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Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/40000548
Building Research Note, 1980-06

ISSN 0701-5232

BUILDING RESEARCH NOTE

ACOUSTIC INSULATION FACTOR: A RATING FOR THE INSULATION OF BUILDINGS AGAINST OUTDOOR NOISE

by

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Ottawa, June 1979
Revised June 1980

National Research Council Canada
Conseil national de recherches Canada

NO 148

ACOUSTIC INSULATION FACTOR: A RATING FOR THE INSULATION OF BUILDINGS AGAINST OUTDOOR NOISE

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I. INTRODUCTION

The Acoustic Insulation Factor (AIF) is used as a measure of the reduction of outdoor noise provided by the elements of the outer surface of a building. It was originally developed for use with aircraft as the noise source, but has recently been extended for use with noise from road traffic and railways.

This paper is intended as background information to supplement the design procedures presented in the Central Mortgage and Housing Corporation's publications *New Housing and Airport Noise*[1] and *Road and Rail Noise: Effects on Housing*.[2] The following section deals with the basic nature of the AIF. Specific details relevant to its application for insulation against aircraft and surface transportation noise are given in Sections III and IV. The final section presents a detailed procedure for determining the AIF from the laboratory sound transmission loss data for a building component.

II. BASIC FEATURES OF THE ACOUSTIC INSULATION FACTOR

1. Why the AIF was Developed

In North America the most widely used rating for the sound insulation of building components is the Sound Transmission Class (STC).[3] If the advantages of standardization were the only relevant concern, then STC would have been the logical choice as the noise reduction rating for the CMHC standards for insulation against transportation noise. Unfortunately the use of STC in this type of application has several significant shortcomings.

The STC was originally developed for rating the sound reduction of internal floors and partitions with sources such as the human voice whose dominant sound energy is in the middle and high frequency ranges. However, there is no information to show that the STC properly rates the effectiveness of a partition for protection against other types of noise spectra, for example, noise with a strong low frequency component. Because of this, the standard defining the STC specifically recommends against its use in applications involving the exterior walls of buildings for which noise problems are most likely to involve motor vehicles or aircraft. As these noise sources are of prime interest in this context, an alternate rating appropriate for these types of noise was clearly desirable.

Another important consideration was the requirement for a simple design process that could readily be used both by developers and by the CMHC staff in evaluating developers' proposals. When more than one component (e.g., windows, exterior walls) is involved, calculation of the combined STC is a mathematically complicated problem, unless all components are required to have the same STC. Although this appears reasonable at first glance, it leads to requirements for doors and windows with unusually high sound insulation properties (and correspondingly high prices). Through use of the Acoustic Insulation Factor (AIF) it is possible to have a very simple design procedure without placing unduly stringent sound insulation requirements on the doors and windows.

2. Determining the Required AIF

The acoustical insulation that should be provided by the outer shell of a building obviously depends on both the loudness of the noise outdoors and the maximum acceptable noise indoors.

People are more sensitive to noise when sleeping (or trying to sleep) than when conversing or listening to television. At the other extreme, sensitivity to intrusive noise is apt to be minimal while performing tasks with which noise does not directly interfere, such as preparing a meal, washing dishes, or taking a shower. Because of these variations in sensitivity to noise, the criteria for maximum acceptable indoor noise levels should be based on the intended use of each room. The design procedures in the CMHC standards follow this principle by adjusting the required acoustical insulation on the basis of designated room use.

The difference between the indoor noise criterion and the outdoor noise level establishes the acoustical insulation requirement for the exterior shell. In most rooms this exterior shell is composed of several components; these may include windows, exterior doors, exterior walls and the roof-ceiling system. In this context a "component" may include several similar elements; for example, all the windows in an exterior wall are considered to comprise one component. Noise is transmitted into a room through all the components; in practice, some components usually transmit more noise than others. In the case of a room envelope with N components, the CMHC standards require that no component transmit more than 1/N of the total sound power that would give the maximum acceptable noise level inside the room. Thus, for example, in a room with only two exterior components (wall and windows), neither should transmit more than one-half of the total allowable sound power. Mathematically this basic requirement can be expressed as:

$$\text{Required AIF} = L(\text{outside}) - L(\text{inside}) + 10\log_{10}(N) \qquad (1)$$

where N is the number of components and the sound levels (L) are expressed on a common decibel scale, with appropriate frequency weighting. Fortunately this concept can readily be presented in tabular form more useful to users unfamiliar with the mathematics of decibel scales. Tables 1 and 2 in the publication *New Housing and Airport Noise*[1] are based directly on Eq. (1). A slightly modified expression is used for the corresponding Table 6.1 in the standard for noise from ground transportation. The exact form of the requirements and the reasons for the minor differences are presented in the sections dealing with the specific publications.

3. The AIF of Individual Components

The AIF is a rating of the noise reduction provided by the various components that make up the exterior surface of a room. This section presents a brief discussion of some of the physical effects determining the AIF of individual components.

The AIF is fundamentally very different from single figure ratings such as the STC. This may best be illustrated by considering an example where one component (a window) transmits essentially all the sound power entering the room. The window transmits a certain fraction of the sound power incident on its outer surface. This fraction depends on the specific window construction and is determined primarily by such features as the glass thickness and the space between panes, if it is double- or triple-glazed. Single-figure ratings such as the STC are based on this characteristic fraction and are normally assumed to be valid for a window of any area. In practice the difference between the indoor and outdoor noise levels (i.e., the noise reduction) depends not only on the fraction of power transmitted, but also on the size of the window and the acoustical absorption provided by the furnishings and surfaces of the room. The actual noise reduction may be evaluated by adding to the STC a correction of $10 \log_{10}(A/S)$ where S is the component area (in square metres) and A is the room's acoustical absorption in metric sabins. To calculate this correction, the designer must determine what the acoustical absorption is.

The AIF was formulated to avoid the need to calculate corrections for absorption and component size, in keeping with the goal of minimizing the acoustical expertise needed by users of the CMHC standards. Rather than a single-figure value, each construction is assigned a series of values; the value selected from the series depends on the ratio of the component to the floor area (see, e.g., Table 5). Each of the values indicate the noise reduction that would be obtained if:

(a) only that component is transmitting sound,

(b) room absorption is "typical,"

(c) the noise source has appropriate spectral and directional characteristics.

The values in the AIF tables are based on the assumption that typical residential rooms have acoustical absorption (in metric sabins) numerically equal to 80 per cent of their floor area (in square metres). For the usual room height of 2.4 m, this corresponds to a reverberation time of 0.5 s, which is characteristic of a moderately furnished living room or bedroom. In rooms with deep-pile carpeting and abundant upholstered furniture, the absorption might significantly exceed 80 per cent of the floor area; on the other hand, most bathrooms and kitchens have very little absorption. Using the same simple assessment of acoustical absorption for these different situations obviously causes some deviation from the nominal design criteria. However, these deviations are unlikely to exceed 1 or 2 dB (a barely perceptible difference) and should tend to average out over the rooms of a typical home. Because of the considerable variation expected in the occupant's choice of furnishings, the simplified procedure seems adequate for this application.

The characteristics of the noise source must also be considered in any prediction of the noise reduction provided by a building facade. The fraction of the incident sound that is transmitted by a facade depends on both the spectral balance of the sound and the angle at which the sound waves strike the surface.

To arrive at a unique rating for each building component, one must evaluate the performance for an assumed "typical" sound spectrum and range of angles of incidence. In the case of the AIF, this was done on the basis of extensive experimental and theoretical evaluations[4] of the reduction of aircraft noise at sites where the Noise Exposure Forecast is in the range from 25 to 35. The detailed assumptions and rationale are discussed in Section V. A correction is necessary in applying the AIF tables with road and railway noise because the conditions are rather different, as discussed in Section IV.

III. INSULATION AGAINST AIRCRAFT NOISE

The Acoustic Insulation Factor was originally developed for use in the Central Mortgage and Housing Corporation publication *New Housing and Airport Noise*.[1] This section presents the details pertinent to the application of the AIF in that context, together with some extensions relevant for non-residential applications.

1. Noise Descriptor and Criteria

The noise descriptor currently used for the regions surrounding major Canadian airports is the Noise Exposure Forecast (NEF). The relationship between the NEF and the A-weighted equivalent level commonly used to describe noise from road and railway traffic has been discussed in a previous publication.[5] The NEF is a prediction of the annual average exposure to aircraft noise at a site. Maps showing the contours for NEF values of 25, 30, 35 and 40 are prepared by the airport authorities (Transport Canada and Department of National Defence) for most airports in Canada. These maps are available from the regional offices of CMHC.

The use of the following design procedure to obtain an acceptable indoor noise climate is recommended for residential developments where the outdoor NEF is greater than 25 and for non-residential buildings where the outdoor NEF is greater than 30. Detailed recommendations for land use planning are presented in Table 1 and the recommended indoor noise exposure criteria for various uses are given in Table 2.

2. Basic Calculation of the Required AIF

Given the outdoor NEF at the site and the recommended maximum indoor noise exposure from Table 2, the required Acoustic Insulation Factor may be calculated as follows:

$$\text{Required AIF} = \text{NEF(outside)} - \text{Desired NEF(inside)} + 10 \log_{10}(N) \qquad (2)$$

where N is the number of components in the exterior envelope of the room. In general, all elements of the same type (for example, all the windows in a room) should be considered to comprise one component and their combined area used as the component area. In special cases where there is more than one type of exterior wall or window construction, all the elements of each type comprise one component. Table 3 presents values of the required AIF for various applications obtained using Eq. (2) with the indoor noise criteria of Table 2. Once the required AIF values for the components have been established, appropriate components can be selected from those listed in the AIF tables. Tables 5, 6, 7 and 8 present the AIF values for some windows, exterior walls, roof-ceiling systems and doors, respectively.

3. Adjustments to the Basic Calculation of Required AIF

It is recognized that other architectural considerations may lead to designs having some components with AIF ratings that exceed the requirements in Table 3. In such cases it is reasonable to slightly relax the AIF requirements for the other components of the exterior shell. In the present version of the CMHC publications, if the AIF of any component exceeds the required AIF by 10 or more, the calculation should be repeated for the other components with the "total number of components" reduced by one. This reduction in the number of components lowers the required AIF for the others. No adjustment is made if a component's AIF exceeds the requirements by less than 10. This inflexibility can cause overdesign of the weakest components (usually the windows).

The most important design consideration is to ensure that the total sound power transmitted by the components is consistent with the desired difference between the outdoor and indoor noise exposures. The required AIF values in Table 3 indicate the average acoustical insulation required for the N components of a room envelope. Deviations from this average AIF are acceptable, provided the increase in sound power transmitted by the weaker components is offset by a corresponding decrease in the sound power transmitted by the others. The necessary adjustments can be calculated simply using Table 4, as illustrated in the following example. (Note that the "average" AIF is not a simple arithmetic average of the component AIF values.)

Example 1: Consider the design for a bedroom in a house at a site where the NEF = 32. The room has three components in its exterior envelope: ceiling/roof, exterior wall, and windows. From Table 3 the average required AIF is 37. If other architectural considerations led to choosing a roof/ceiling with AIF = 50 and an exterior wall with AIF = 43, what AIF is required for the windows?

From the three-component column of Table 4 the roof/ceiling selected (AIF more than 10 points above the required average value) indicates -30, i.e., it would transmit 30 per cent less than its share of the total transmitted power. Similarly the selected wall, which has an AIF six points above the required average value, transmits 25 per cent less than its share of the total transmitted power. The total sound transmission by these two components is thus 55 per cent less than their share of the total power. Therefore the window component may be allowed to transmit up to 55 per cent more than its share of the total, and from the table its AIF rating can thus be 4 dB below the specified average value, i.e., AIF 33.

If the same situation were evaluated using the current CMHC procedure, the windows would be required to have AIF=35 (the value from Table 3 for a bedroom with two components at NEF=32).

4. Associated Ventilation Requirements

No matter what components are selected, the difference between the outdoor and indoor NEF is unlikely to exceed 20 dB if the windows are opened to provide ventilation. For residential rooms with a window opening of 0.3 m^2 (the minimum requirement of the Canadian Residential Standards),[6] the noise reduction is typically between 10 and 20 dB, depending on the size and furnishing of the room. Obviously the noise reduction can be increased by partially closing the windows, but for sites where the NEF is greater than 25, the indoor noise limits of Table 2 cannot be satisfied if the windows are opened appreciably. Although this does not pose a problem during the winter, the windows can only be kept closed during the summer if an alternative means of ventilation is provided. For most heavily-populated areas in Canada a mechanical ventilation system would have to include air conditioning to provide reasonable comfort in the warmer months.

The CMHC standards for insulating residential buildings against aircraft noise require "alternative means of ventilation" for sites where the NEF is greater than or equal to 30. For sites where the NEF is between 25 and 30, an alternative means of ventilation is recommended, but not mandatory. In practice the phrase "alternative means of ventilation" is normally interpreted as a requirement for air conditioning.

Where it is not mandatory, developers may not wish to include air conditioning because of the resulting increase in the selling price or rental rate. The use of a forced-air heating system with ducting appropriate for air conditioning should be encouraged in such cases. This will permit the eventual occupants to readily add air conditioning at a later date if they find the noise admitted by opening the windows for ventilation to be unacceptable. Even without air conditioning, such a system can partially fulfil the ventilation requirements if provisions are made to exhaust the cold air return ducts to outside and suck fresh air from outside into the cold air return plenum. To minimize noise entering through the air-handling system, the inlet and outlet ducts should be designed to provide some noise attenuation. Lining the ducts with suitable acoustical absorption material and including at least one 90° bend in the lined segments is one example of such treatment.

IV. INSULATION AGAINST TRAFFIC AND RAILWAY NOISE

This section presents information concerning the application of the AIF as used in the CMHC publication *Road and Rail Noise: Effects on Housing.*[2] Although the calculations are very similar to those for insulation against aircraft noise (and the tables of AIF ratings for building components are identical) there are some differences in the details.

1. Noise Descriptor and Criteria

Noise from road and railway traffic is normally described in terms of the A-weighted sound level, and the CMHC standard conforms with this practice. Traffic noise fluctuates appreciably, not only with the passby of individual noisy vehicles but also from one period of day to another and from day to day, as the volume of traffic changes. Despite all these variations in the noise level, a single figure descriptor must be used as the basis of a design procedure. In this case the descriptor selected is the 24-hour Equivalent Sound Level, commonly denoted L_{eq}(24 h). As reasons for this choice of descriptor have been discussed in previous publications,[5,7,8] they will not be presented here.

The equivalent sound level, L_{eq}(24 h) at the building site may be calculated following the procedures in the CMHC publication[2] or its NRC counterpart.[8,9] The calculation should be based on the highest value of the Annual Average Daily Traffic predicted for the next ten years to ensure a reasonable estimate of the long-term average noise climate.

The noise criteria, which have been discussed in previous publications,[7,8] are presented in Table 9. Like the requirements for insulation against aircraft noise, the recommended maximum noise levels vary depending on the type of room. An outdoor noise level is also specified; this limit applies to that part of the outdoor space intended for recreation, e.g., patios and balconies.

2. Basic Calculation of the Required AIF

The calculation procedure for road and rail traffic noise resembles that discussed previously for aircraft noise - the required AIF depends on the difference between the outside noise level and the indoor noise criterion, with an adjustment for the number of components transmitting the sound. Values of the required AIF for a range of outdoor noise levels and the indoor noise criteria of Table 9, are presented in Table 10. These were calculated using the equation:

$$\text{Required AIF} = \text{Outside } L_{eq}(24\text{ h}) - \text{Indoor } L_{eq}(24\text{ h}) + 10\log_{10}(N) + 2\text{ dB} \qquad (3)$$

Despite the apparent similarity of this expression to that in the calculation for insulation against aircraft noise, it is applied somewhat differently. In the case of aircraft noise, the outdoor noise was assumed to be the same at all exterior surfaces. For road or railway noise a significant difference is found between the sound reaching the wall facing the noise source, and the sound reaching the sheltered side of the building. It would be wasteful to design all the exterior facades to meet the noise control requirements for the noisiest side of the building. Therefore the calculation was structured to predict the noise reaching each wall of the building, and the calculation of the required AIF allows for these different incident noise levels for each wall.

For rooms that have only one exterior facade (the usual case in row housing or apartment blocks) the calculation of the number of components (N) is the same as that for aircraft noise: all similar elements of the same type (for example, all the windows) can be considered to comprise one component and their combined area is used as the component area.

If a room has more than one exterior facade, the required AIF must usually be calculated separately for each facade. The number of components must be determined for each facade; these numbers are added to obtain the number of components for the room (N). For each exterior facade the required AIF can then be determined from Table 10, using the number of components for the room and the predicted value of $L_{eq}(24\text{ h})$ at that facade. (Note that where any facade of a building is shielded from noise and the outdoor noise level is 55 dBA or less, the components of that wall are not included in the calculation.)

The term "+2 dB" in Eq. (3) is present because of the dependence of sound insulation on the spectral balance of the noise source, as discussed in Section II and Appendix A. The AIF tables were originally developed for insulation against aircraft noise. The reduction in L_{eq}(24 h) from road or railway traffic that will be provided by a given construction is typically less than the reduction of aircraft noise provided by the same construction.

Ceiling/roof systems are not included in the components for insulation against road or railway traffic noise. Because the roof is usually at least partially screened from direct view of the noise source, all roof designs commonly used in Canada should provide an AIF of at least 50 relative to the incident sound level at the noisiest face of the building. Thus all typical roof constructions should automatically meet the AIF requirements for sites where L_{eq}(24 h) is less than 75 dBA. Nevertheless, it would be wise design practice to minimize the ventilation openings to the attic space on the noisy side of the building.

3. Adjustments to the Basic Calculation of Required AIF

Other architectural considerations may lead to designs having some components whose AIF exceeds the requirements calculated using Table 10. The required AIF values listed in Table 10 indicate the average acoustical insulation that should be provided by the N components of a room. If, however, some components transmit less than their permitted share of the sound power, it is reasonable to slightly relax the AIF requirements for the other components of the exterior shell. Procedures for this are presented in Part 3 of Section III.

4. Associated Ventilation Requirements

As discussed with respect to aircraft noise, the difference between the outdoor and indoor noise levels is unlikely to exceed 20 dB (and is usually less) if the windows are opened to provide ventilation.

If the incident L_{eq}(24 h) outside the windows is less than 55 dBA, the indoor noise criteria should be satisfied even with open windows, except that bedrooms may be marginally noisier than desired. The CMHC standards for insulation against the noise from road and rail traffic require that a means of ventilation other than open windows be provided if the incident sound level at that wall is greater than 55 dBA. The implication of the phrase "alternate means of ventilation" with respect to air conditioning has been discussed previously in relation to aircraft noise.

The use of the single criterion (55 dBA) to determine the need for an alternate means of ventilation is not fully consistent with the basic approach of the CMHC design rules. All other aspects of the noise insulation requirements are related to indoor noise criteria based on the intended use of each room. The same approach can be applied to ventilation requirements, by assigning an AIF value for ventilation openings. For a window opened to satisfy the minimum window opening

(0.3 m^2) specified in residential standards, the AIF ratings shown below would apply.

Room Floor Area (m^2)	5	7	8	10	13	16	20	25	32
Open Window AIF	9	10	11	12	13	14	15	16	17

These values were calculated on the basis of "typical acoustical absorption" as discussed in Section II. If the required AIF for an openable window is lower than the appropriate value in the above table, then an alternate means of ventilation is not required to meet the indoor noise criterion. The proviso that open windows are an acceptable means of ventilation if the outside noise is less than 55 dBA would still apply as a bottom limit.

Because the required AIF varies depending on the intended use of a room, this approach would provide an additional incentive for developers to locate the least noise-sensitive rooms, such as kitchens and bathrooms, on the noisy side of the building.

Even in cases where the entire building is air conditioned, the different incident noise levels at different surfaces of the building should still be considered in the design of a ventilating system, at least to the extent of locating air inlets and outlets in the quietest positions available.

V. CALCULATION OF COMPONENT AIF FROM LABORATORY DATA

One major problem associated with the use of AIF ratings for CMHC applications is the need to rate components such as windows produced by various manufacturers. In many cases such products have already been tested in a laboratory, in accordance with the ASTM Method E90 for measurement of sound transmission loss.[10] A detailed procedure for calculating the AIF from laboratory transmission loss data and a simple way to estimate the AIF from the Sound Transmission Class (STC) are presented below.

1. Calculating the AIF from Transmission Loss Data

The difference between the outdoor A-weighted noise level and the resulting indoor level (or the difference between outdoor and indoor NEF in the case of aircraft noise) depends on both the transmission loss characteristic of the external shell and the spectrum of the noise source as discussed in Appendix A. The spectrum used for calculations of the AIF is shown in Fig. 1; it is normalized to give an A-weighted level of approximately 80 dBA to provide a convenient range of values for the calculation. The A-weighted sound pressure levels for the individual 1/3 octave bands (which are the values used in calculating the AIF) are indicated in the figure.

The calculation procedure is illustrated by the example given in the work sheet in Fig. 2. By subtracting the transmission loss values from the source sound levels, the corresponding transmitted sound levels in each 1/3 octave band are obtained. Combining these 1/3 octave band levels yields the A-weighted sound level that would be measured in a room if only that component were transmitting sound and the component area (in square metres) were numerically equal to the acoustical absorption (in metric sabins). The A-weighted source level is taken to be 77 dBA; combining the values in column A would give 80.3 dBA, but this must be adjusted to allow for differences between the source sound field at an exterior facade and that in laboratory test chambers, as discussed in Appendix A. The difference between this adjusted (77 dBA) source level and the calculated transmitted A-weighted level is the AIF for component area equal to 80 per cent of room floor area. For other percentages (P) of component area relative to floor area, the AIF may be calculated by subtracting $10 \log_{10}(P/80)$ from the value for P = 80 per cent. The calculated values should be rounded to the nearest integer.

2. Estimating the AIF from STC

In some cases a manufacturer or his agent may know the STC of a product but be unable to provide the 1/3 octave band transmission loss data. This should not occur because, in order to determine the STC, one must first obtain the transmission loss data for the 1/3 octaves from 125 Hz to 4000 Hz. Laboratory reports of STC determinations consistent with the ASTM Standard E413 should include this information.

If detailed transmission loss data are not available, the AIF can be estimated from the STC value, using Table 11 for doors and windows, and Table 12 for other components. This simple procedure yields a "typical" value which is within 1 dB of the value obtained from the detailed calculation for most building components. For some types of windows (particularly factory-sealed double glazing), however, the estimated value may be as much as 3 lower than the result of the detailed calculation. These discrepancies are caused by major dips or peaks in the frequency dependence of the transmission loss. Because of these effects, it is usually to a manufacturer's advantage to use the detailed calculation procedure.

REFERENCES

1 *New Housing and Airport Noise (Metric Edition).* Central Mortgage and Housing Corporation, Ottawa, Canada, Publication NHA 5185 1/78 (1978).

2 *Road and Rail Noise: Effects on Housing.* Central Mortgage and Housing Corporation, Ottawa, Canada, Publication NHA 5156 12/77 (1977).

3 *Determination of Sound Transmission Class, Tentative Classification for.* ASTM E413-70T (Am. Soc. Testing and Materials, Philadelphia, PA).

4 Quirt, J.D., *Insulating Buildings from Aircraft Noise.* J. Acoust. Soc. Am. 63, 823-831 (March 1978).

5 Quirt, J.D., *Intrusion of Outdoor Noise in Dwellings: Comparison of Proposed Limits*. Nat. Res. Council, Div. Bldg. Res., Building Research Note 130 (June 1978).

6 *Ventilation - Section 33, Residential Standards*. Associate Committee on the National Building Code, National Research Council of Canada, Ottawa (1977).

7 Northwood, T.D., *An Approach to Regulations for Residential Construction Near Major Sources of Traffic Noise*. J. Acoust. Soc. Am. 63, Paper S46 (Supplement No. 1) (May 1978).

8 Northwood, T.D., J.D. Quirt, and R.E. Halliwell, *Residential Planning with Respect to Road and Rail Noise*. Noise Control Engineering, 13, 2, 1979, p. 63-75 (NRCC 17942).

9 Quirt, J.D., *Keeping Traffic Noise Outdoors*. J. Acoust. Soc. Am. 63 (Supplement No. 1), Paper S47 (May 1978).

10 *Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions*. ASTM E90-75 (Am. Soc. Testing and Materials, Philadelphia, PA).

TABLE 1: Recommendations for Land Use Planning

Proposed Land Use	NEF 25 to 30	NEF 30 to 35	NEF 35 to 40
Hospital, theatre, auditorium	Control indoor noise by appropriate acoustical insulation. Must consider individual noise maxima as well as NEF.	Cost of noise insulation may be prohibitive at sites with occasional very noisy events.	Not a recommended use.
Residential or schools	Control indoor noise by appropriate acoustical insulation. Outdoor noise is distinctly noticeable, but not a severe problem.	Control indoor noise by appropriate acoustical insulation. Noise interferes with many outdoor activities. Developments with minimal use of outdoor space are recommended.	Not a recommended use.
Hotel, motel, restaurant, offices, commercial uses such as retail sales or ser services	Noise not a significant problem.	Control indoor noise by appropriate acoustical insulation.	Control indoor noise by appropriate acoustical insulation.

Industrial and commercial uses may be acceptable at sites where NEF is greater than 40, provided that noise sensitive areas such as offices have adequate acoustical insulation.

TABLE 2: Recommended Indoor Noise Exposure Criteria

Use of Space	Recommended Maximum Indoor NEF	Comments
Theatre, auditorium	-5	Should design to ensure that maximum noise from flyovers does not significantly exceed internally generated background noise.
Hospital or residential bedrooms	0	
Residential living room, dining room, etc.	5	
Hotel or motel bedroom	5	Less sensitive than residential bedrooms because of higher internally generated background noise.
Private office, conference room, classrooms	5	If negligible distraction and speech interference are mandatory, maximum noise levels from individual flyovers should also be considered.
Residential kitchen, bathroom, utility room	10	Internally generated noise is common and speech interference is not a major concern.
Open plan offices or schools	10	Internal noise sources might essentially mask aircraft noise.
Restaurants, commercial uses such as retail stores or services	15	

TABLE 3: Required Acoustic Insulation Factor (AIF) for various applications

Intended Room Use	No. of Compo-nents	Outdoor Noise Exposure Forecast (NEF)															
		25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
(a) Residential bedroom	1	25	26	27	28	29	30	31	32	33	34	35					
	2	28	29	30	31	32	33	34	35	36	37	38					
Hospital room	3	30	31	32	33	34	35	36	37	38	39	40					
	4	31	32	33	34	35	36	37	38	39	40	41					
	5	32	33	34	35	36	37	38	39	40	41	42					
	6	33	34	35	36	37	38	39	40	41	42	43					
(a) Residential living	1	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
or dining room, etc.	2	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
Classrooms	3	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
(b) Private offices or	4	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
conference rooms	5	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Hotel/motel bedrooms	6	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
(a) Residential kitchen,	1	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
bathroom, utility	2	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
room, etc.	3	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
	4	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
(b) Open-plan offices	5	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
	6	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
	1						15	16	17	18	19	20	21	22	23	24	25
(b) Restaurants, stores	2						18	19	20	21	22	23	24	25	26	27	28
and services	3						20	21	22	23	24	25	26	27	28	29	30
	4						21	22	23	24	25	26	27	28	29	30	31
	5						22	23	24	25	26	27	28	29	30	31	32
	6						23	24	25	26	27	28	29	30	31	32	33

NOTE: Values of required AIF in the body of the table are consistent with recommended maximum indoor NEF criteria presented in Table 2.
Room uses of Type (a) are not recommended where the outdoor NEF is greater than 35.

TABLE 4: Chart for redistributing AIF requirements to compensate for components whose AIF's deviate from the average required value. Values in the body of the table indicate the percentage of transmitted sound power above (+ve) or below (-ve) the specified average sound power per component

Component AIF minus Average Required AIF	Total No. of Components 2	3	4	5	6	
10 or more	-45	-30	-22	-18	-15	Percentage change in total transmitted sound power
9	-44	-29	-22	-18	-15	
8	-42	-28	-21	-17	-14	
7	-40	-27	-20	-16	-13	
6	-37	-25	-19	-15	-12	
5	-34	-23	-17	-14-	-10	
4	-30	-20	-15	-12	-11	
3	-25	-17	-12	-10	-8	
2	-18	-12	-9	-7	-6	
1	-10	-7	-5	-4	-3	
0	0	0	0	0	0	
-1	13	9	6	5	4	
-2	29	20	15	12	10	
-3	50	33	25	20	17	
-4	76	50	38	30	25	
-5	108	72	54	43	36	

Worksheet for Table 4 (using Example I)

Outdoor Noise Exposure Forecast 32
Number of components 3
Type of Room bedroom

Averaged Required AIF (from Table 3) 37

Component	AIF	AIF Minus Average Required AIF	Increase in Transmitted Sound
ceiling/roof	50	13 (more than 10)	-30 %
exterior wall	43	6	-25 %
window	33	-4	50 %

Overall increase in total transmitted sound power = -5%
(sum of column above)

TABLE 5: Acoustic Insulation Factor for Various Types of Windows

Window area as a percentage of total floor area of room[1]														Single glazing	Double glazing of indicated glass thickness					Triple Glazing	
4	5	6	8	10	13	16	20	25	32	40	50	63	80		2mm and 2mm glass	3mm and 3mm glass	4mm and 4mm glass	3mm and 6mm glass	6mm and 6mm glass	3mm, 3mm and 3mm glass	3mm, 3mm and 6mm glass
Acoustic Insulation Factor (AIF)[2]														Thickness	Interpane spacing in mm[3]					Interpane spacings in mm[5]	
35	34	33	32	31	30	29	28	27	26	25	24	23	22	2mm	6						
36	35	34	33	32	31	30	29	28	27	26	25	24	23		13						
37	36	35	34	33	32	31	30	29	28	27	26	25	24	3mm	15	6					
38	37	36	35	34	33	32	31	30	29	28	27	26	25	4mm, 6mm	18	13	6				
39	38	37	36	35	34	33	32	31	30	29	28	27	26		22	16	13	6	6	6,6	
40	39	38	37	36	35	34	33	32	31	30	29	28	27	9mm[4]	28	20	16	13	13	6,10	6,6
41	40	39	38	37	36	35	34	33	32	31	30	29	28		35	25	20	16	16	6,15	6,10
42	41	40	39	38	37	36	35	34	33	32	31	30	29	12mm[4]	42	32	25	20	20	6,20	6,15
43	42	41	40	39	38	37	36	35	34	33	32	31	30		50	40	32	25	24	6,30	6,20
44	43	42	41	40	39	38	37	36	35	34	33	32	31		63	50	40	32	30	6,40	6,30
45	44	43	42	41	40	39	38	37	36	35	34	33	32		80	63	50	40	37	6,50	6,40
46	45	44	43	42	41	40	39	38	37	36	35	34	33		100	80	63	55	50	6,65	6,50
47	46	45	44	43	42	41	40	39	38	37	36	35	34		125	100	80	75	70	6,80	6,65
48	47	46	45	44	43	42	41	40	39	38	37	36	35		150	125	100	95	90	6,100	6,80
49	48	47	46	45	44	43	42	41	40	39	38	37	36			150	125	110	100		6,100
50	49	48	47	46	45	44	43	42	41	40	39	38	37				150	135	125		

Source: National Research Council, Division of Building Research, June 1980.

Explanatory Notes:

1) Where the calculated percentage window area is not presented as a column heading, the nearest percentage column in the table values should be used.
2) AIF data listed in the table are for well-fitted weatherstripped units that can be opened. The AIF values apply only when the windows are closed. For windows fixed and sealed to the frame, add three (3) to the AIF given in the table.
3) If the interpane spacing or glass thickness for a specific double glazed window is not listed in the table, the nearest listed values should be used.
4) The AIF ratings for 9mm and 12mm glass are for laminated glass only; for solid glass subtract two (2) from the AIF values listed in the table.
5) If the interpane spacings for a specific triple-glazed window are not listed in the table, use the listed case whose combined spacings are nearest the actual combined spacing.
6) The AIF data listed in the table are for typical windows, but details of glass mounting, window seals, etc. may result in slightly different performance for some manufacturers' products. If laboratory sound transmission loss data (conforming to ASTM test method E-90) are available, these should be used to calculate the AIF.

TABLE 6: ACOUSTIC INSULATION FACTOR FOR VARIOUS TYPES OF EXTERIOR WALL

Percentage of exterior wall area to total floor area of room	16	20	25	32	40	50	63	80	100	125	160	Type of Exterior Wall
	45	44	43	42	41	40	39	38	37	36	35	EW1
	46	45	44	43	42	41	40	39	38	37	36	EW2
	47	46	45	44	43	42	41	40	39	38	37	EW3
	48	47	46	45	44	43	42	41	40	39	38	EW4
Acoustic	55	54	53	52	51	50	49	48	47	46	45	EW5 or EW1R
Insulation	56	55	54	53	52	51	50	49	48	47	46	EW2R or EW3R
Factor	57	56	55	54	53	52	51	50	49	48	47	EW4R
	58	57	56	55	54	53	52	51	50	49	48	EW6
	59	58	57	56	55	54	53	52	51	50	49	EW7
	61	60	59	58	57	56	55	54	53	52	51	EW5R
	63	62	61	60	59	58	57	56	55	54	53	EW8 or EW6R
	64	63	62	61	60	59	58	57	56	55	54	EW7R

Note: Where the calculated percentage wall area is not presented as a column heading, the nearest percentage column in the table should be used.

Source: National Research Council, Ottawa, November 1976.

Explanatory Notes:

1) EW1 denotes exterior wall as in Note 2), plus sheathing, plus wood siding or metal siding and fibre backer board.
   EW2 denotes exterior wall as in Note 2), plus rigid insulation (25-50 mm), and wood siding or metal siding and fibre backer board.
   EW3 denotes simulated mansard with structure as in Note 2), plus sheathing, 38 x 89 mm framing, sheathing, and asphalt roofing material.
   EW4 denotes exterior wall as in Note 2), plus sheathing and 20 mm stucco.
   EW5 denotes exterior wall as in Note 2), plus sheathing, 25 mm air space, 100 mm brick veneer.
   EW6 denotes exterior wall composed of 12.7 mm gypsum board, rigid insulation (25-50 mm), 100 mm back-up block, 100 mm face brick.
   EW7 denotes exterior wall composed of 12.7 mm gypsum board, rigid insulation (25-50 mm), 140 mm back-up block, 100 mm face brick.
   EW8 denotes exterior wall composed of 12.7 mm gypsum board, rigid insulation (25-50 mm), 200 mm concrete.
2) The common structure of walls EW1 to EW5 is composed of 12.7 mm gypsum board, vapour barrier, 38 x 89 mm studs, and 50 mm (or thicker) mineral wool or glass fibre batts.
3) R signifies the mounting of the interior gypsum board on resilient clips.
4) An exterior wall conforming to rainscreen design principles and composed of 12.7 mm gypsum board, 100 mm concrete block, rigid insulation (25-50 mm), 25 mm air space, and 100 mm brick veneer has the same AIF as EW5.
5) An exterior wall described in EW1 with the addition of rigid insulation (25-50 mm) between the sheathing and the external finish has the same AIF as EW3.

TABLE 7: ACOUSTIC INSULATION FACTOR FOR VARIOUS CEILING-ROOF COMBINATIONS

Acoustic Insulation Factor	Ceiling-roof combination
44	C1
47	C1R
50	C2 or C1DR
52	C3
53	C2D
55	C2DR

Source: National Research Council, Ottawa. September 1975.

Explanatory Notes

1) C1 denotes 12.7 mm gypsum board, 75 mm mineral wool batts, flat roof joist and beam construction, built-up roofing.
   C2 denotes 12.7 mm gypsum board, 75 mm mineral wool batts, typical wood roof truss with ventilated attic, sheathing and asphalt roofing.
   C3 denotes paint finish, 150 mm concrete slab, 50 mm rigid insulation, built-up roofing.
2) R signifies mounting the gypsum board on wood strapping or resilient clips.
   DR signifies the addition of a second layer of 12.7 mm gypsum board mounted on resilient clips.
   D signifies the addition of a second layer of 12.7 mm gypsum board.

TABLE 8: ACOUSTIC INSULATION FACTOR FOR VARIOUS TYPES OF EXTERIOR DOORS

Percentage of total door area to total floor area of room	4	5	6.3	8	10	12.5	16	20	25	Exterior Door Type
	33	32	31	30	29	28	27	26	25	D1
	37	36	35	34	33	32	31	30	29	D2
	39	38	37	36	35	34	33	32	31	D3
	40	39	38	37	36	35	34	33	32	D4
Acoustic	41	40	39	38	37	36	35	34	33	D5
Insulation	42	41	40	39	38	37	36	35	34	D1 — sd
Factor	45	44	43	42	41	40	39	38	37	D2 — sd
	47	46	45	44	43	42	41	40	39	D3 — sd
	48	47	46	45	44	43	42	41	40	D4 — sd
	49	48	47	46	45	44	43	42	41	D5 — sd
	51	50	49	48	47	46	45	44	43	D3 — D3
	53	52	51	50	49	48	47	46	45	D5 — D5

Note: Where the calculated percentage door area is not presented as a column heading, the nearest percentage column in the table should be used.

Source: National Research Council, Ottawa, November 1976.

Explanatory Notes:

1) All prime doors must be fully weatherstripped.
2) D1 denotes 44 mm hollow core wood door (up to 10% of area glazed).
   D2 denotes 44 mm glass-fibre reinforced plastic door with foam or glass-fibre insulated core (up to 5% of area glazed).
   D3 denotes 35 mm in solid slab wood door.
   D4 denotes 44 mm steel door with foam or glass-fibre insulated core.
   D5 denotes 44 mm solid slab door.
3) Except as noted specifically above, doors shall not have inset glazing.
4) sd denotes storm door. The AIF values apply when the glazed sections are closed.

TABLE 9: Recommended maximum exposure to noise from road or railway traffic for various types of space.

Designated Use of Space	Recommended Maximum L_{eq}(24 h)	Comments
Theatre, auditorium	30	Ensure that maximum passby noise of individual vehicles does not exceed indoor background noise.
Hospital or residential bedroom	35	Maximun noise from individual vehicles should not exceed 45 dBA.
Residential living room, dining room, etc.	40	
Hotel/motel bedroom	40	
Private office, conference room, classrooms	40	If negligible distraction and speech interference are mandatory, maximum noise from individual vehicles should not exceed 45 dBA.
Residential kitchen, bathroom, utility room	45	Speech interference is not of major concern in these environments.
Open-plan offices or schools	45	Internal noise sources are likely to essentially mask the traffic noise.
Restaurants, commercial uses such as retail stores or services	50	If a quiet, restful atmosphere is desired, L_{eq}(24 h) = 45 dBA would be preferable. For a busy store or restaurant, internally generated noise is likely to mask the traffic noise.
Outdoor recreation areas where speech comprehension is of some concern	55	Speech communication should be adequate at distances under 2 m.

TABLE 10: Required Acoustic Insulation Factor (AIF) for various applications

Designated Room Use	No. of Compo-nents	Outdoor Noise Level, L_{eq}(24 h)																			
		56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
- Residential bedroom	1	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
	2	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
- Hospital room	3	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
	4	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
	5	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
	6	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
	7	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
	8	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
- Residential living	1	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
or dining room, etc.	2	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
- Private offices	3	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
- Conference rooms	4	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
- Hotel/motel bedrooms	5	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
- Classrooms	6	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
	7	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
	8	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
- Residential kitchen,	1	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
bathroom or	2	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
utility room, etc.	3	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
- Open-plan offices or	4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
Classrooms	5	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	6	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
	7	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
	8	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
- Restaurants, stores	1	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
and services	2	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	3	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	4	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
	5	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
	6	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
	7	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	8	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36

NOTE: Values of AIF in the body of the table are consistent with the recommended maximum noise levels presented in Table 9 and were calculated using Eq. 3 as discussed in the text.

TABLE 11: Approximate conversion from STC to AIF for windows and doors:

Window (or door) area expressed as percentage of room floor area	Acoustic Insulation Factor (AIF)
80	STC-5
63	STC-4
50	STC-3
40	STC-2
32	STC-1
25	STC
20	STC+1
16	STC+2
12.5	STC+3
10	STC+4
8	STC+5
6.3	STC+6
5	STC+7
4	STC+8

Note: For area percentages not listed in the table use the nearest listed value.

Examples: For a window whose area = 20% of the room floor area and STC = 32 the AIF is 32 + 1 = 33.

For a window whose area = 60% of the room floor area and STC = 29 the AIF is 29 - 4 = 25.

TABLE 12: Approximate conversion from STC to AIF for exterior walls:

Exterior wall area expressed as percentage of room floor area	Acoustic Insulation Factor (AIF)
200	STC-10
160	STC-9
125	STC-8
100	STC-7
80	STC-6
63	STC-5
50	STC-4
40	STC-3
32	STC-2
25	STC-1
20	STC
16	STC+1
12.5	STC+2
10	STC+3
8	

Note: For area percentages not listed in the table use the nearest listed value.

Example: For a wall whose area = 120% of room floor area and STC = 48 the AIF is 48 - 8 = 40.

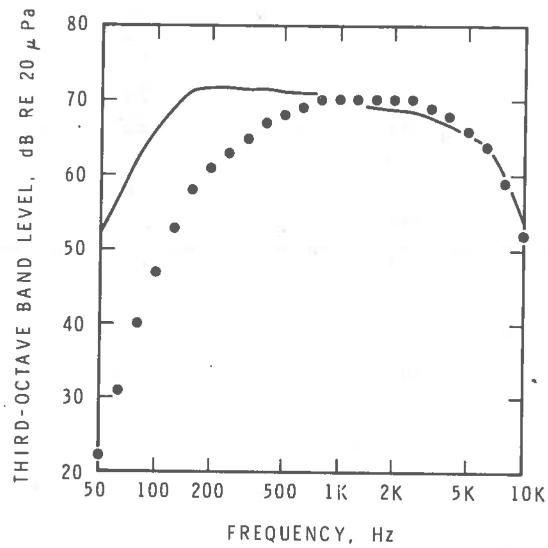

FIGURE 1

SOURCE SPECTRUM FOR AIF CALCULATIONS.
(A-WEIGHTED 1/3-OCTAVE BAND SOUND PRESSURE LEVELS INDICATED BY ●)

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TABLE A-1: Comparison of AIF and reduction in A-weighted sound level for various source spectra. Values are average results for 20 window transmission loss characteristics, as discussed in text.

Outdoor Noise Source Spectrum		Mean Value of AIF Minus Calculated Reduction of A-Weighted Sound Level	Standard Deviation
A	(Aircraft nearby)	-1.9	0.9
B	(Standard AIF source)	Zero by definition	0
C	(Distant aircraft)	2.9	0.7
D	(Trucks, etc.)	3.5	1.4
E	(French R_{route})	3.0	1.0
F	(Cars, etc.)	1.6	1.1
G	(Diesel locomotives)	3.9	2.0
H	(Wheel-rail noise)	0.1	0.2

Note: Letters denoting spectra relate to curves in Figs. A1, A2, A3.

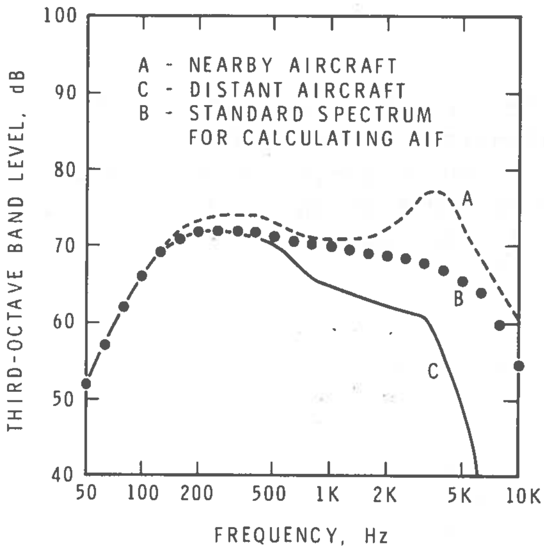

FIGURE A1

SOURCE SPECTRA FOR SOME JET AIRCRAFT (REFERENCE LEVEL FOR DECIBEL SCALE WAS ARBITRARILY SELECTED TO PROVIDE CONVENIENT VALUES FOR THE AIF CALCULATION PROCEDURE ILLUSTRATED IN FIG. 2)

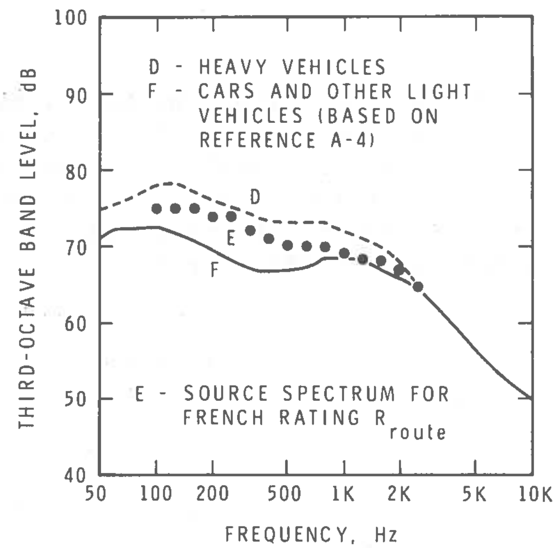

FIGURE A2

SOURCE SPECTRA FOR TYPICAL ROAD TRAFFIC (REFERENCE LEVEL FOR DECIBEL SCALE WAS SELECTED AS NOTED IN FIG. A1)

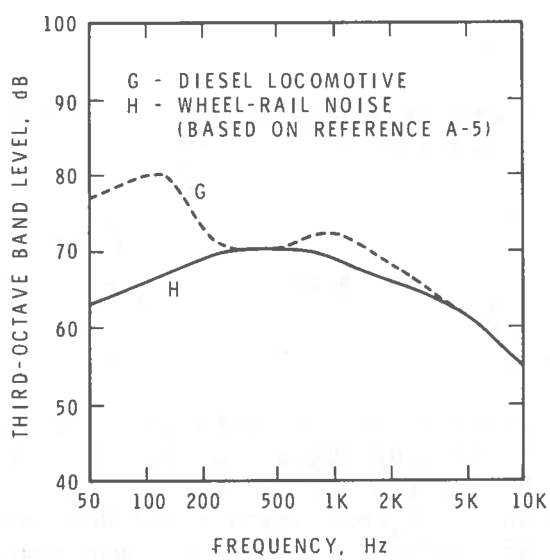

FIGURE A3

SOURCE SPECTRA FOR TYPICAL RAILWAY NOISE SOURCES (REFERENCE LEVEL FOR DECIBEL SCALE WAS SELECTED AS NOTED IN FIG. A1) where the expression in the first bracket is proportional to the length of the line segment (and hence its emitted sound power) and the second factor allows for inverse square law spreading. Using this in the same way that the $\sin\theta$ factor was used in Eq. (A-3) and integrating over θ from 0° to 85° gives the results listed below for specific values of ϕ.

Vertical Angle ϕ	TL(line source) - TL(laboratory)
0	2.0
10	1.9
20	1.5
30	0.8
40	-0.2
50	-1.6
60	-3.5

The exact numbers should not be taken too seriously. They apply strictly to the case of a limp partition. The fundamental point is that the values may be positive or negative, depending on the location of the line source relative to the facade. A similar range of values can be obtained for other source orientations. As there is no obvious basis for selecting one case as clearly most representative of the situations near an airport, no specific correction is made for the difference between random (laboratory) incidence and that at exterior facades.

In some special cases with very limited range of angles, either very close to normal incidence or near grazing incidence, using a correction based on calculations like those presented above might be justified. For general applications, calculation of the AIF from laboratory TL data requires only the 3 dB adjustment for the difference between incident and reverberant source sound fields discussed at the beginning of this section.

2. Dependence on Spectral Balance of the Noise Source

The noise from aircraft or from highway traffic includes significant sound energy over a wide range of frequencies. In passing from outdoors to indoors, the character of the sound is altered, because typical building components provide more sound attenuation for higher frequencies. The over-all perception of "loudness" or "noisiness" of the sound can be described using a descriptor such as the A-weighted level or the Perceived Noise Level (PNL) which is the basic measure of noise for the NEF. In general, the greater the contribution of the high frequency bands to the outdoor noise level (dBA, PNL, etc.) the greater the difference between the indoor and outdoor noise levels. The exact difference depends on the details of the frequency dependence of both the noise source and the transmission loss. Peaks or dips in either the transmission loss or the source spectrum can appreciably affect the difference in A-weighted levels, particularly in cases where a noise peak coincides with a transmission loss dip.

To avoid placing undue emphasis on irregularities in the transmission loss, the standard spectrum for AIF calculations (shown in Fig. 1 and again as the middle curve in Fig. A1) was deliberately smoothed. The over-all spectral balance was chosen to fall between the two limiting curves shown in Fig. A1. The upper curve in Fig. A1 is an average of six jet aircraft flyovers (landing approaches of DC-9, DC-8 and Boeing 707 aircraft at distances of 350 to 500 ft from the measurement position). The lower curve was obtained by subtracting from the upper curve a correction appropriate for atmospheric absorption over a distance of 3000 ft.* These curves provide a reasonable indication of the extremes of spectral balance found in the area near a major airport. The middle curve is considered "typical" of such sites and was specifically tailored to give agreement with the results of extensive experimental studies reported in Reference 4.

Figures A2 and A3 present typical source spectra for road traffic and railway traffic, respectively. In both cases these spectra would be appropriate for sites within ∿100 m from the sources; diminished high frequency content would be expected at greater distances. Figure A2 also presents the source spectrum used for calculating the French rating R_{route} which is used to rate building elements for insulation against road traffic noise.[A-3] The AIF and the calculated reduction in A-weighted sound level for each of the spectra in Figs. A1, A2 and A3 were calculated for twenty selected transmission loss curves. The transmission loss data included a variety of single-glazed, double-glazed and triple-glazed windows, and should provide a reasonable estimate of the range of variations in frequency dependence of the transmission loss to be expected in actual buildings. (Table 1 presents a summary of the results of these calculations.)

From these results it appears that the reduction in the A-weighted sound level for typical road traffic noise is approximately 2 dB less than the reduction for noise with the standard AIF spectrum. To permit the use of the AIF component ratings in Tables 5 to 8 for applications involving both aircraft and traffic noise, a correction of 2 dB is used in calculating the required AIF for traffic noise. It should be noted that this difference is quite consistent with the difference between the R_{route} and R_{rose} ratings used in France for insulation against road and aircraft noise, respectively.[A-2] The mean value of $R_{rose} - R_{route}$ for 85 window tests listed in Ref. A-3 was 1.9 dB.

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*Air absorption corrections were based on Fig. 13 of *Community Noise Exposure Resulting from Aircraft Operations*, Report AD/A-004822 prepared for U.S. Aerospace Medical Research Laboratory by W.J. Galloway (Nov. 1974). It is recognized that other propagation effects also alter the spectral balance, and that these corrections are at best coarse estimates.

In cases where a specific source, such as diesel locomotives, clearly dominates the outdoor L_{eq}(24 h), an alternative correction might be preferable. This could be obtained either by using the appropriate value from Table A1, or by following a detailed calculation procedure like that illustrated in Fig. 2, but using the transmission loss data and A-weighted source sound pressure levels appropriate for that specific application.

REFERENCES

A-1 Waterhouse, R.V., *Interference Patterns in Reverberant Sound Fields*. J. Acoust. Soc. Am. 27, pp. 247-258 (1955).

A-2 Cremer, L., *Theorie der Schalldämmung dünner Wände bei shrägem Einfall*. Akust. Z 7: 81-103 (1942); English summary in Benchmark Papers in Acoustics, Vol. 10, edited by T.D. Northwood. Dowden, Hutchinson and Ross (1977), p. 367-388.

A-3 Azou, S., *Étude des caractéristiques acoustiques de matériaux et d'équipements*. Cahier 1397, Centre Scientifique et Technique du Bâtiment, Paris (Oct. 1976).

A-4 Olson, N., *Statistical Study of Traffic Noise*. Report APS-476, Division of Physics, National Research Council of Canada (1970). (Publication No. NRC 11270).

A-5 Lotz, R. *Railroad and Rail Transit Noise Sources*. Journal of Sound and Vibration, 51, pp. 319-336 (April 1977).