools, hospitals, and professional buildings) are not discussed in depth in the HUD report. Recommendations are made for airborne noise control criteria in mixed dwelling-commercial structures.

The STC rating criteria for airborne sound insulation of walls, partitions, and floor-ceiling assemblies in the NIBC are identical to those of HUD Grade II recommendations. However, the NIBC also lists field tested STC rating (FSTC) requirements. The NIBC has no provisions for airborne sound insulation requirements for partitions within the same dwelling unit as does HUD.

Penetrations:

The SSBC has a general provision that states the STC rating of partitions should be maintained and not altered due to penetrations, flanking transmission, or voiding airspaces. Both, the NYCBC and UBC have the same provision but indicate more specifically the types of penetrations and openings of concern (e.g. pipe sleeves, medicine cabinets, bathtubs, ductwork openings, etc.), and provide some examples for sealing the penetrations properly (e.g. backplastering). The BHBC states that pipes within separations are to be wrapped and voids around these pipes packed with sound deadening material. It also calls for caulking (with non-hardening, non-skinning caulking material) of the perimeters of separation walls and the perimeters of openings cut into, or through, the separation wall. The BHBC also specifies that medicine cabinets, vents, or electrical outlets serving one dwelling unit are not to be placed back-to-back with, or immediately adjacent to, other medicine cabinets, vents, or electrical outlets serving another dwelling unit.

The HUD recommendations refer the reader to the text and discussions accompanying the recommended criteria for specific solutions to penetration problems. The HMO does not mention this aspect of airborne noise control specifically.

STRUCTURE BORNE NOISE:

In the UBC, floor-ceiling constructions separating one dwelling unit from another are required to have a minimum Impact Insulation Class (IIC) rating of at least 50, 45 if field tested as defined by UBC Standard No. 35-2.

The NYCBC requires that floor-ceiling assemblies separating dwelling units are to have a minimum Impact Noise Rating (INR) or 0. The INR are to be obtained from NYCBC reference standard RS 12-3 [C26-1208.2(b)(1-3]. The BHBC also calls for an INR rating of 0 or greater [Sec. 1314], whereas the NCBC only requires an INR of -5[Sec. 2.5(a)].

The BHBC, NYCBC, NCBC, and NIBC state that floor coverings may be included in the floor-ceiling assembly when obtaining ratings. However, these floor coverings must then be maintained as a permanent part of the overall floor-ceiling system. The floor covering may be replaced by other floor coverings only with the same (or better) noise reduction characteristics.

HUD has recommended IIC (as well as STC) ratings listed for floor-ceiling constructions between dwelling units according to Grade (as described above) and according to the function of the floor-ceiling partition (e.g. bedroom above bedroom, kitchen above living room, etc.)(see table 2). HUD declares it desirable to have floor-ceiling partitions separating spaces of equivalent functions, e.g. bedroom over bedroom.

The NIBC has precisely the same required criteria for impact sound insulation of floor-ceiling assemblies between dwelling units as HUD's Grade II impact sound insulation recommendations [Art. V, Sec. 3.10(b)].

After some discussion in his text, the author of the HMO declares that neither the IIC nor the INR systems are appropriate for building code provisions. Therefore, the HMO has no direct provisions for impact noise regulation. However, impact noise is somewhat indirectly controlled by HMO airborne NNIC rating requirements between spaces.

The SSBC has no provisions for impact noise insulation requirements.

MECHANICAL SYSTEMS AND EQUIPMENT NOISE CONTROL:

Detailed HUD discussions with illustrations and NYCBC regulations deal specifically with the following noise control problems which the SSBC, BHBC, and UBC do not. The HMO mentions some of them. The NIBC and NCBC also do not.

Ductwork:

The NYCBC and HUD are concerned with various noise problems of ductwork. When two dwelling units share a common duct in which "cross-talk" can occur, the NYCBC sets forth requirements to assure minimum attenuation of sound traveling between the two units [C26-1208.2(a)(5)]. Also the NYCBC specifies the minimum length required of duct lining from the fan discharge or intake. Toilet exhaust ducts are required to have a minimum amount of duct lining [C26-1208.3(a)(3)]. Maximum permissible air flow velocities in ducts is established to control noise from air flow and turbulence [C26-1208.3(c)]. Duct vibration isolation is established which requires the installation of flexible connections between fan equipment and ductwork [C26-1208.3(b)(9)]. Maximum permissible sound power levels for duct terminal units (e.g. grilles, diffusers, registers, induction units, and fan coil units) are established [C26-1208.2(d)]. These maximum sound power levels are measured in dB according to octave band readings.

The HMO is not concerned specifically with ductwork and duct terminals, but treats mechanical equipment noise with more general terms by specifying maximum Noise Criteria (NC) ratings for various rooms [Sec. XX03.2].

The HUD report has detailed discussions and illustrations concerning ductwork noise control.

Boilers and Boiler Rooms:

The NYCBC requires that boiler rooms adjoining dwelling units, either vertically or horizontally, be isolated from these units by a floor-ceiling partition with an STC rating of no less than 50 [C26-12-8.3(a)(1)]. Structure-borne noise in boiler rooms is controlled in the NYCBC by prescribing the location and minimum static deflection required for boiler isolators. Boiler breeching and piping is also controlled by requiring a minimum length of pipe to be resiliently supported and isolated as well as requiring the minimum static deflection of these isolators [C26-1208.3 (b)(1)]. The HUD report has detailed discussions and illustrations concerning acoustical control of heating and cooling equipment including, but not limited to, equipment selection, installation, and system noises.

Other:

The NYCBC has regulations and HUD has recommendations (in text discussion) pertaining to the following mechanical systems and equipment noises:

1) both metal and masonry incinerator charging chutes (including resilient isolation requirements for metal chutes, interior finishes for masonry chutes, plumbness, etc.),
2) piping (including resilient isolation requirements, isolation of piping connected to power driven equipment and/or pressure reducing valves, etc.),
3) isolation of equipment that is not power driven, but connected to power driven equipment (such as heat exchangers and absorbtion refrigeration machines),
4) isolation requirements for fans and fan motors (including minimum resilient pad thickness, minimum isolator efficiency, provisions for leveling, and maximum deflections of isolators),
5) pumps (3 h.p. or more including minimum vibration isolator efficiency, provisions for leveling, and minimum resilient pad thickness),
6) compressors (including minimum vibration isolator efficiency, provisions for leveling, and minimum resilient pad thickness),
7) cooling towers (including minimum static deflection, minimum isolator efficiency, minimum resilient pad thickness, and provisions for leveling),
8) evaporative condensers (including minimum vibration isolator efficiency, maximum static deflection, minimum resilient pad thickness, and provisions for leveling), and
9) all types of elevator machinery (e.g. gear-driven, gearless, motor generators, and controllers) [C26-1208.3(b)(2-10)].

MECHANICAL EQUIPMENT SPACE:

The NYCBC requires that spaces or shafts containing mechanical equipment (air conditioning, refrigeration, ventilation, elevator machinery, or other mechanical equipment) is to be separated, both vertically and horizontally, by construction that has a minimum STC rating of 50. A mechanical space in which there is equipment totaling more than 75 rated h.p. is not permitted to be located either vertically or horizontally adjacent to dwelling units, unless the total sound power level output does not exceed those listed in NYCBC Table 12-3 in any octave band [C26-1208.3(a)(2)].

The NYCBC also concerns itself with specific problems of noise control such as noise from ventilation openings into mechanical spaces. The locations of such openings and/or the sound attenuation at these openings are controlled.

The NYCBC controls exterior mechanical equipment noises so that mechanical equipment of a building located outside is subject to noise output limitations when this noise infringes upon the occupancy groups J-1, J-2, or J-3 when they are within a 100' sphere of the equipment noise (unless the sound pressure levels, in octave bands, of noise from the equipment does not exceed certain requirements listed in NYCB Table 12-5, as measured within the dwelling unit).

The HMO recommends that sound transmitted from spaces or shafts containing the above described mechanical equipment, ductwork, etc.; are not controlled by STC ratings of partitions, but by NC curves. Maximum NC ratings are listed for a) bedrooms in dwelling units; b) any room other than a bedroom in a dwelling unit; c) wards, semi-wards, semi-private, or private rooms used for bed-patient care in a hospital, infirmary, sanatarium, etc.; and d) classrooms, lecture halls, or other rooms used primarily for educational purposes [Sec XX03.3].

Minimum airborne noise insulation requirements for mechanical equipment spaces are not listed in the UBC or the SSBC.

The HUD report contains a small discussion as well as recommendations for sound insulation between dwelling units and mechanical equipment spaces. HUD recommends that whenever possible, the placement of living areas vertically or horizontally adjacent to m.e. rooms should be avoided. However, when such cases are unavoidable, HUD sets forth impact and/or airborne sound insulation criteria according to partition function (e.g. bedroom to m.e. space) and room location with respect to the m.e. space (e.g. m.e. space over kitchen, bedroom over m.e. space, etc.) as well as the dwelling unit grade (i.e. Grade I, Grade II, or Grade III). HUD also makes provisions to increase recommended STC ratings by 5 points if noise levels in the mechanical equipment space exceeds 100 dB(A), measured using a linear scale of a standard sound level meter.

Both the NYCBC [C26-1208.3(a)(2)b] and the HMO [Sec. XX03.2] have provisions for pure-tone corrections due to mechanical equipment noise. In the NYCBC, sound power levels of octave bands containing pure-tones from mechanical equipment must be reduced by 5 dB. Criteria for a significant pure-tone is given in the NYCBC. Approximately the same requirements are given in the HMO.

Minimum airborne noise insulation requirements for mechanical equipment spaces are not listed in the UBC, SSBC, BHBC, NCBC, NIBC, or SSBC.

<u>MISCELLANEOUS:</u>

DEFINITIONS:

The HMO, NIBC, and UBC have definitions of abbreviations, acoustical terminology, and sometimes their derivations incorporated into their codes. The HUD report has a section for acoustical terminology used in the report. The BHBC, NCBC, NYCBC, and SSBC have no provisions for definitions of acoustical terms.

TABLE 1

FEDERAL HOUSING ADMINISTRATION
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
CRITERIA FOR AIRBORNE SOUND INSULATION
OF WALL PARTITIONS BETWEEN DWELLING UNITS:

Partition Function Between Dwellings			Grade I	Grade II	Grade III
Apt. A		Apt. B	STC	STC	STC
Bedroom	to	Bedroom	55	52	48
Living Room	to	Bedroom[1,2]	57	54	50
Kitchen[3]	to	Bedroom[1,2]	58	55	52
Bathroom	to	Bedroom[1,2]	59	56	52
Corridor	to	Bedroom[2,4]	55	52	48
Living Room	to	Living Room	55	52	48
Kitchen[3]	to	Living Room[1,2]	55	52	48
Bathroom	to	Living Room[1]	57	54	50
Corridor	to	Living Room[2,4,5]	55	52	48
Kitchen	to	Kitchen[6]	52	50	46
Bathroom	to	Kitchen[1]	55	52	48
Corridor	to	Kitchen[2,4,5]	55	52	48
Bathroom	to	Bathroom	52	50	46
Corridor	to	Bathroom[2,4]	50	48	46

NOTES; RE: TABLE 1

1. The most desirable plan would have the dwelling unit partition separating spaces with equivalent function, e.g., living room opposite living room, etc.; however, when this arrangement is not feasible, the partition must have greater sound insulating properties.
2. Whenever a partition wall might serve to separate several functional spaces, the highest criterion must prevail.
3. Or dining, or family, or recreation room
4. It is assumed that there is no entrance door leading from the corridor to living unit.
5. A common approach to corridor partition construction correctly assumes the entrance door as the acoustical weakest "link" and then incorrectly assumes that the basic partition wall need be no better acoustically than the door. However, the basic partition wall may separate the corridor from sensitive living areas such as the bedroom and bathroom without entrance doors, and must therefore have adequate insulating properties to assure acoustical privacy in these areas. In areas where entrance doors are used, the integrity of the corridor-living unit partition must be maintained by utilizing solid-core entrance doors, with the proper gasketing. The most desirable arrangement has the entrance door leading from the corridor to a partially enclosed vestibule or foyer in the living unit.
6. Double-wall construction is recommended to provide, in addition to airborne sound insulation, isolation from impact noises generated by the placement of articles on pantry shelves and the slamming of cabinet doors. Party walls which utilize resilient spring elements to achieve good sound insulation may be used, providing cabinets are not mounted on them. It is not practical to use such walls for mounting of wall cabinets because the sound insulating performance of the walls can easily be short-circuited, unless specialized vibration isolation techniques are used.

TABLE 2

FEDERAL HOUSING ADMINISTRATION
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT,
CRITERIA FOR AIRBORNE AND IMPACT SOUND INSULATION
OF FLOOR-CEILING ASSEMBLIES BETWEEN DWELLING UNITS:

Partition Function Between Dwellings			Grade I		Grade II		Grade III	
Apt. A		Apt. B	STC	IIC	STC	IIC	STC	IIC
Bedroom	above	Bedroom	55	55	52	52	48	48
Living Room	above	Bedroom[1,2]	57	60	54	57	50	53
Kitchen[3]	above	Bedroom[1,2]	58	65	55	62	52	58
Family Room	above	Bedroom[1,2,4]	60	65	56	62	52	58
Corridor	above	Bedroom[1,2]	55	65	52	62	48	58
Bedroom	above	Living Room[5]	57	55	54	52	50	48
Living Room	above	Living Room	55	55	52	52	48	48
Kitchen	above	Living Room[1,2]	55	60	52	57	48	53
Family Room	above	Living Room[1,2,4]	58	62	54	60	52	56
Corridor	above	Living Room[1,2]	55	60	52	57	48	53
Bedroom	above	Kitchen[1,4,5]	58	52	55	50	52	46
Living Room	above	Kitchen[1,4,5]	55	55	52	52	48	48
Kitchen	above	Kitchen	52	55	50	52	46	48
Bathroom	above	Kitchen[1,2]	55	55	52	52	48	48
Family Room	above	Kitchen[1,2,4]	55	60	52	58	48	54
Corridor	above	Kitchen[1,2]	50	55	48	52	46	48
Bedroom	above	Family Room[1,5]	60	50	56	48	52	46
Living Room	above	Family Room[1,5]	58	52	54	50	52	48
Kitchen	above	Family Room[1,5]	55	55	52	52	48	50
Bathroom	above	Bathroom	52	52	50	50	48	48
Corridor	above	Corridor	50	50	48	48	46	46

NOTES; RE: TABLE 2

1. The most desirable plan would have the floor-ceiling assembly separating spaces with equivalent function, e.g. living room above living room etc.; however when this arrangement is not feasible the assembly must have greater acoustical insulating properties.
2. This arrangement requires greater impact sound insulation than the converse, where a sensitive area is above a less sensitive area.
3. Or dining, or family, or recreation room.
4. The airborne STC criteria in this table apply as well to vertical partitions between these two spaces.
5. This arrangement requires equivalent airborne sound insulation and perhaps less impact sound insulation than the converse.

TABLE 3

FEDERAL HOUSING ADMINISTRATION
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
SUGGESTED CRITERIA FOR AIRBORNE SOUND INSULATION WITHIN A DWELLING UNIT

Partition Function Between Rooms			Grade I STC	Grade II STC	Grade III STC
Bedroom	to	Bedroom[1]	48	44	40
Living Room	to	Bedroom[1]	50	46	42
Bathroom	to	Bedroom[2]	52	48	45
Kitchen	to	Bedroom	52	48	45
Bathroom	to	Living Room	52	48	45

NOTES; RE: TABLE 3

1. Closets may profitably be used as buffer zones, providing unlouvered doors are used.
2. Doors leading to bedrooms and bathrooms preferably should be of solid-core construction and gasketed to assure a comfortable degree of privacy.

Townhouses and row-houses where the living unit occupies more than one story should be separated by double-wall construction with a rating of STC = 60 or greater. Suggested criteria between rooms in a given dwelling are the same as listed in Table 3 above in addition, the floor-ceiling structures should have IIC ratings which are least numerically equivalent to or greater than the listed STC criteria.

Roof-top or indoor swimming pools, bowling alleys, ballrooms, tennis courts, gymnasiums, and the like require extremely specialized acoustical considerations.

Constructions which meet the above recommended criteria should provide adequate acoustical privacy in most cases. However, after sufficient data are obtained which may relate occupant subjective satisfaction with objective measurements of the acoustical properties of structures, it may become appearent that revision is necessary and desirable. Such subsequent revisions might be in the more stringent direction or indeed, perhaps in the less stringent direction to effect a desirable balance between acoustical privacy and economic feasibility. Nevertheless, the inherent flexibility of the system provides for ease of revision and a basis upon which subsequent incremental changes might be made by code authorities and architects.

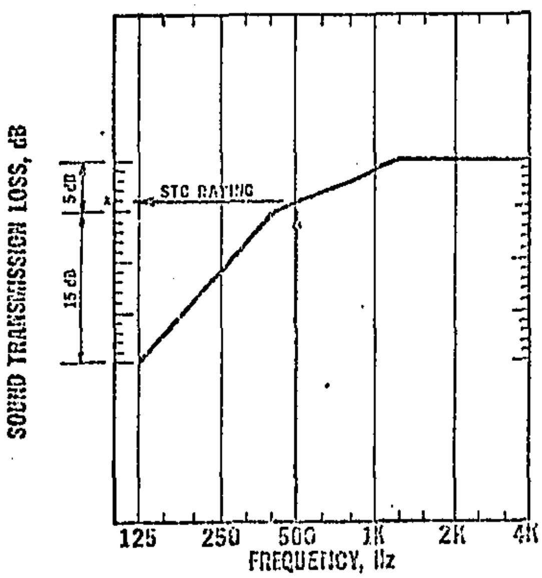


fig. 1

SOUND TRANSMISSION CLASS

[use with 1/3-octave data;
5cm = 25 dB,
5cm = 1 frequency decade,
STC = TL value of reference curve at 500 Hz]

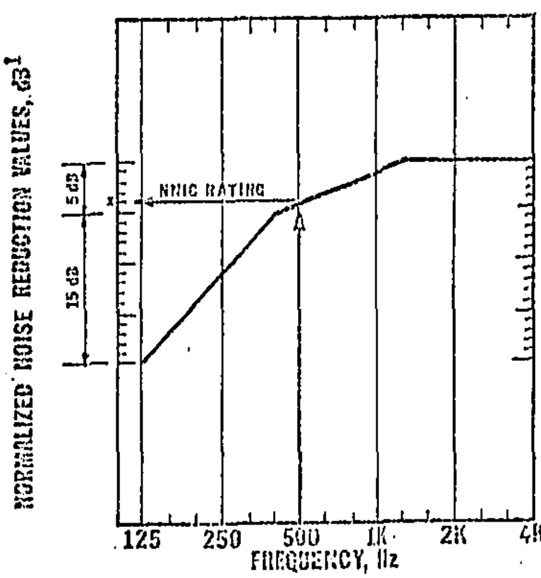


fig. 2

NORMALIZED NOISE ISOLATION CLASS

[use with 1/3-octave data;
NNIC = NNR value of reference curve at 500 Hz]

1. dB RE 0.0002 dyne/cm^2 normalized to T_0 = 0.5 sec.

IMPACT INSULATION CLASS

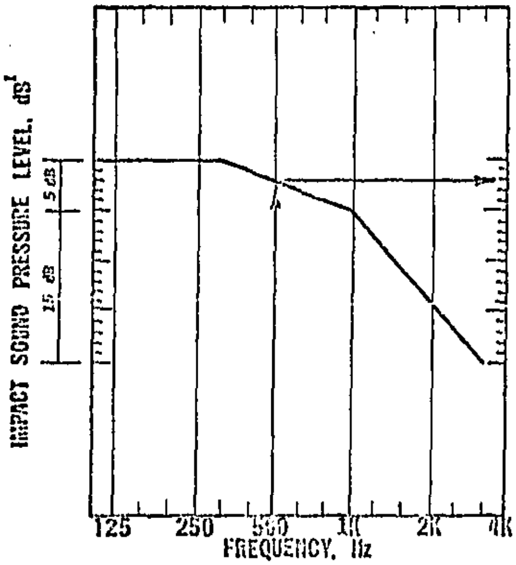


fig. 3a
IIC REFERENCE CONTOUR

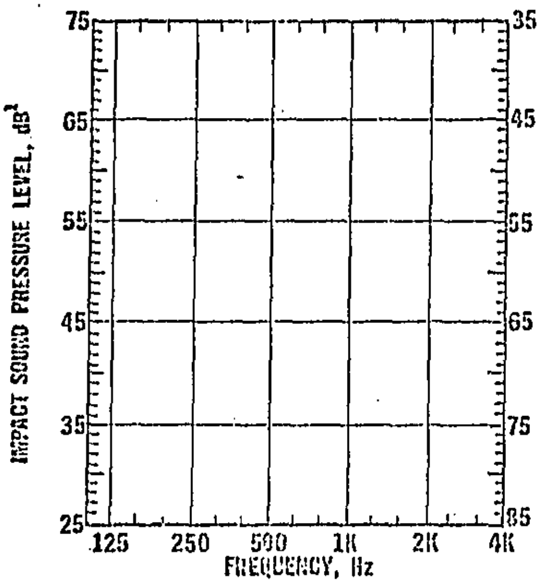


fig. 3b
IIC RATING GRID

1 RE: 0.0002 DYNE/CM^2

IMPACT NOISE RATING

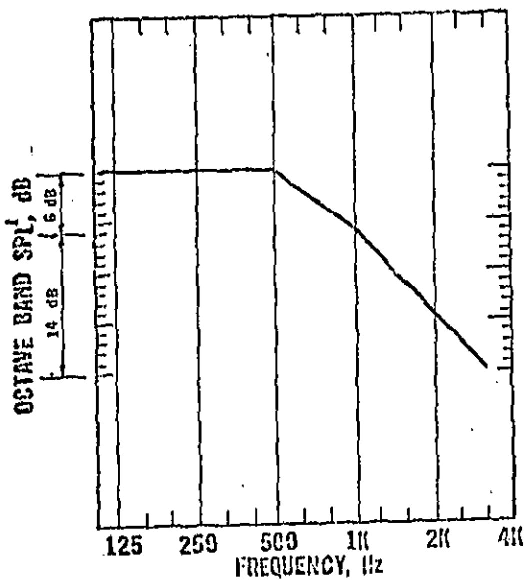


fig 4a
INR REFERENCE CONTOUR

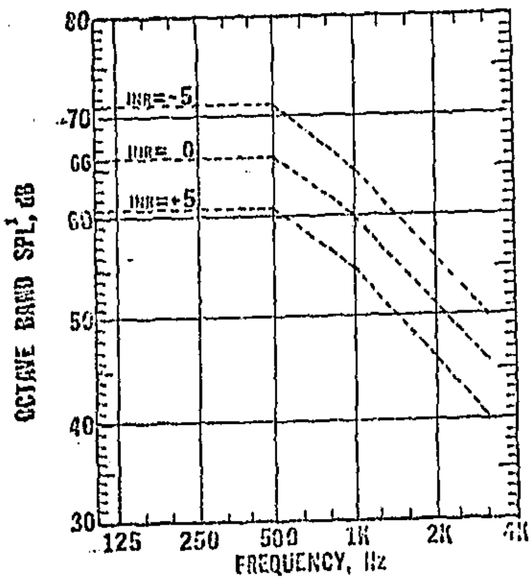
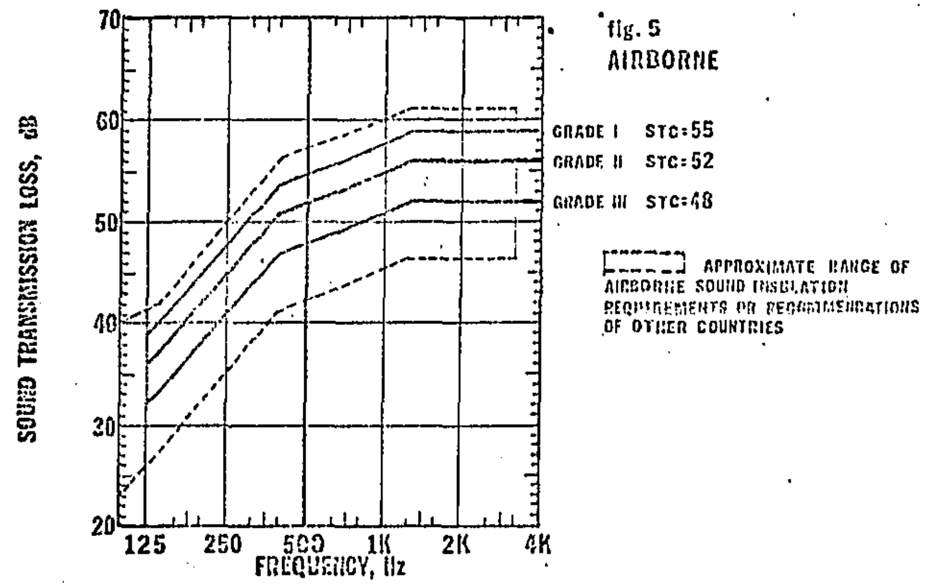
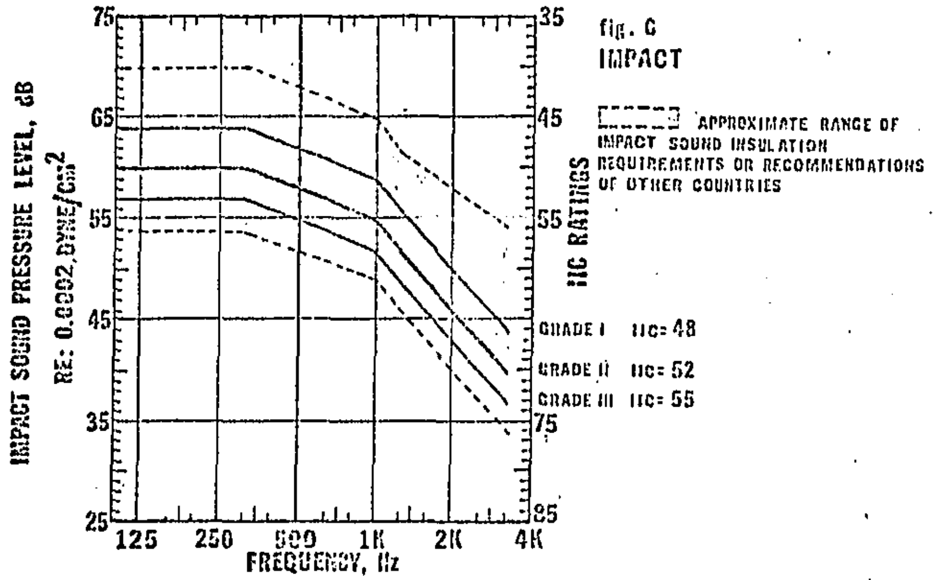


fig 4b
INR RATING GRID

1. NORMALIZED TO A_0 = 100 SABINS

FHA RECOMMENDED SOUND INSULATION CRITERIA





ISO RECOMMENDED SOUND INSULATION CRITERIA

ISO RECOMMENDATION ISO/R 717-1968(E)

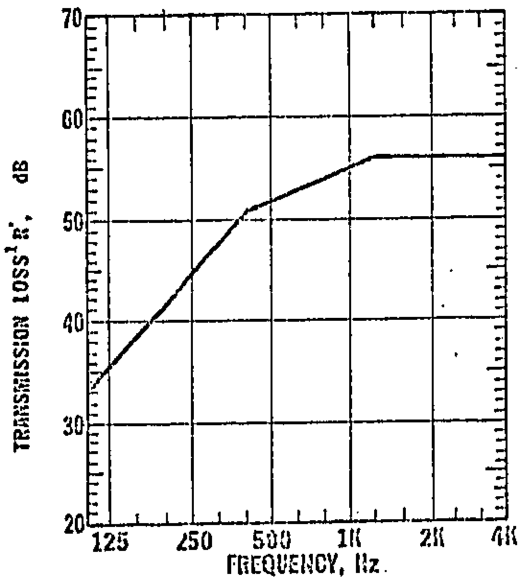


fig. 7
ISO AIRBORNE SOUND REFERENCE CONTOUR

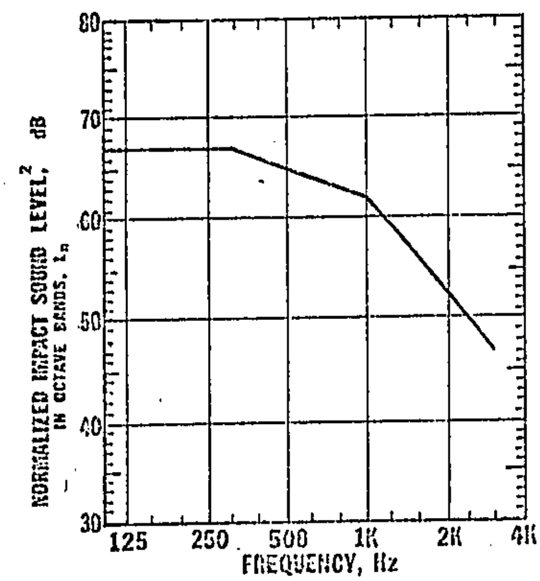


fig. 8
ISO IMPACT SOUND REFERENCE CONTOUR

1. $R' = L_1 - L_2 + 10 \log_{10}(S/A)$, dB
2. $L_n = L - 10 \log_{10}(A_o/A)$, dB $A_o = 10\,m^2$

SECTION FOUR

DOMESTIC NOISE CONTROL THROUGH BUILDING CODE PROVISIONS
(Results of Questionaires and Correspondence)

On the Municipal Level:

The municipalities sent the questionaire were those that indicated concern for community noise control programs according to a status report on city noise ordinances.[1] Sixty-seven municipalities in the 40 states were sent the questionaire; 35 answered, slighty over 50%.

Many of the cities responded that they have some type of general noise control program. Table 4 indicates that most of them have adopted general nuisance ordinances which are not enforced unless there is a complaint. Many of these nuisance ordinances which are enforced by the local police department equipped with some pressure level meters. In some instances, it was indicated that noise nuisance ordinances were enforced by a pollution control inspector of the local Air Pollution Control Department: such is the case in Columbia, South Carolina.

Some cities, such as Lakewood, Colorado have noise control programs consisting mainly of vehicle monitoring, compliance testing, and complaint response. The cities of California enforce state legislated vehicle noise codes.

Many of the communities answered that the main structure of their noise control programs lies mostly within their zoning regulations and ordinances; e.g. setting maximum allowable ambient noise levels within a particular type zone. Tempe, Arizona establishes noise control through extensive land-use planning which is enforced through their zoning department.

Of the 35 cities answering the questionaire, only 5 indicated that their noise control programs included provisions within their local building codes. These five cities are: New York, New York; Newark, Calif.; Northbrook, Ill.; Pocatello, Idaho; and Portland, Oregon. Four other cities indicated that they have adopted the Uniform Building Code in their local ordinances, but they do not enforce Appendix Chapter 35, "Sound Transmission Control". These cities are Albuquerque, N. Mex.; Beverly Hills, Calif.; Minneapolis, Minn.; and Torrence, California. Beverly Hills stated that its building department only enforces noises from fixed mechanical equipment (e.g. air conditioning equipment, pool pumps, industrial machinery, etc.). The status report in Sound and Vibration indicated that the municipalities of Los Angeles, Calif.; Chicago, Ill.; Wichita, Kan.; Ann Arbor and Milford, Michigan;

Bloomington, Minn.; Helena, Mont.; Irving, Texas; and Milwaukee, Wisconsin have some type of noise control within their local building codes, but these cities did not reply to the questionaire sent to them by this author.[2]

The only municipality responding to the questionaire with a totally comprehensive program for noise control was New York City. New York City's Bureau of Noise Abatement is responsible for the administrative and technical aspects of the city's noise control programs while the Division of Noise Enforcement of the Department of Air Resources is primarily responsible for enforcing the provisions of the noise control ordinances, but not those of the building code. The Department of Buildings is responsible for the enforcement of the sound control provisions in the New York City building code. However, there is minimal contact between the Department of Buildings and the Department of Air Resources.

Only six municipalities responded indicating that they have established a budget for general noise control and enforcement. These budgets ranged from 1.8¢ per capita (Columbia, S.C.) to 44.6¢ per capita (Palo Alto, Calif.). The City of Portland replied that it has proposed a budget of $30,000, about 7.7¢ per capita for noise control and enforcement (primarily for enforcement of newly adopted building code sound provisions).

Staff involved directly with the enforcement of general noise control programs range from one man part-time (Columbia's Pollution Control Officer) to New York's more than 40 full-time personnel. The New York City Bureau of Noise Abatement staffs 18 physicists and engineers plus support personnel. The New York City Division of Noise Enforcement has three senior inspectors, 20 inspectors, plus clerical and administrative help. Generally though, noise enforcement is done on a part-time basis by police officers or by other part-time personnel, sometimes averaging as little as 2-3 house per week. Building code regulations for noise control are usually enforced part-time by building inspectors and plan-checking personnel. Such is the case even in New York City Department of Buildings.

Both New York City and Portland indicated that approximately 5% of their building department's total time is spend on noise control enforcement. Portland's proposed budget for noise control includes hiring a full-time acoustician. Pocatello, Idaho stated that approximately 1% of its building department's total time is spent on noise control enforcement.

The amount of instrumentation used to support their noise control programs varied with the responses from the different cities. Some had only sound pressure level meters for enforcement purposes as compared to the various types of equipment (and consultation services) used by the City of New York. The N.Y.C. Bureau of Noise Abatement spends as much as $200,000 in one year for equipment purchases and consultation contracts. Appendix F is a list of equipment for the New York City Division of Noise Enforcement, Bureau of Noise Abatement, and Department of Buildings.

The City of Pocatello first adopted building code sound control provisions as early as 1965 using the Uniform Building Code (UBC) as a model. In 1968, after extensive consultation with experts and research, New York City adopted its comprehensive building code noise control regulations. The most recent city to adopt sound control provisions within its local building code is Portland which also used the UBC recommendation as the model code. Portland adopted its provisions in December 1973. Most cities responding to the questionnaire with sound control provisions within their building codes replied that they also used the UBC recommendations as guidelines. However, Northbrook, Illinois, like New York City, established its building code provisions through extensive research and consultation with experts.

Of the municipalities responding, enforcement of their building code regulations is the responsibility of some type of building department (e.g. Bureau of Buildings, Department of Buildings, etc.). However, the entire noise control program of Columbia, S. C. is under the Department of Building and Inspection where the immediate supervisor of the Pollution Control Official is the Building Official. However, since Columbia uses the Southern Standard Building Code, they do not enforce noise control as part of their building code since the SSBC only provides recommendations for airborne sound control.

Pocatello indicated that approximately 1% of its noise control budget is for the enforcement of sound control provisions in building codes. Portland, Oregon stated that 80% of its proposed budget for noise control will be spent on enforcing building code provisions (if the budget is approved). The other communities did not respond to this question.

Of those cities that answered, with the exception of New York City, they all indicated that training of personnel who were to enforce the building code regulations had minimal professional training usually amounting to no more than on-the-job training or practice in the field. Sometimes if a noise control course is available locally, the city would send their personnel to take the course. The New York City Department of Noise Enforcement (NYCDNE) personnel must successfully complete a rigorous one-week training taught semi-annually before assignment in the field. All NYCDNE personnel (except support personnel) have at least a Bachelor of Physics or Bachelor of Electrical Engineering Degree. In the Department of Buildings, all new examining personnel attend a course concerning noise control in buildings.

Of the six cities with building code provisions, two indicated that they had good inter-agency contact (e.g. joint inspections, conferences, etc.) and coordination; these two cities being Northbrook, Ill. and Portland, Oregon. The other cities, including New York City, indicated that they had minimal or no contact at all with other departments or agencies within their own municipal government.

In five of six municipalities with sound control provisions in their building codes, the attitude of the general public was rated as being "for" these provisions. The only other answer was that the general public was indifferent towards these provisions. As far as the building trades are concerned, only Newark, California indicated that it was receiving any resistance, that being from the local Home Builders Association. The other municipalities indicated that the building trades were either for, or indifferent in attitude towards the building code provisions. Portland, who just recently adopted the recommended Uniform Building Code provisions for noise control, stated that the response from the building trades, "has been constructive." The professional community (e.g. architects, engineers, acousticians, etc.) are, on the most part, "for" the building code provisions.

Of these six municipalities with building code provisions, only one, Northbrook, indicated that they may have any improvements pending. They intend to expand their ordinances to "include other uses."

To generate public awareness of their building code regulations pertaining to sound control, Newark provides a brochure advising designers of its building code requirements. Portland indicated that its citizens are becoming increasingly aware of the necessity for sound control and that its citizens have been taking an active part in meetings concerning the problem. The other communities with noise control building code provisions did not comment concerning the extent of, or the methods used to generate, public awareness of their noise control provisions.

Portland stated that a major accomplishment of their building code provisions for noise control has been to provide specific requirements that can be enforced. Newark believes that there is a higher quality in multi-family units (with increased privacy) being built according to their building code noise control provisions. Northbrook and Pocatello responded along the same lines implying that the increased privacy provided for better buildings.

Northbrook noted that a shortcoming of its noise control building code provisions was that it may need to be "updated at intervals." The other cities state that there are no areas of their sound control provisions that need to be improved or revised.

When asked what problems may have arised due to the noise control provisions within their building codes, Northbrook answered that in some instances, the sound control requirements may reduce fire ratings. Newark stated that some of the indirect problems arising from its provisions were, in plan checking, designers providing correct construction details for sound control; and in the field, good workmanship to provide correct construction and installation techniques. New York City cited failure of equipment and building component manufacturers to readily comply with noise control constraint requirements.

Of the twenty municipalities which have some type of noise control program but do not have noise control provisions within their local building codes, only five indicated that they intend to adopt such provisions in the future. These 5 cities being College Park, Ga.; Dallas, Texas; Lakewood, Colo.; Washington, D.C.; and Boulder, Colorado which stated that they may adopt building code provisions within the next 2 to 3 years.

Mr. Martin P. Walsh, Jr. of the Cincinnati Department of Buildings and Inspections answered the survey indicating that Cincinnati has decided to exclude sound control provisions from its local building codes for the following reasons:

1) Noise control provisions would be enforced in the event of the alteration and rehabilitation of multiple dwelling units adding unnecessary cost to housing, and increasing the chance of abandonment of vacant structures due to the prohibitive costs of rehabilitation.
2) The Cincinnati Housing Bureau has had no complaints that could not be handled by nuisance codes.
3) People with loud audio equipment (e.g. 150 watt stereos) can overpower any economical sound barrier.
4) The amount of sound to be attenuated depends on the background masking noise level which may relate to the location of the building and this particular aspect is better handled through zoning ordinances.
5) No partition or floor-ceiling assembly is equally effective (in airborne sound control) for the full range of frequencies. Every system has a natural frequency it will respond to since it interrelates to conditions of support, span, attachment, and stiffness of intersecting partitions, etc.
6) In regards to floor impact noise, new dwelling units are almost always carpeted which has a very favorable influence on Impact Noise Reduction ratings.
7) Many items inspectors check with regard to fire-stopping inside combustible spaces, etc., serve to lessen flanking paths of sound.
8) The apartment industry seems well aware of the sales/advertising potential of sound proofed units and the city finds great voluntary attention to this.

9) The Federal Housing Administration (FHA) has checked such systems in their property standards and thus introduced a strong financing coercive tool in this area for years.
10) In comparing standard wall constructions used in multi-family dwellings meeting fire resistance requirements for dwelling unit separation to standard acoustical test tables, usually those in use are of the STC rank "good - normal speech can be heard faintly, if at all."

Some of the cities of California (Palo Alto and San Francisco) have indicated that they will adopt noise control provisions within their building codes if, and when, such codes are required by state legislation.

Washington, D. C. indicated that if they do adopt building code provisions, they will probably use the New York City Building Code and the Federal Housing and Urban Development (HUD) recommendations as guidelines. Dallas, and the cities in California, indicated that the Uniform Building Code would be used as the model code for developing their sound control provisions. College Park, Ga. stated that it would research the matter extensively while Lakewood, Colorado replied that their model code would probably be the model sound control ordinance for building codes proposed by R. Weston in the <u>Harvard Journal on Legislation</u>.[3]

All of these cities indicated that if they did adopt sound control requirements in their building codes, these requirements would be enforced through their building departments (by building inspectors, building officials, etc.). However, none of these cities said that they would provide for the training of their personnel.

For these cities which have general noise control programs, but no provisions within their building codes, the general public's attitude seems to be "for" the establishment of such provisions in three of the cities, and indifferent in six others. There is no evidence of resistance on the part of the general public. Even though the building trades seem to be indifferent towards the matter of establishing sound control in building codes for these cities, Palo Alto indicates that the building trades in its community appear to be against the establishment of such codes. However, Palo Alto was the only city with general noise programs to report this. The professional community (e.g. architects, engineers, and acousticians, etc.) is generally in favor of establishing such provisions (as reported by four communities) or indifferent (as reported by three communities).

Of the ten municipalities that do not have a comprehensive noise control program, seven indicated that they have plans to, or that it is possible that they may, increase the coverage of their present noise control programs. (Burbank, California replied that it would adopt a general noise control program only through state action.) Only Pittsburgh, Pennsylvania indicated that it had no plans for adopting any general noise control programs. Tucson, Arizona; Nashville, Tennessee; and Albuquerque, New Mexico replied that they would include performance type provisions if, and when, they established a comprehensive noise control program.

The general public seems to be either for or indifferent towards the idea of establishing noise control programs within these cities, but not against it. The building trades appear to be either for or indifferent (except for those in Minneapolis, Minn.) towards the establishment of community noise control programs. The professional community in these cities have the same attitude as the building trades concerning this matter.

Of the seven cities that stated they may adopt a comprehensive community noise control program, when asked if they intend to include building code regulations, four cities (Albuquerque, Honolulu, New Orleans, and Tucson) stated either "yes" or that it was "possible." Arlington, Va. responded that it would adopt building code provisions if required by state legislation. Both Cincinnati and Minneapolis said they would not adopt building code regulations and Oklahoma City did not know if building code regulations would be included in a general noise program.

A comprehensive comparison of sound control provisions in eight domestic building codes (or recommendations) is given in the next section of this report.

On the State Level:

Of the four states that were sent the questionnaire, only one state, Hawaii, replied. California, Virginia and New York did not answer.

The State of Hawaii has a budget of $60,000 designated for noise control. That is approximately 8¢ per capita for its population of 750,000.

The scope of its noise control program consists of the "control of excessive noise in the state through the promulgation of regulation." However, what these regulations are were not indicated in the reply to the questionnaire. It was stated though that noise control provisions within state building codes may be established in the next three years.

Hawaii also reports that the general public seems to be for the establishment of such noise control provisions, whereas the building trades and professional community appear to be against such provisions.

No other information was offered in the returned questionnaire.

On the National Level:

The Noise Control Act of 1972 (NCA-72), enacted by Congress on October 18, 1972 and signed by the President, October 27, 1972, calls for the National Bureau of Standards (NBS) and the Environmental Protection Agency (EPA) to cooperate on the research and development of improved methods of standards for measuring, monitoring, and controlling noise. The appropriations of $3,000,000 for the fiscal year ending June 30, 1973; $6,000,000 for the fiscal year ending June 30, 1974; and $12,000,000 for the fiscal year ending June 30, 1975; were authorized to carry out the Noise Control Act.[4] The current appropriation yields approximately 5.9¢ per capita for the U.S. population of 203,165,573. The NCA-72 requires that the EPA coordinate noise research programs of all federal agencies. This includes the Department of Housing and Urban Development (HUD) which has established strong noise control standards to be observed in the approval of all HUD projects.

The EPA, as the NCA-72 requires, also currently provides technical assistance and information to state, local, and other federal agencies (e.g. HUD) for the abatement and control of noise that jeopardizes the public health or welfare.[5]

Currently, the EPA is preparing model urban noise control legislation and is considering incorporating a general provision for building code requirements. This provision would provide for the

> "Establishment of special noise insulation districts within which specified building performance standards and noise insulation districts shall apply, in order to protect building occupants from excessive noise of external origins."[6]

However, it should be noted that this legislation is still in draft form and may be changed before publication. It should also be noted that this section concerns the abatement of noise originating from external sources and is not concerned with the control of noise penetrating one dwelling unit from another dwelling unit.

The U. S. Department of Housing and Urban Development (HUD) of the Federal Housing Authority (FHA) has developed a comprehensive report on noise control entitled, "A Guide to Airborne, Impact, and Structure Borne Noise-Control in Multifamily Dwellings." This report, published in September 1967, contains a complete section pertaining to FHA recommended criteria for noise control in dwelling units, as well as the development of these criteria. A thorough description of these criteria is given in the next section of this report.

Miscellaneous:

The National Institute of Municipal Law Officers (NIMLO) Model Ordinance Service has a model ordinance concerning community noise control. However, this model ordinance is primarily concerned with nuisance noises and does not contain noise control provisions for community building codes. A letter from Mr. Chris C. Oynes, NIMLO Legal Assistant, to this author indicated that the NIMLO has no plans to include any performance (specifically STC ratings) provisions within a revised model ordinance in the near future.

TABLE 4 - TABULATION OF QUESTIONNAIRE RESULTS

Questions Pertaining to Municipalities With General Noise Control Programs Exclusive Of Building Code Provisions

Municipality	Future Plans To Adopt Noise Control Provisions Within Local Building Codes	Probable Models For Drafting	Probable Administrative Location	Provisions For Personnel Training	General Public's Attitude Towards Adopting Bldg. Code Noise Control	Bldg. Trades' Attitude Towards Adopting Bldg. Code Noise Control	Professional Community's Attitude Toward Adoption Bldg. Code Control
Alburquerque, N.M.	--	--	--	--	--	--	--
Anniston, Ala.	--	--	--	--	--	--	--
Arlington, Va.	--	--	--	--	--	--	--
Beverly Hills, Calif.	--	--	--	--	--	--	--
Boulder, Colo.	2-3 yrs.	--	--	--	--	--	--
Burbank, Calif.	--	--	--	--	--	--	--
Cincinnati, Ohio	Anti-	--	--	--	--	--	--
College Park, Ga.	Yes	Rsch	Bldg.D.	(2)	Ind.	Ind.	For
Columbia, S.C.	(6)	--	(3)	(5)	For	Ind.	Ind.
Dallas, Tex.	Yes	UBC	Bldg.D.	Informal	--	--	--
Denver, Colo.	--	--	--	--	--	--	--
Gainesville, Fla.	No	--	(10)	None	For	Ind.	For
Hartford, Conn.	--	--	--	--	--	--	--
Honolulu, Hawaii	--	--	--	--	--	--	--
Lakewood, Colo.	Yes	HMO	Bldg.D.	On Job	--	--	--
Minneapolis, Minn.	--	--	--	--	--	--	--
Nashville, Tenn.	--	--	--	--	--	--	--
New Orleans, La.	--	--	--	--	--	--	--
New York City, N.Y.	--	--	--	--	--	--	--
Newark, Calif.	--	--	--	--	--	--	--
Northbrook, Ill.	--	--	--	--	--	--	--
Oklahoma City, Okla.	--	--	--	--	--	--	--
Palo Alto, Calif.	(1A)	--	Bldg.I.	Local	Ind.	Against	For
Pawtucket, R.I.	--	--	--	--	Ind.	Ind.	Ind.
Pittsburg, Pa.	--	--	--	--	--	--	--
Pocatello, Idaho	--	--	--	--	--	--	--
Portland, Ore.	--	--	--	--	--	--	--
Princeton, N.J.	--	--	--	--	--	--	--
San Francisco, Calif.	(1A)	UBC	Bldg.D.	--	For.	Ind.	For
Scottsbluff, Neb.	No	--	--	--	Ind.	Ind.	Ind.
Tacoma, Wash.	--	--	--	--	--	--	--
Tempe, Ariz.	--	--	--	--	--	--	--
Torrence, Calif.	(1A)	--	--	--	--	--	--
Tucson, Ariz.	--	--	--	--	--	--	--
Washington, D.C.	Yes	NYBC,HUD	--	--	Ind.	Uncertain	Uncertain

Questions Pertaining To Municipalities With No Noise Control Programs

Municipality	Any Future Plans For Adopting General Community Noise Control Programs	Types Of Ordinances Planned	Models To Be Used For Drafting General Community Noise Controls	General Public's Attitude Towards Community Noise Control Programs	Bldg. Trades' Attitude Towards Community Noise Control Programs	Professional Community's Attitude Towards Future Noise Control Programs	Future Plans Include Adopting Noise Control Provisions Into Bldg. Codes	If So, What Models For Drafting Noise Provisions Will Be Used
Alburquerque, N.M.	Yes	N,Per	NIMLO,EPA	For	--	--	Yes	UBC,Calif,NYCBC,EPA
Anniston, Ala.	--	--	--	--	--	--	--	--
Arlington, Va.	Yes	Z	--	For	For	For	(1A)	--
Beverly Hills, Calif.	--	--	--	For	--	For	--	--
Boulder, Colo.	--	--	--	--	--	--	--	--
Burbank, Calif.	(1A)	--	--	For	Ind.	Ind.	--	--
Cincinnati, Ohio	--	--	--	--	--	--	Anti-	--
College Park, Ga.	--	--	--	--	--	--	--	--
Columbia, S.C.	--	--	--	--	--	--	--	--
Dallas, Tex.	--	--	--	--	--	--	--	--
Denver, Colo.	Yes	Z,V	--	Ind.	--	--	--	--
Gainesville, Fla.	--	--	--	--	--	--	--	--
Hartford, Conn.	--	--	--	--	--	--	--	--
Honolulu, Hawaii	Possible	--	--	--	--	--	Possible	UBC
Lakewood, Colo.	--	--	--	--	--	--	--	--
Minneapolis, Minn.	--	--	--	--	--	--	--	--
Nashville, Tenn.	Yes	Per	--	Ind.	Against	Ind.	No	--
New Orleans, La.	Yes	N	--	Ind.	For	For	Possible	--
New York City, N.Y.	--	--	--	--	--	--	--	--
Newark, Calif.	--	--	--	--	--	--	--	--
Northbrook, Ill.	--	--	--	--	--	--	--	--
Oklahoma City, Okla.	Yes	Unkwn.	--	--	--	--	Unkwn.	Unkwn.
Palo Alto, Calif.	--	--	--	--	--	--	--	--
Pawtucket, R.I.	--	--	--	--	--	--	--	--
Pittsburg, Pa.	No	--	--	Ind.	Ind.	Ind.	--	--
Pocatello, Idaho	--	--	--	--	--	--	--	--
Portland, Ore.	--	--	--	--	--	--	--	--
Princeton, N.J.	--	--	--	--	--	--	--	--
San Francisco, Calif.	--	--	--	--	--	--	--	--
Scottsbluff, Neb.	--	--	--	--	--	--	--	--
Tacoma, Wash.	--	--	--	--	--	--	--	--
Tempe, Ariz.	--	--	--	--	--	--	--	--
Torrence, Calif.	Yes	--	--	--	--	--	--	--
Tucson, Ariz.	Possible	Per	Rsch.	For	For	For	Yes	Rsch.
Washington, D.C.	--	--	--	--	--	--	--	--

TABLE 4 - TABULATION OF QUESTIONNAIRE RESULTS

Municipality	Population	Scope of Municipal Noise Control Programs	$ Budget for Noise Control Programs	Cost Per Capita	Current Staff Size	Instrumentation to Support Programs	Noise Control Provisions Within Local Building Codes	First Adopted	Models Used for Drafting Building Code Noise Control Provisions	Administrative Location for Enforcement	% of Budget for Enforcement of Bldg. Code Noise Control Provisions	Personnel Training	Interagency Coordination	General Public Attitude Towards Bldg. Code Noise Control Provisions	Building Trades Attitude Towards Bldg. Code Noise Control Provisions	Professional Community Attitude Towards Bldg. Code Noise Control	Any Improvements Pending
								NOISE CONTROL PROVISIONS WITHIN LOCAL BUILDING CODES									
Alburquerque, N.M.	243,000	None	--	--	--	--	No(22)	--	--	--	--	--	--	--	--	--	--
Anniston, Ala.	---	None	--	--	--	--	No	--	--	--	--	--	--	--	--	--	--
Arlington, Va.	170,000	None	--	--	--	--	No	--	--	--	--	--	--	--	--	--	--
Beverly Hills, Calif.	33,000	N,DC(24)	--	--	2P	OBNA	No(22)	--	--	(7,3)	--	Pract.	None	--	--	--	Unkwn.
Boulder, Colo.	80,000	N,Z,V	30,000	37.5¢	1F,2P	3 SPLM	No	--	--	--	--	Local	Yes	For	Ind.	For	Unkwn.
Burbank, Calif.	88,000	None(24)	--	--	--	--	No	--	--	--	--	--	--	--	--	--	--
Cincinnati, Ohio	---	--	--	--	--	--	No	--	--	--	--	--	--	--	--	--	--
College Park, Ga.	18,200	N	00	--	--	--	No	--	--	--	--	--	--	--	--	--	--
Columbia, S.C.	111,715	N	2,000	01.8¢	1P(4)	--	(3)	--	--	(3)	--	(5)	--	--	--	--	(6)
Dallas, Tex.	844,965	Z	--	--	--	--	No	--	--	--	--	--	--	--	--	--	--
Denver, Colo.	---	--	--	--	--	--	No	--	--	--	--	--	--	--	--	--	--
Gainesville, Fla.	65,000	Z,N	0,000	12.3¢	--	--	N.	--	--	--	--	--	--	--	--	--	--
Hartford, Conn.	150,000	N	--	--	--	--	No	--	--	--	--	--	--	--	--	--	--
Honolulu, Hawaii	600,000	Z(18),V	--	--	--	--	No	--	--	--	--	--	--	--	--	--	--
Lakewood, Colo.	120,000	Z,V	46,608	38.8¢	--	--	No	--	--	--	--	--	--	--	--	--	--
Minneapolis, Minn.	---	--	--	--	--	--	(19)(23)	--	USC	--	--	--	--	--	--	--	--
Nashville, Tenn.	500,000	Z	--	--	--	--	No	--	--	--	--	--	--	--	--	--	--
New Orleans, La.	600,000	Z	--	--	--	--	No	--	--	--	--	--	--	--	--	--	--
New York City, N.Y.	1,900,000	Yes	1 mil	12.6¢	40+(19)	(20)	Yes	1968	Rsch	Bldg.Dept	--	Class	None	For	For	For	None
Newark, Calif.	31,000	Yes	00	--	3F	(11)	Yes	1971	UBC	--	--	Min.	Min.	For	Resist(12)	Ind.	None
Northbrook, Ill.	31,500	Yes	00	--	4F	--	Yes	11-70	Rsch	Bldg.Dept	--	None	Yes	For	For	For	Yes
Oklahoma City, Ok.	---	--	--	--	--	--	No	--	--	--	--	--	--	--	--	--	--
Palo Alto, Calif.	56,000	N,V(24)	25,000	44.6¢	--	--	No	--	--	--	--	--	--	--	--	--	--
Pawtucket, R.I.	77,000	N	--	--	--	--	No	--	--	--	--	--	--	--	--	--	--
Pittsburg, Pa.	550,000	None	--	--	--	--	No	--	--	--	--	--	--	--	--	--	--
Pocatello, Idaho	450,000	V,DC	Min.	--	3F	SPLM	Yes(23)	1965	UBC	Bldg.Dept	01%	1000	None	--	--	For	None
Portland, Ore.	385,000	--	(14)	(14)	40P(14,15,16)		Yes(23)	12-73	UBC	Bur.Bldg.	60%	None	Yes	For	(17)	For	--
Princeton, N.J.	12,500	N	00	--	1F	SPLM	No	--	--	--	--	--	None	Ind.	Ind.	Ind.	--
San Francisco, Calif.	71,000	N(24)	--	--	--	--	No	--	--	--	--	--	--	--	--	--	--
Scottsbluff, Neb.	1,500	N	00	--	--	--	No	--	--	--	--	--	--	--	--	--	--
Tacoma, Wash.	154,531	Z	--	--	--	--	No	--	--	--	--	--	--	--	--	--	--
Tempe, Ariz.	98,000	Z,N,L	--	--	--	--	No	--	--	--	--	(21)	--	--	--	--	--
Torrance, Calif.	134,000	N,V(24)	--	--	--	--	No(22)	--	--	Bldg.Saf	--	--	--	--	--	--	--
Tucson, Ariz.	375,000	None	--	--	--	--	No	--	--	--	--	--	--	--	--	--	--
Washington, D.C.	800,000	N	--	--	--	--	No	--	--	--	--	--	--	--	--	--	--

ABBREVIATIONS; RE: TABLE 4

Anti-	The City of Cincinnati is against the establishment of noise control within building codes
BC	Noise control provisions within local building codes
Bldg. Dept.	Building Department
Bldg.D.	Building Department
Bldg.I.	Building Inspection
Bldg.O.	Building Official
Bur.Bldg.	Bureau of Buildings
Class	A course on the subject of noise control in buildings
EPA	U.S. Environmental Protection Agency
F	Full-time
HMO	Model sound control building code ordinance proposed by the Harvard Journal of Legislation
HUD	Federal Housing and Urban Development recommendations
ICBO	International Conference of Building Officials meetings
Ind.	Indifferent
L	Extensive land-use planning
Local	Local training classes
mil.	Million
min.	Minimal
N	General nuisance ordinances
NIMLO	National Institute of Municipal Law Officers model ordinances
NYCBC	New York City building code
OBNA	Octave-Band Noise Analyser
P	Part-time
Pract..	Practice or on-the-job training
Rsch	Extensive research
SPLM	Sound pressure level meter
SSBC	Southern Standard Building Code
UBC	Uniform Building Code (Appendix Chapter 35)
Unkwn.	Unknown
V	Vehicular noise control ordinances
Z	Zoning noise control ordinances

NOTES; RE: TABLE 4

(1A) Only if by state action
(1B) State regulations
(2) None necessary
(3) Not within building codes, but in Pollution Control Ordinances supervised by Building Official
(4) One man part-time, the Pollution Control Officer
(5) Short courses (e.g. EPA courses)
(6) Not within the near future
(7) Fixed mechanical nature: Building Dept; Nuisance: Police Dept.
(8) Plan Checking and Inspection Division of the Mechanical Inspection Division of the Building Department
(9) Within Municipal Noise Ordinances, not Building Codes
(10) Inspection Division of Community Development Department
(11) Engineers are required to supply the necessary information
(12) Resistance from the Home Builders Association
(13) Under supervision of the Environmental Planning Office
(14) Proposed budget of $30,000; which is 7.7¢ per capita
(15) 5% total time divoted to noise control
(16) Proposed budget includes the hiring of a full-time acoustician
(17) "Their response has been constructive."
(18) General nuisance ordinances
(19) The New York City Bureau of Noise Abatement staffs 18 physicists and engineers plus support personnel; the Division of Noise Enforcement of the Department of Air Resources staffs 3 senior inspectors, 20 inspectors, plus clerical and administrative support
(20) See list on page
(21) One training class by two acoustical experts
(22) The Uniform Building Code is in use, but the recommendations of Appendix Chapter 35 are not enforced
(23) The Uniform Building Code is in use, Appendix Chapter 35 recommendations are enforced.
(24) State vehicular noise regulation

SECTION FIVE

INTERNATIONAL NOISE CONTROL THROUGH BUILDING CODE PROVISIONS

The following is a list of capsular descriptions of required or recommended airborne and impact sound insulation criteria of 10 selected foreign countries. (These countries were selected according to the availability of up-to-date information and the variety of noise control provisions utilized by them.)

Austria:

The standard: O NORM B8115

Airborne sound insulation of walls and floor-ceiling constructions between dwelling units;

Schallschutzgruppe (sound protection group) One: ISO airborne reference curve
Schallschutzgruppe Two: ISO airborne reference curve +5 dB

Impact sound insulation of floor-ceiling constructions;

Schallschutzgruppe One: ISO impact reference curve -3 dB
Schallschutzgruppe Two: ISO impact reference curve +7 dB

Limit on noise produced by domestic equipment included within standard.

Canada:

The standard: National Building Code of Canada 1970, Section 9.11, "Sound Control", NRC No. 11246. (Also, Canadian Code for Residential Construction 1970, Section 11, "Sound Control", NRC No. 11562.)

Airborne sound insulation of walls and floor-ceiling construction;

For all dwellings regardless of size:
(1) "Construction shall provide a sound transmission class (STC) rating of not less than 45 between dwelling units in the same building and between a dwelling unit and any space common to two
(2) "Every service room or space such as storage room, laundry, workshop, or building maintenance room or garage serving more than one dwelling unit, shall be separated from the dwelling units by a construction providing a sound transmission class (STC) rating

of not less than 45."
(STC ratings are to be determined in accordance with ASTM E90-70.)

Impact sound insulation of floor-ceiling constructions;

No provisions.

Denmark:

The standard: Bygningsreglement for købstaederne i landet

Airborne sound insulation of walls and floor-ceiling constructions;

Between rooms in different dwelling units: ISO airborne reference curve -2 dB (R_m = 49 dB)
In double houses, between kitchen and bathroom in one house and room in the other: ISO airborne reference curve +1 dB (R_m = 52 dB)

Impact sound insulation of floor-ceiling constructions;

100	125	160	200	250	315	400	500	Hz
65	65	65	65	63	61	59	57	dB
630	800	1000	1250	1600	2000	2500	3150	Hz
55	53	51	48	45	42	39	36	dB

Limit on noise produced by domestic equipment included within standard.

England:

The standard: British Standard Code of Practice, CP 3 : Chapter III, 1960, "Sound Insulation and Noise Reduction". Also, The Building Regulations, 1965, Part G, for England and Wales.

Correspondence with the Building Research Advisory Service (England), Department of Environment, indicates that the British Standards Institution has published a Code of Practice on sound insulation and noise control in buildings. This Code of Practice is not mandatory, only advisory. However, the Central Government has drafted Building Regulations which are fully mandatory. The Building Regulations are interpreted and administered by local governments (building inspection departments). Part G of these regulations establishes minimum requirements of sound insulation for all separating walls and floors between dwelling units.

Three grades of sound insulation have been established: Party-wall grade, Grade I, and Grade II. The Part-wall grade is used for airborne sound insulation horizontally between dwellings. Grade I-airborne-sound and Grade I-impact-sound are the highest insulation requirements that are "practicable" for airborne and impact sound insul vertically between flats. Grade II is no longer acceptable for sound control standards and has very little relevance to present regulations. (Grade II curves are 5 dB lower at all frequencies for airborne sound, and 6 dB worse (graphed above Grade I) at all frequencies for impact sound.)

All gradings are based on measurements made in accordance with BS 2750:1956; normalized to 0.5 seconds reverberation time in the receiving room. Grading curves are applied to field measurements. In order to comply with a particular grade, the total adverse deviation from the grade curve is not to exceed 23 dB (measured at all 1/3-octave frequency bands between 100 and 3150 Hz).

Frequency Hz	Party-Wall Airborne	Grade I Airborne	Grade I
	minimum sound reduction through-		
	walls (dB)	floors (dB)	floors (dB)
100	40	36	63
125	41	38	64
160	43	39	65
200	44	41	66
250	45	43	66
315	47	44	66
400	48	46	66
500	49	48	66
640	51	49	65
800	52	51	64
1000	53	53	63
1250	55	54	61
1600	56	56	59
2000	56	56	57
2500	56	56	55
3150	56	56	53

Federal Republic of Germany (West Germany):

The standard: DIN 4109

Airborne sound insulation of walls and floor-ceiling constructions;

Minimum: ISO airborne reference curve
Recommended: ISO airborne reference curve +3 dB

Impact sound insulation of floor-ceiling constructions;

Minimum: ISO impact reference curve
Recommended: ISO impact reference curve +10 dB

Limit on noise produced by domestic equipment included within standard.

France:

The standard: – –

Airborne sound insulation of wall and floor-ceiling constructions;

Sound level in 1/3-octave bands
100– 320 Hz; D_n = 36 dB
400–1250 Hz; D_n = 48 dB
1600–3200 Hz; D_n = 54 dB

Impact sound insulation of floor-ceiling constructions;

Sound level in 1/3-octave bands
100– 320 Hz; L_n = 66 dB
400–1250 Hz; L_n = 62 dB
1600–3200 Hz; L_n = 51 dB

Limit on noise produced by domestic equipment included within standard.

Israel:

The State of Israel's Environmental Protection Service (EPS) of the Prime Minister's Office is a very new agency. Mr. Richard Laster, Legal Advisor of the EPS, was kind enough to answer and return the questionnaire sent by this author. He wrote back stating that the questionnaire was translated into Hebrew and then distributed to fourteen bodies, governmental or otherwise, so as to conduct his own survey concerning the use of noise control techniques in Israeli building construction. Although the annual budget for noise control in Israel is $175,000 (5¢ per capita for a population of 3,000,000); only four of the nine agencies that returned the questionnaire to him indicated that they were involved in any way with noise control in buildings.

Mr. Laster noted that there are standards in the Planning and Building Laws of 1965 which require a standard width for outside walls in buildings to help control noises originating from outdoor sources. However, there are no standards presently in Israel concerning any other type of noise control for buildings.

If the building codes are to be improved (either generally, or specifically concerning noise control), the models that would probably be used would be German or Swiss.

Netherlands:

The standard: NEN 1070

Airborne sound insulation of walls and floor-ceiling constructions;

Insulation Index for protecting a sensitive room:
- Quality moderate: 0 dB
- Quality good: +3 dB

Insulation Index between two sensitive rooms:
- Quality moderate: -3 dB
- Quality good: 0 dB

The Insulation Index is based upon four octave bands with centers on (Airborne Sound)
- 250 Hz; 38.5 dB
- 500 Hz; 48.8 dB
- 1000 Hz; 55.3 dB
- 2000 Hz; 56.8 dB

Impact sound insulation of floor-ceiling constructions;

Insulation Index for protecting a sensitive room:
- Quality moderate: 0 dB
- Quality good: +3 dB

The Insulation Index is based upon four octave bands with centers on (Impact Sound)
- 250 Hz; 72 dB
- 500 Hz; 70 dB
- 1000 Hz; 67 dB
- 2000 Hz; 58 dB

Switzerland:

The standard: Provisorische Richtlinien fur den Schallschutz im Wohnungsbau

Airborne sound insulation of walls and floor-ceiling constructions;

Minimum: ISO airborne reference curve
Recommended: ISO airborne reference curve +3 dB

Impact sound insulation of floor-ceiling constructions;

Minimum: ISO impact reference curve
Recommended: ISO impact reference curve +10 dB

Limit on noise produced by domestic equipment included within standard.

Sweden:

The standard: SBN 67

Airborne sound insulation of walls and floor-ceiling constructions of semi-detached houses;

Between living rooms: ISO airborne reference curve +3 dB
Between store-rooms and living rooms: ISO airborne reference curve

Airborne sound insulation of walls and floor-ceiling constructions of other type residential buildings;

Between living rooms: ISO airborne reference curve
Between store-rooms and living rooms: ISO reference curve -4 dB

Impact sound insulation of floor-ceiling constructions of semi-detached houses;

Between living rooms: ISO impact reference curve +2 dB
Between store-rooms and living rooms: ISO reference curve -3 dB

Impact sound insulation of floor-ceiling constructions of other type residential buildings;

Between living rooms: ISO impact reference curve +2 dB
Between store-rooms and living rooms: ISO reference curve -3 dB

Limit on noise produced by domestic equipment included within standard.

Of the thirteen foreign countries sent a questionnaire by this author concerning noise control within their national building codes, only Canada, England, and Israel responded with information pertaining to the matter. Sweden sent back information concerning traffic noise control. Austria and West Germany replied that the questionnaire was being fowarded to another agency. Over three months have expired to date since the questionnaires were first mailed out to them.

Other countries with some type of noise control requirements or recommendations within their national building codes are:

- Belgium*
- Bulgaria
- Czechoslovakia
- Finland
- Norway
- Poland
- Scotland
- U.S.S.R.

* no national requirements, but British, French, and German standards are applied in certain areas.

SECTION SIX

THE PEOPLE INVOLVED

THE ARCHITECT

One of the primary responsibilities of the architect is to provide for the safeguarding of the building occupant's health and welfare. This of course includes maintaining optimal environmental conditions within the building, a provision which is inherent in good building design.

The problem of sound control is that of the architect's. Acoustics is an integral part of the building design and cannot be isolated as a separate entity to be added after the building has been designed. All too often, an unanticipated noise problem is discovered after the building is built (usually by the building occupant) and then an architect (and/or acoustician) is called in to solve the problem, usually at considerable expense. When concerned with developing the proper acoustical environment, the architect must take into consideration all elements of design including the structure, the location of various types of spaces, and even the surface finish materials to be used. Most of today's architects have but a smattering of acoustics and noise control thereby making many design mistakes either out of ignorance, neglect, or lack of awareness of poor acoustical situations. Architects need to become more aware of proper sound control techniques and implement these techniques into their designs.

Due to economic requirements stressing the need for dry-unit construction and flexibility in partition arrangement, today's architect designs for thinness and lightweight construction in both partitions and floor-ceiling assemblies. Therefore, contemporary structures use low-mass systems which, 35 years ago, would have been considered to be too light and of poor construction and design details should be reconsidered in terms of sound control.

The architect's principal problems relating to sound control are:

1) transmission of sound through, or over, partitions,
2) transmission of sound through floor-ceiling assemblies,
3) transmission of sound via structural components,
4) street and outside noises penetrating the building,
5) mechanical equipment and systems noises,
6) electrical equipment and systems noises, and
7) "cross-talk" through ductwork from one space to another.

Comprehensive sound control provisions within building codes would help insure that architects provide proper solutions to these noise control problems.

THE BUILDERS

Although the building industry has made great advancement in the building and structural technologies, conventional building techniques yield some of the noisiest buildings in existence. Buildings providing for good acoustical environments are increasingly in demand. Mortgage agencies specify sound insulation criteria when they lend their money (because quiet buildings are more rentable), and city building codes are gradually being changes to provide for sound insulation requirments. Constructing quiet buildings has created some problems for the builder such as:

1) increased costs,
2) availability of desired materials,
3) ease of installation,
4) delay in completion of work, and
5) good workmanship.

Estimating the additional costs involved in constructing buildings with good acoustical insulation is very difficult since there is relatively little reliable information on the subject. However, some estimates indicate that the additional expenses for the acoustical design and treatment of buildings might range from 2% to 10% of the total cost of the building, depending on the geographic area, labor market, and economic factors.[1]

Many builders (and architects) may consider the costs of sound insulation too high. The same criticism was heard in the past with respect to central heating and air-conditioning. Nevertheless, despite their high costs, central heating and air-conditioning are now considered to be necessities, not only in office buildings, but in homes (and automobiles) as well. Hopefully, when noise control criteria are uniformly adopted within building codes, the building industry will find materials and methods of construction on a nonprohibitive cost basis that will not compromise quality and safety, but will insure good sound control.

Possibly the highest price that builders (as well as architects, investors, and owners) might pay for a building lacking good sound control is expressed in terms of loss of reputation and public confidence; consequentially, a loss of profit for all parties concerned.

The builder must at all times be certain that the planned sound insulating performance of walls and floor-ceiling assemblies are not nullfied by careless work of tradesmen or contractors. Meticulous attention to details and discontinous construction is highly important. Builders and contractors must be alert to the problems and complexities of noise control.

THE ENFORCEMENT AGENCIES

Enforcement of sound control requirements within building codes are, as with other building code requirements, usually the responsibility of a building construction control department, whether on the national or local level. Enforcement is usually accomplished by withholding building permits until all plans have been inspected and found to meet the building code criteria in force. Plan-checking is usually followed up by inspection of the building while it is under construction. In this stage, construction methods and techniques, as well as installation methods and workmanship, are checked to insure that the plans are abided by. In some instances, sound insulation measurements are made after the building is completed. This is usually done by an independent department firm which sends its results to the building department. If the building department is not satisfied with the results or methods of testing by the independent firm, it may send out its own inspectors to conduct such tests. (Many European countries have mobile laboratories, usually small trucks, for this purpose.)

Since the transmission values of most partitions are known, it is therefore usually easy to determine whether or not the building plans meet the building code sound control requirments. The use of standard decibel rating systems alleviates the problem of a building inspector having to use his own personal judgement as to whether or not the components or systems in the plan meet the building code requirements. In many instances, when the transmission loss values of a particular building component are not known, it is usually required that an accredited laboratory make such measurements and notify the building department.

Here in the United States, there are no provisions for sound control requirements within building codes at the national level (except for HUD financed projects). Generally, local municipal authorities decide if sound control is to be compulsary within their local building codes; and then excercise the option to enforce, at their own discretion, such sound control requirements. Many existing sound control requirements within local building codes are unenforceable because they either fail to spell out, in quantitative terms, the amount of sound insulation necessary for sufficient sound control (e.g., proper sealing of penetrations in sound control partitions) or they fail to provide suitable methods of measuring sound insulation. Many local building code officials have expressed the need for national guidance in writing enforceable sound control standards.[2]

All too often, the building department is restricted by its budget. Noise control seems to rank low priority. Many times the building department lacks sufficient equipment and properly trained personnel to enforce their noise control requirements. Usually, the building inspectors must fit the inspection for proper sound control into their other duties. Quite often, these inspectors receive minimum training in sound control and lack complete understanding concerning sound control in buildings.

THE OCCUPANT

Some of the most common noise originating from people (particularly within multifamily dwellings) are: radio and television sound intruding from adjacent apartments, children playing indoors, family disputes, pedestrian circulation, babies crying, etc. A house party can get as loud as 115dB(A), a screaming child, 92dB(A).[3] Much more of a problem for the building occupant are the noises produced by "sophisticated" home appliances (e.g. vacuum cleaners, washing machines), office machinery and equipment (such as typewriters and duplicating machines), and other types of working machines. Many of the noises affecting the building occupant are inherent of the building itself and its systems. Some of these being: boiler noises (combustion noise and turbulance of flame), plumbing noises (flow of water, toilets flushing, water-hammer, etc.), electric motors, and air conditioning system noises (air flow, fan noise, compressor noise and vibrations, cooling tower noise, ect.). Comprehensive building code criteria pertaining to sound control, and the enforcement of such criteria would help provide adequate protection from many of the above mentioned noises.

The noisiest room of a household is the kitchen. This is due to the profusion of noise generating appliances as well as the space's hard, reflective surfaces. At the source, a blender may emit noise approaching 95dB, an air exhaust fan 90dB, and a garbage disposal 80dB. Most of the noise in the kitchen is airborne, but many times it is also transmitted directly into the building structure via vibrations only to be emitted as noise later in another space.

While lack of freedom from the intrusion of unwanted noise is a major problem for the occupant, the lack of acoustical privacy is another major source of difficulty. Good acoustical privacy provides for the prevention of sounds (e.g. conversations) generated in one space (or household) from being broadcast into another space (or household). Many property management firms have indicated that they have experienced increasing market resistance to the rental of apartments and office space which maintain unwanted and excessive noise transmission.[4]

Noise intrusion into a building originating from outside noise sources comes from many sources. Building occupants many times must contend with construction noises, transportation noises (aircraft, trucks, and motorcycles being some of the worst offender), and in many cases, noises from nearby industrial areas. The home has traditionally served as a place to retreat from daily anxieties and tension. However, the peacefulness of the home is many times subverted by the outside world when it cannot be shut out.

In a report by the United States Department of Housing and Urban Development, the frequency of complaints from dwelling occupants seems to be independent of income brackets in virtually all types of apartment buildings, including high-rise as well as low-story, garden types.[5] However, those owning their own homes and condominiums will usually express a greater concern about noise than apartment dwellers. A partial explanation may be that the apartment resident is more mobile and less financially committed to a location than the home owner. He is able to relocate more easily if the acoustical environment becomes a problem.

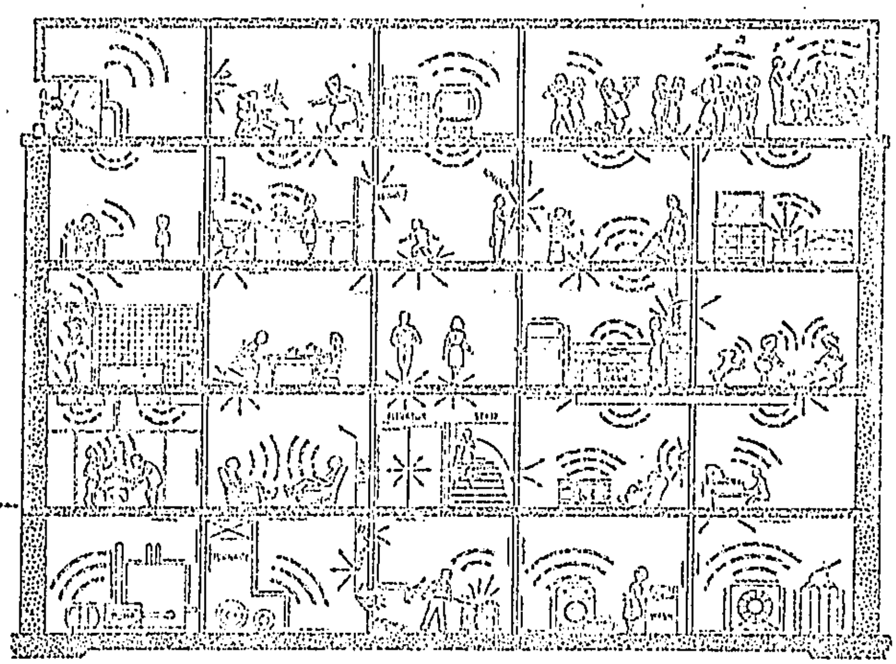


Fig. 9 Common indoor sources of noise. (From HUD report, "A Guide to Airborne, Impact, and Structure Borne Noise-Control in Multifamily Dwellings," by Berendt, R.D., Winzer, G.E., and Burroughs, C.B., Washington, D.C., 1967, FT/TS 24.)

SECTION SEVEN

SOUND CONTROL WITHIN BUILDING CODES: EVALUATION OF ITS EFFECTIVENESS AND POTENTIAL

Quite often, both internationally and nationally, building code noise insulation criteria are in the form of recommendations rather than requirements. These recommendations are frequently applied in a variety of forms of regulations on the local level. In many countries and domestic municipalities that do have sound control requirements in their building codes, these requirements are only moderate, designed only to eliminate extremely poor cases of sound control.[1] Compromised noise control standards provide only partial noise control for most building situations. Many architects and building designers are misled to believe that their buildings are good acoustically when they meet these mild requirements. It may therefore be sensible to establish moderate minimum requirements along with uncompromising recommendations where stringent building code control regulations are not practical. Many times, those countries and municipalities that do not have building code sound control requirements usually do not have comprehensive measures which include noise criteria for air-conditioning and heating systems, mechanical equipment and systems (including elevator machinery), plumbing systems, penetrations in sound control partitions, etc. New York City is one of the few (if not the only municipality) to have such extensive provisions within its building code.

Most building codes depend on the use of standard reference contours for rating sound control. The use of these contours avoids the problem of vagueness and relieves the enforcement personnel of having to rely upon personal judgement. However, these contours are intended mainly for use to control noises that have approximately the same characteristics of speech in terms of sound pressure level vs. frequency (e.g. office machinery, home appliances, radios, etc.). Use of these reference contours to control noises that differ from the noise characteristics of speech results in unsatisfactory noise control. Pure tones (the simplest periodic sounds) orginating from electrical and mechanical machinery and systems are not sufficiently controlled when reference standards are used. Building codes need to be updated and corrected to provide for this deficiency in sound control.

Present day systems specified in building codes for rating noise control depend on seperate measurements and specifications for each construction element. Today's building codes have not established adequate standards, if any at all, pertaining to the control of flanking transmission of sound. Field measurements may be made to account for flanking transmission, but most building codes do not have criteria for conducting such field tests. Also, many of the codes that do provide for field testing do not indicate what field test measurements are necessary for a sound control partition to be acoustically satisfactory. There has been a model ordinance proposed that takes into account flanking transmission of sound, but it too relies heavily on field testing.[2]

The present day system of measuring impact noise insulation of floor-ceiling assemblies specified in building code have been highly criticised. Standard tapping machines (usually the ISO standard tapping machine) do not imitate impact nioses found most often in buildings, e.g. these machines produce sound levels that are much higher than those of footstepts, a major source of impact noise. These machines, "cannot be shown to be capable of distinguishing with meaningful precision the relative merits of floor-ceiling systems with respect to their ability to supress to a state of acceptability the transmitted sounds which arise from the kinds of impact normally encountered [in buildings]."[3] In other words, due to a great potential for error, many floors which qualify under the tapping test will be much better than necessary causing increased project cost, whereas, many floors which qualify under the tapping test will be much poorer than required resulting in reduced occupancy, lower commercial value, or expensive post-installation improvements.[4]

With the increase of traffic, both surface and air, as well as construction noises, the importance of insulating dwellings and other buildings from external noise sources has recently been realized. However, not much is being done about it in terms of building code regulations. In considering proper lighting within a building, economic and energy conservation factors have made the use of window facades imperative. To save more energy, more window area is used in order to utilize more natural daylight. These window facades usually do not provide for sufficient sound attenuation which, at best, is approximately 30 dB.[5] A conflict arises. Double-glazing might be used, but this requires artificial ventilation which in most cases is also very costly and consumes a substantial amount of energy. It is exceedingly difficult to establish significant and meaningful noise insulation standards within these parameters. Therefore, building codes are very ineffective when it comes to insulating buildings from external noise sources. The dilemma has yet to be solved. (A possible solution would be to control the noise at the source and/or also through siting and zoning laws instead of noise attenuation through building components.)

Enforcement of comprehensive sound control provisions for building schools surely will result in better acoustical conditions for learning (e.g. less noise to distract the student). And surely, if comprehensive sound control provisions are enforced while building hospitals, the patient will find it easier to recuperate without disturbing noises. Enforcement of such provisions also may result in increased efficiency in working conditions. Comprehensive provisions would help remove noise, in the form of impaired efficiency or costly nervous strain, from the payroll of the average business. In an office where the noise level was reduced to 35 dB from 45 dB, the office workers, engaged in a variety of machine operations, showed a 12% increase in output.[6] The elimination of costly noise is so profitable that it has reached the state of importance accorded to the other environmental problems such as air conditioning, heating, and lighting.

Room-to-room reduction is just as important as reduction of noise between dwelling units. Members of an individual family deserve privacy from each other and conflicts (e.g. parents sleeping late in the morning while the children watch television) should be avoided. The Federal Housing Authority (and HUD) has recommendations pertaining to this matter, but there are no provisions for this in domestic building codes. Here again, building codes need to be updated and corrected to insure intrafamily privacy.

Building codes do not provide for sound control where the noise source and the listener are within the same space. Many European countries do establish maximum permissible noise levels to be emitted from household equipment and appliances within the home. However, none of the building codes within the United States do.

Building code sound control provisions are exposing architects and builders to the existence, needs of, and complexities of sound control in buildings.

Of course, the effectiveness of noise control provisions within building codes depends mostly on the enforcement of such provisions. This aspect is discussed in Section 6 of this report.

SECTION EIGHT

CONCLUSION

Noise disturbs sleep, causes annoyance, interrupts conversations and trains of thought, and may even be partly responsible for subtle effects upon physical and mental health. According to the World Health Organization, health is, "a state of complete physical, mental, and social well-being." Therefore, it is quite obvious that noise is a detriment to health and should be controlled whenever and wherever possible. The occupant of a building has the right to use the building without interference of peace of mind, privacy, sleep, or the pursuit of work or pleasure from noise. The occupant should be protected from buying or renting a building or space, only to find that it maintains an improper acoustical environment.

The United States lags far behind many European countries in terms of noise control through the use of building codes. The problems of noise control in buildings have not yet received the attention they deserve. Sound control has yet to reach the status afforded to that of air conditioning within our building programs and designs. Mr. Rudolph M. Marrazzo, of the U.S.P.A., stated in a letter to this author:

> "The Office of Noise Abatement and Control believes that acoustical criteria for building codes, whether contained in a noise ordinance or separate from it, form an essential component of an effective noise abatement program."[1]

Lacking uniformity, existing noise control requirements within local building codes vary from one municipality to another. Failing to provide uniformity as guidance, future sound control criteria within a building codes will be just as multifarious as today's municipal plumbing requirements. Furthermore, what building code noise criteria that do exist are not comprehensive enough to solve most of today's building noise problems. Dr. Theodore Berland, President of Citizens Against Noise (and author of many books concerning noise control), in a letter to this author, wrote:

> "...there is a definite need for building codes which stringently control the transmission of noise in buildings."

Architects, engineers, and planners should be required to take into account the aspect of noise control in the formulation of their plans and construction of their projects. However, many of these professionals lack the knowledge and understanding pertaining to the basic principles of sound control in buildings. Education of these professionals is essential.

The use of lightweight construction materials having relatively poor sound insulation properties is improper. If this trend continues, homes will have less acoustical privacy than homes of the past. More research is needed concerning the improvement of building methods and systems so as to produce better methods and details to control the transmission of sound within buildings.

When noise cannot be prevented, it should be controlled, at least to the extent of minimizing discomfort, maintaining acoustical privacy, and providing for the proper acoustical environment.

APPENDIX A

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SECTION EIGHT [none]

APPENDIX C

SAMPLE COVER LETTER AND QUESTIONNAIRE
SENT TO DOMESTIC MUNICIPALITIES

university of florida, college of architecture and fine arts

gainesville, florida 32611

DEPARTMENT OF ARCHITECTURE

January 15, 1974

Gentlemen:

Enclosed is a brief survey concerning community noise-control provisions within local building codes. The purpose of this survey is to aid in the preparation of a study to review and report past and current efforts of such provisions.

Results of our survey will be evaluated as to the effectiveness of these noise-control provisions. We will also attempt to indicate the kind of improvements that need to be made. This survey is conducted under the auspices of the State of Florida, by the University of Florida.

If your community presently has building code noise-control provisions, please advise us as to how we may obtain a copy of these provisions, and at what cost.

Your cooperation and prompt return of the enclosed survey would be greatly appreciated. If you would like a copy of the results, we will be very happy to supply this to you upon request.

Yours very truly,

Richard L. Katz

Richard L. Katz

campus address: 101C AFA complex *tel.no.: 904—392-0204*

ARCHITECTURE LANDSCAPE ARCHITECTURE INTERIOR DESIGN URBAN DESIGN

SURVEY: NOISE-CONTROL BUILDING CODE PROVISIONS

1. What is the population of your municipality?

2. Does your municipality have a noise control program?
   If YES, please complete section ONE of this survey.
   If NO, please complete section THREE of this survey.

SECTION ONE: Please complete this section if your municipality has a noise control program.

---

3 What is the scope of your noise control program .

4. What is the annual budget allocated for your noise control program?

5. Does your noise control program include provisions within local building codes?
   If YES, please complete this section.
   If NO, please go on and complete section TWO.

6. What percentage of your noise control budget is used for the administration and/or enforcement of the building code sections of noise control?

7. When were the noise control building code provisions established? What amendments have been made since?

8. Which building code models were used for drafting the original ordinances?

9. In concerning noise control through the use of building codes, describe the organizational and administrative location of this particular aspect within your noise control program.

(Section ONE con't)

10. What is your current staff size, both full-time and part-time, in your general noise-control program?

11. Describe the major program elements and the approximate percentage of total staff time. What percentage of the staff deals directly with noise-control through the use of building code provisions?

12. What type of acoustical instrumentation do you have to support your program?

13. What is the scope of your training program for your personnel who administer and enforce the noise-control building code provisions?

14. What type of coordination do you have with other public agencies?

15. To what extent has your program generated public and private awareness?
15B. What methods has your program used to insure public and private awareness?

16 A. What has been the general public's reaction?

16 B. How have the various building trades reacted?

16C. How has the professional (e.g. architectural, engineering) community reacted?

17. What do you believe has been the major accomplishments of building code noise control provisions?

18. Are there any areas within your noise control building code provisions that need improvement or revision?

19. What, if any, problems have occurred due to your noise control building code provisions?

20. What are your community's future plans for noise control through building code provisions?

21. How may we obtain a copy of your present building code noise-contol provisions and at what cost?

SECTION TWO: Please complete this section only if your community presently has a noise-control program but does not have noise-control provisions within the local building codes.

1. Does your community have any future plans for noise-control provisions within the local building code?

2. If yes, what type of noise-control ordinances will be incorporated into the local building code?

3. Which building code model will probably be used (or what other method will be used) for drafting the original noise-control building code provisions?

4. In concerning noise-control through the use of building codes, what will be the organizational and administrative location of this particular aspect within your noise-control program?

5. To what extent will you train your personnel who administer and enforce the noise-control building code provisions? What size staff, both full-time and part-time do you expect to have to administer and enforce adopted noise-control building code provisions?

6. What means do you intend to employ to stimulate public awareness?

7. Presently, what is the public's attitude towards noise-control building code provisions:

   A) The general public seems to be (for) (against) (indifferent)

   B) The building trade community seems to be (for) (against) (indifferent)

   C) The professional community (e.g. architectural, engineering) community seems to be (for) (against) (indifferent)

8. Do you have any further comments concerning the future of noise-control building code provisions within your community?

SECTION THREE: Please answer this section only if your community at present does not have provisions for community noise control or a noise control program.

1. Does your community have any future plans for a noise-control program?

2. If yes, what type of ordinances will be incorporated into your noise-control program (e.g. "nuisance type ordinances", "performance type ordinances")?

3. If performance type ordinances are indicated, will these ordinances be incorporated into your local building codes?

4. Which building code model will probably be used (or what other method will be used) for drafting the original noise-control building code provisions?

5. To what extent is your community's attitude towards a community noise-control program:
   A) Does the general public presently seem to be (for) (against) (indifferent)?

   B) Does the building trade community seem to be (for) (against) (indifferent)?

   C) Does the professional community (e.g. architectural, engineering) seem to (for) (against) (indifferent)?

6. Do You have any further comments concerning the future of a noise-control program within your municipality?

Please return to: Richard L. Katz
Department of Architecture
University of Florida
Gainesville, Florida 32611

APPENDIX D

SAMPLE COVER LETTER AND QUESTIONNAIRE SENT TO FOREIGN COUNTRIES

university of florida, college of architecture and fine arts **DEPARTMENT OF ARCHITECTURE**

gainesville, florida 32611 United States

January 18, 1974

Gentlemen:

Enclosed is a brief survey concerning community noise-control provisions within building codes. The purpose of this survey is to aid in the preparation of a study to review past and current efforts of such provisions internationally.

Results of our survey will be evaluated as to the effectiveness of these noise-control provisions. We will also attempt to indicate the kind of improvements that need to be made here in the United States. This survey is conducted under the auspices of the State of Florida, by the University of Florida.

Your cooperation and prompt return of the enclosed survey would be greatly appreciated. If you would like a copy of the results, we will be very happy to supply one to you upon request. Please also advise us as to whom else we may contact to obtain further information pertaining to building code noise-control provisions in your country. Thank you.

Yours truly,

Richard L. Katz

Richard L. Katz

RLK:rk
Enclosure

campus address: 101C AFA complex *tel. no.: 904—392-0204*

ARCHITECTURE LANDSCAPE ARCHITECTURE INTERIOR DESIGN URBAN DESIGN

SURVEY: NOISE-CONTROL BUILDING CODE PROVISIONS

1. What is the population of your country?

2. What is the scope of your general noise-control program?

3. What is the annual budget allocated for your noise-control program?

4. Does your general noise-control program include provisions within building codes?

   If yes, please complete SECTION ONE.
   If no, please complete SECTION TWO.

SECTION ONE: Please complete this section only if your country has noise-control provisions within its building codes.

---

5. What percentage of your noise-control budget is used for the administration and enforcement of the noise control sections in your building codes?

6. When were the noise-control building code regulations established? What amendments have been made since?

12. What is the scope of your training program for your personnel who administer and enforce building code noise-control provisions?

13. What type of coordination do you have with other public agencies_

14. To what extent has your program generated public and private awareness? What methods has your program used to insure public and private awareness?

15.a. What has been the general public's reaction in your country?

b. How have the various building trades reacted?

c. How has the professional (e.g. architectural, engineering) community reacted?

16. What do you believe has been the major accomplishments of your building code noise-control provisions?

17. Are there any areas within your building code noise-control provisions that need improvement or revision (for example: enforcement)?

18. What problems, if any, have occurred due to your noise-control in building codes?

19. What are your country's future plans for noise-control through the means of building codes?

20. How may we obtain copies of your present building codes pertaining to noise-control and at what cost?

Thank you for your cooperation. Please return this survey to:

Mr. Richard L. Katz
Dept. of Architecture
University of Florda
Gainesville, Florida 32611 U.S.A.

SECTION TWO: Please complete this section only if your country presently has a general noise-control program, but does not have noise-control provisions within building codes.

21. Does your country have any future plans for noise-control provisions within building codes?

22. If yes, what types of noise-control ordinances will be incorporated into your building codes?

23. Which building code model(s) will be used (or what other method will be used) for drafting your country's original building code noise-control provisions?

24. What will be the administrative location of your building code provisions within your general noise-control program?

25. To what extent will you train your personnel who will administer and enforce the noise-control provisions in your building codes. What size staff do you expect to have to administer and enforce adopted noise-control building code provisions?

26. What means do you intend to employ to stimulate public awareness of the need for noise-control through the use of building codes?

27. Presently, what is the public's attitude towards noise control by building code provisions?

The general public seems to be (for) (against) (indifferent).

The building trades community seems to be (for) (against) (indifferent).

The professional community (e.g. architectural, engineering) seems to be (for) (against) (indifferent).

28. Do you have any further comments concerning the future of building code provisions for noise control in your country?

Thank you very much for your cooperation. Please return this survey to:

Mr. Richard L. Katz
Dept. of Architecture
University of Florida
Gainesville, Florida 32611 U.S.A.

APPENDIX E

COUNTRIES APPROVING/DISAPPROVING ISO RECOMMENDATION R 717, "RATING OF SOUND INSULATION FOR DWELLINGS"

20 member bodies approved the recommendation in draft form:

Argentina
Australia
Austria
Brazil
Canada
Chile
Czechoslovakia
Germany
Hungary
Israel
Japan
Netherlands
New Zealand
Poland
Sweden
Switzerland
U.A.R.
United Kingdom
U.S.S.R.
Yugoslavia

6 member bodies opposed the approval of the draft:

Belgium
Denmark
France
Italy
Norway
United States of America

The ISO Council adopted ISO Recommendation R 717 in May 1968.

APPENDIX F

NEW YORK CITY
NOISE ABATEMENT EQUIPMENT INVENTORY

Department of Buildings:

1 Octave Band Analyzer
1 Sound Level Meter
1 Vibration Analyzer
1 Graphic Level Recorder
1 Hi-Fi Tape Recorder

Division of Noise Enforcement:

20 B&K Sound Level Meters
20 B&K Sound Level Calibrators (type 4230)

Bureau of Noise Abatement:

1 B&K Statistical Distribution Analyzer (type 4420)
1 B&K Real Time Third Octave Band Analyzer Model 3347
1 B&K Frequency Analyzer Type 2130
1 B&K Control and Display Unit type 4710
2 B&K Level Recorder-Strip Chart Type 2305
1 B&K Tape Reader 7102 Type B&K/SE
1 B&K 25 dB Log Potentiometer Type ZR0004
2 B&K 50 dB Log Potentiometer Type ZR0005
1 B&K Beat Frequency Oscillator Type 10022
1 B&K Measuring Amplifier Type 2607
1 B&K Random Incidence Corrector UA 0055
1 B&K Integrator ZR0020
1 General Radio Random Noise Generator Type 1382
1 General Radio Sound and Vibration Analyzer Type 1564A
1 Hewlett Packard Calculator Model 9810A
1 Varian Computer Type 620/L
1 Teletype Typewriter ASR33
1 CBS Highway Noise Monitor
2 B&K Sound Level Meter Model 2204
2 B&K Precision Sound Level Meter Type 2206
1 General Radio Sound Level Meter Type 1151C
1 General Radio Sound Level Meter Type 1565A
3 General Radio Sound Level Meter Type 1565B
2 B&K Octave Filter Set Type 1613
1 B&K Microphone Calibrator Type 4142
3 General Sound Level Calibrator Type 1562A
2 General Radio Sound Level Calibrator Type 4230
2 B&K Piston Phone Type 1613
3 Nagra Tape Recorder Type 4122
1 Nagra Tape Recorder Type IVD
1 Nagra Tape Recorder Type IVB
1 Nagra Tape Recorder Model IVSJ
1 Nagra Tape Recorder Type DJ
1 Panasonic Tape Recorder Model 9810A

APPENDIX G

WHERE TO WRITE

The following addresses have been selected from correspondence indicating that these are specific agencies to write to in seeking information concerning sound control in building codes:

Austria:

Bundesministerium fur Gesunheit und Urnwelschutz
Sektion 3
Stubenring 1, A-1012
AUSTRIA

Canada

H. Brian Dickens, Head
Codes and Standards Group
National Research Council of Canada
Ottawa,
K1A-OR6

England

The Department of Environment
Building Regulations Division
Caxton House, Tothill Street
London, SW 1, England

Israel:

Mr. Richard Laster, Legal Advisor
Prime Minister's Office
Hakirya Building 3
Jerusalem, 91000 ISRAEL

Poland:

Instytut Ksztaltowania Srodowiska
Institute for Environmental Reforming
Warszawa, ul. Nowogrodzka 1/3 POLAND

United States:

Rudolph M. Marrazzo, Director
Technical Assistance and Operations Division (HM-571)
Office of Noise Abatement and Control
U.S. Environmental Protection Agency
Washington, D.C. 20460

West Germany:

Institut fur Bautecknik
Institute for Building Sciences
1 Berlin 30 (West Deutschland)
Reinspiesch-Ufer 72-76

For Documents and Standards (Domestic or Foreign):

American National Standards Institute, Inc. (ANSI)
1430 Broadway
New York, New York 10018

For More Information Concerning New York City's Building Code:

Mr. Irving E. Minkin, P.E.
Executive Engineer
Department of Buildings
100 Gold Street
New York, New York 10038