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1. INTRODUCTION

In evaluating the criteria for acceptable indoor noise levels incorporated in New Housing and Airport Noise[1] and Road and Rail Noise: Effects on Housing,[2] it is instructive to compare the two documents with each other and with regulations proposed in other countries. Naturally, such comparisons are only approximate because of the variety of noise descriptors used in the various recommendations. A reasonably reliable qualitative comparison is possible, however, through the use of established "rule of thumb" conversions for the various noise scales.

To provide a framework for comparison, proposals from the U.S.A. and from Europe will be presented. The criteria in the CMHC documents will then be discussed in relation to these studies.

2. PROPOSALS BY U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA)

In 1974 the EPA issued a publication entitled Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety.[3] This document brings together the results of many previous studies and makes recommendations based on a synthesis of the best available information. A wide variety of noise descriptors are discussed and evaluated for suitability as single-figure ratings of environmental noise.

The A-weighted Equivalent Sound Level (L_{eq}) was selected as the basic descriptor of noise exposure. For matters related to annoyance or interference with people's activities the A-weighted Equivalent Day-Night Sound Level (L_{dn}) was used. The quantity L_{dn} is derived from L_{eq} for both daytime (07:00 to 22:00 h) and nighttime (22:00 to 07:00 h) periods, with a 10 dB correction added to the nighttime level to allow for the increased sensitivity to noise during the period when most people are sleeping.

The EPA report summarizes the results of many of the major sociological surveys of people's adverse response to environmental noise. The noise data from these surveys were translated from the original descriptors - L_{eq} (24 h), Noise Exposure Forecast (NEF), and Community Noise Rating (CNR) - using the approximate rules of thumb:

$$L_{dn} \simeq NEF + 35 \simeq CNR - 35$$

The major surveys exhibited strong similarities whose fundamental trends are presented in Figure 1.[4]

The curve in Figure 1 is not an exact prediction of community response to noise. Numerous factors may influence that response; for example, the noise from a drop forge or the shrill squeals from retarders in railway yards may be significantly more annoying than would be assumed from their L_{dn} and the curve in Figure 1 because they are clearly identifiable and therefore tend to catch one's attention.

On the basis of such social survey data, careful evaluation of speech interference, and consideration of various prior recommendations for acceptable sound levels, the EPA has made specific recommendations regarding acceptable levels of environmental noise. Their summary of noise interference with human activities and the resulting health and welfare effects may be summed up as follows:

1.) The most useful criterion of the effects of noise on human health and welfare and that which correlates best with human attitudes toward noise is the degree to which noise interferes with speech communication. Other criteria are less readily quantified. Generally, they depend on factors such as the distracting or startling effects of specific sounds in relation to locally-produced sounds. Nevertheless, such effects are important, for example in connection with sleep interference.

2.) The threshold level at which noise begins to interfere with normal conversational speech is about 45 dBA. This is a suitable criterion for noise intrusion in inhabited indoor rooms. A corresponding outdoor level, assuming a 15-dB reduction between outdoors and indoors, would be 60 dBA. To take account of less readily identifiable effects, a margin of 5 dB is applied, giving noise criteria, indoors and outdoors, of L_{dn} = 40 dBA and 55 dBA, respectively.

3.) With an outdoor level corresponding to L_{dn} = 55 dBA, normal-voice conversation is possible over distances up to 3.5 m. At this level there would typically be no organized community reaction to noise, although 1 per cent of the population could be expected to complain and 17 per cent would indicate "highly annoyed" in a social survey. Noise in these circumstances is usually less important than other factors governing the attitude towards the area.

4.) Levels 5 dB higher begin to interfere with indoor speech communication and result in substantially increased adverse community

reaction. Conversely, levels 5 dB lower reduce the noise intruding indoors to the point where locally-produced noises would typically dominate. Noise would cease to be a significant environmental factor in the community, although there would still be a few individuals who would complain about it.

3. PROPOSALS TO THE COMMISSION OF EUROPEAN COMMUNITIES

In September 1976 a report, Classes of Acoustical Comfort in Housing,[5] was submitted to the Commission of the European Communities. It summarizes the laws, standards, and recommendations (on the subject of building acoustics) of the member nations of the European Community. A set of standardized "classes of acoustical comfort" for description of housing in all the member nations was proposed. Acoustical comfort is defined, in this report, as "the ability of buildings to protect the users against noise and to provide an acoustical environment suitable to human activity."

For insulation against outdoor noise the recommended limits are expressed in terms of the A-weighted Equivalent Sound Level (L_{eq}) for daytime and nighttime periods, with the proviso that the sound level of individual noise peaks should not exceed L_{eq} + 10 dB. The proposed Class 3 (recommended legal minimum standards) for insulation against outdoor noise follow:

	Maximum Indoor L_{eq}	Maximum Indoor Peak Level
Daytime	35 to 40 dBA	45 to 50 dBA
Nighttime	30 to 35 dBA	40 to 45 dBA

Very few member nations of the European Community have as yet established legal rules in this area. The limits indicated above, however, are essentially consistent with the recommendation, VDI 2719, of the Federal Republic of Germany, and with the requirements that qualify a building for the "Label Acoustique," certification of "improved acoustical comfort" in France.

4. CMHC PUBLICATION ROAD AND RAIL NOISE: EFFECTS ON HOUSING[2]

(a) Proposed Noise Level Limits

The noise level limits for road and rail noise proposed by CMHC have been expressed, for reasons to be discussed in 4 (c) below, in terms of the A-weighted Equivalent Sound Level for a full day (L_{eq} (24 h)). The proposed limits are as follow:

Outdoor amenity space	L_{eq} (24 h) = 55 dBA
Indoor (i) living rooms etc.	L_{eq} (24 h) = 40 dBA
(ii) bedrooms	L_{eq} (24 h) = 35 dBA

(b) Comparison with Other Proposals

In order to compare these proposals with the recommendations reported in Sections 2 and 3, it is necessary to take into account the relation between L_{dn}, L_{eq} (24 h), and the A-weighted Daytime Level (L_d) and Nighttime Level (L_n).

Results of numerous studies of these relations are given in Figure 2, and the approximate curve has been converted to show directly (Figure 3) the relations for L_{eq}, L_{dn}, and NEF. It may be seen from both figures that when L_{eq} (24 h) is greater than 60 dBA the following relations hold:

$$L_{dn} \simeq L_{eq} \text{ (24 h)} + 4 \text{ dB}$$

$$L_{d} \simeq L_{eq} \text{ (24 h)} + 1 \text{ dB}$$

$$L_{n} \simeq L_{eq} \text{ (24 h)} - 3 \text{ dB}$$

These expressions should be approximately valid for the noise from road traffic over most of the noise range designated normally unacceptable. With them, the CMHC requirements on road and rail noise may be recast in the form of Table I.

It will be seen that the requirements for indoor spaces are very similar to the proposed minimum standards for the European Community, and that they also correspond closely with the levels the EPA would expect for typical housing conforming to an outdoor L_{dn} limit of 55 dBA. Although the outdoor noise limit is slightly above the L_{dn} limit recommended by the Environmental Protection Agency, the daytime level ($L_d \simeq 56$ dBA) provides essentially the same speech communication situation as that detailed in Section 2.

(c) Justification for Use of L_{eq} (24 h)

The primary reason for using L_{eq} (24 h) rather than L_{dn} or the combination of L_d and L_n as the noise descriptor for the guideline on road and rail noise is that it simplifies the calculations. A single calculation only (based on total daily traffic flow) is needed rather than the two calculations required if daytime and nighttime periods are separated.

The use of L_{dn} is generally justified on the basis of greater sensitivity to noise at night when people are sleeping or trying to sleep.

The nighttime penalty used in deriving L_{dn} is arbitrary, however, both as to timing and to magnitude; for example, a train passing at 22:02 is considered to be noisier by exactly 10 dB than the same train passing 5 min earlier. It seems philosophically undesirable to contaminate basic physical data by mixing in arbitrary assumptions of this sort. Nevertheless, such mixtures of fact and opinion are common among community noise indices, including, unfortunately, the NEF.

The CMHC regulations are able to adopt a more direct approach to the problem of protecting sleepers by specifically requiring better noise insulation for rooms in which sleep is most important. In this way one can provide not just for those with typical sleeping habits, but also for those (e.g. shift workers, small children, the sick) who sleep during the daytime.

5. CMHC PUBLICATION, NEW HOUSING AND AIRPORT NOISE

The indoor noise criteria in New Housing and Airport Noise[1] are similar to those in the guideline on road and railway noise in that they require lower noise levels in bedrooms. Applying the approximate conversion $L_{dn} \simeq NEF + 35$, the criteria for maximum acceptable indoor noise levels are:

Bedrooms - L_{dn} = 32 dBA
Other rooms - L_{dn} = 37 dBA

Relating these values to the corresponding values of L_d and L_n would require knowledge of how aircraft operations are distributed between daytime and nighttime periods. In general, there are fewer flights per hour during the night than during the day, but this obviously varies considerably from one airport to another.

As a rough estimate, one may assume the outdoor daytime equivalent level to be 6 dB higher than the nighttime level (the points for aircraft noise in Figure 2, for example, show differences of 2, 5, 7 and 9 dB). With the assumed 6 dB difference the criteria could be expressed as in Table II. The daytime and nighttime levels might shift up or down by one or two decibels, depending on how air traffic is distributed between day and night periods, but these values are reasonably representative.

It is evident, from a comparison of Tables I and II, that indoor noise limits for aircraft noise are substantially lower than the proposed limits for intrusion of noise from roads and railways. This may be justified, at least in part, by the difference in character of aircraft noise (discrete noise events) and traffic noise (fluctuating, but comparatively steady). Although traffic noise is reasonably well described by an "average" sound level such as L_{eq}, this is less true for the discrete event character of aircraft noise, and perhaps greater allowance should be made for its tendency to command the attention of

listeners - a property that is particularly important when considering interference with sleep. A second justification for establishing lower limits for indoor levels of aircraft noise is to compensate for the high noise levels that must be tolerated outdoors.

6. SUMMARY

Criteria for maximum acceptable indoor noise levels proposed in Road and Rail Noise: Effects of Housing[2] appear to be consistent with recommendations in several other countries and should ensure a satisfactory degree of acoustical comfort.

By contrast, the indoor limits in New Housing and Airport Noise[1] are considerably more stringent. Although arguments can be made to justify slightly lower indoor noise limits for aircraft noise, the current difference appears to be greater than can be justified by social survey data or by comparison with proposed limits in other countries. With this in mind, it is proposed that the noise limits for bedrooms and other rooms be raised from existing values, NEF = -3 and +2, respectively, to NEF = 0 and +5, respectively. This would reduce the difference between the airport noise guideline and that for road noise, but still provide some allowance for the special character of the airport noise problem.

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TABLE I EXPRESSION OF CMHC ROAD AND RAIL NOISE CRITERIA IN TERMS OF VARIOUS NOISE INDICES

Use	Criterion L_{eq} (24 h)	Approx L_{dn}	Daytime Level	Nighttime Level
Outdoor amenity space	55	59	56	
Living rooms, etc.	40	44	41	
Bedrooms	35	39		32

TABLE II EXPRESSION OF CMHC AIRPORT NOISE CRITERIA IN TERMS OF VARIOUS NOISE INDICES

Use	Guideline Criteria (NEF)	Approx L_{dn} (dBA)	Approx L_{eq} (24 h) (dBA)	Approx Daytime Level (dBA)	Approx Night-time Level (dBA)
Bedrooms	-3	32	29		24
Other rooms	2	37	34	35	
Outside	28 to 35	63 to 70	60 to 67	61 to 68	55 to 62

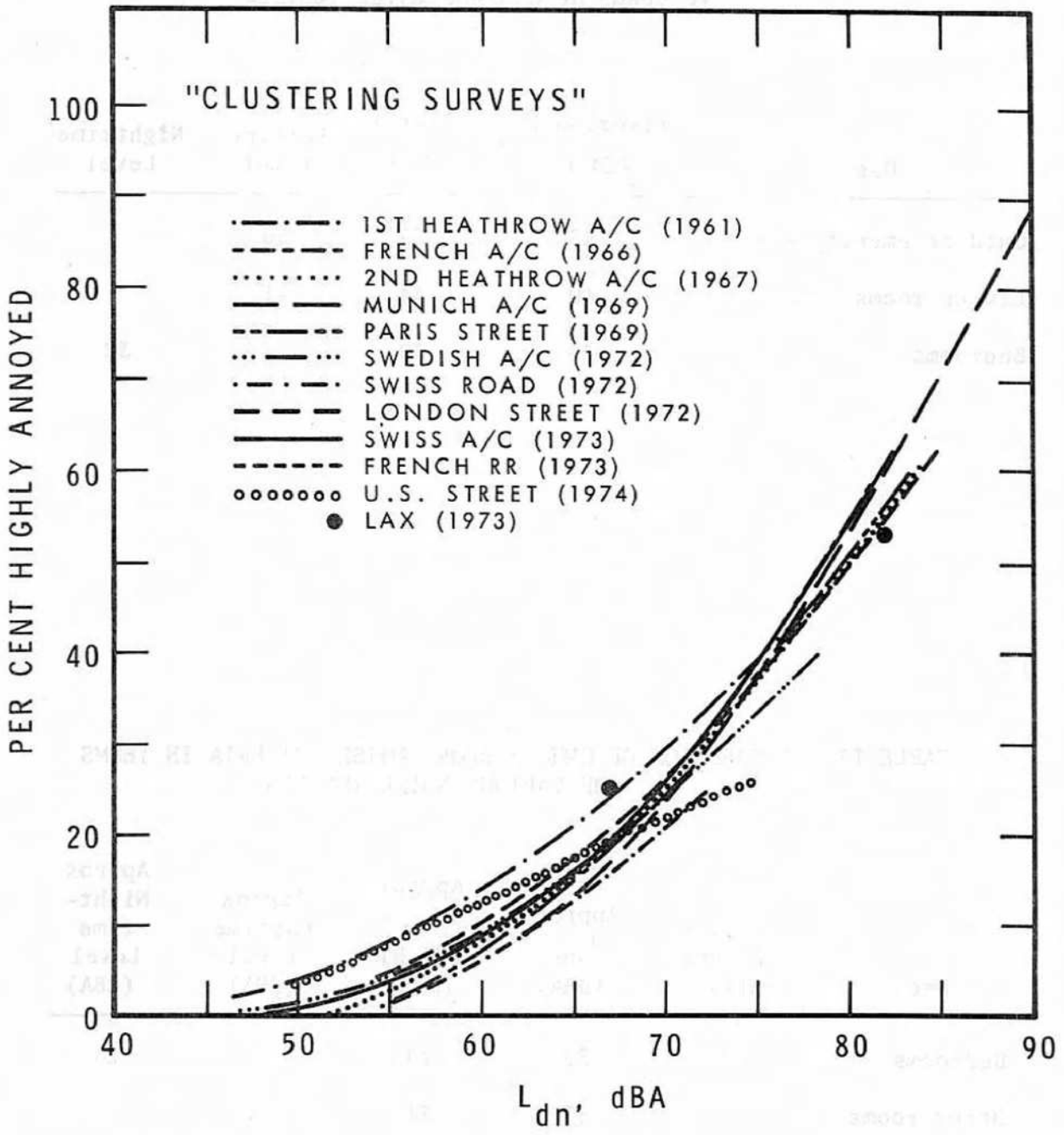

FIGURE 1

SUMMARY OF ANNOYANCE DATA FROM 12 SURVEYS (COURTESY OF T.J. SCHULTZ, REPRODUCED FROM REF. 4)