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THE IMPLICATIONS OF MEASURED AND ESTIMATED DOMESTIC SOURCE LEVELS FOR INSULATION REQUIREMENTS

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1 INTRODUCTION

A recent survey by the Department of the Environment's Building Research Establishment (BRE) [1] found neighbourhood noise to be the most widespread source of noise disturbance after road traffic. The survey consisted of an analysis of data sheets, completed by Environmental Health Officers (EHOs), which dealt with complaints about noise sources. Among the internal noises reported to the EHOs were radio/television/hi-fi, people's voices, doors banging and domestic appliances. The survey also revealed that complaints to EHOs about the noise from domestic premises had increased by 791% between 1975 and 1985. With the increasing incidence of complaint about the noise from domestic premises, the adequacy of sound insulation for party walls and floors between domestic premises is called into question. The research discussed in this paper aims to identify the adequacy of sound insulation, for several types of internal domestic noise sources, by calculating and estimating levels of noise transmitted to an adjoining dwelling or room through various models of wall insulation.

2 MODEL INSULATIONS

To calculate transmitted noise levels, one has to assume particular values of sound insulation. Three sound insulation curves have been chosen: *good insulation* - based on the BS5821 reference values for airborne sound [2] (henceforth referred to as model 1); *poor insulation* - derived from the curve for a cavity masonry wall with poor performance, extracted from the measurements of the performance of plastered walls of lightweight aggregate blockwork [3] - the one-third octave band levels chosen correspond to the mean minus 1.64 standard deviations at each frequency. (model 2); and *partition wall insulation* - based on octave values of airborne sound reduction for a stud partition, 50 x 100 mm studs, with 12 mm insulating board on both sides (to be referred to as model 3)[4]. Table 1 presents the values used for each insulation curve.

These curves will be used to calculate transmitted noise levels of several noise sources and to determine a hypothetical source level from a recorded extreme case of amplified music disturbance.

3 LEVELS OF INTERNAL NOISE SOURCES

3.1 DOMESTIC APPLIANCES

Domestic appliance noise constituted only 1% of all noise sources which caused complaint in the

Table 1: Reference values for the insulation curves

Frequency Hz	Good insulation dB	Poor insulation dB	Partition insulation dB
100	33	25	
125	36	28	16
160	39	30	
200	42	32	
250	45	35	22
315	48	38	
400	51	40	
500	52	43	28
630	53	47	
800	54	49	
1000	55	51	38
1250	56	53	
1600	56	53	
2000	56	54	59
2500	56	56	
3150	56	58	

BRE survey. Nevertheless, in a detailed study of domestic appliance noise, appliances producing noise levels in excess of 75 dBA (1.5m from the appliance) have been identified [5].

The measured noise from -: a Braun Supercompact 1500 hair dryer (speed 3); a Hoover 119 vacuum cleaner; a Kenwood Chef food mixer (speed 4); a Moulinex 241.2 liquidiser; and a Braun MC-1 food processor - has been analysed to determine A-weighted sound pressure levels and one-third octave band spectra. The measurements were made in-situ (in the living room and kitchen of a cottage on the Open University campus). Using a half inch microphone (Bruel and Kjaer Type 4165), connected via a Bruel and Kjaer microphone preamplifier Type 2639 to a Nagra IV-SJ tape recorder, calibrated tape recordings of the noise were made, which were later analysed to determine one-third octave band spectra, (using an Ono Sokki 910 FFT analyser). Measurements of $L_{Aeq,30seconds}$ were made using a noise level analyser (Bruel and Kjaer Type 4427). A-weighted noise levels varied between 72 dB for the hair dryer to 82 dB for the vacuum cleaner and food processor. Examination of the spectra showed marked differences between the appliances. The hair dryer emitted most acoustic energy at high frequencies. The highest levels were found between 1.6 and 5 kHz. The acoustic energy of the vacuum cleaner was spread across the whole frequency range of interest (100 Hz - 3.15 KHz) with a tonal component present in the 250 Hz band. The acoustic energy of the kitchen appliances was centered around the high frequencies. Tonal components were evident in the 160 Hz, 400 Hz and 1.6 kHz bands for the food mixer; 250 Hz, 500 Hz and 2 kHz bands for the liquidiser; and 4 kHz band for the food processor.

3.2 TELEVISION LISTENING LEVELS.

This data has been abstracted from data collected by Open University students as part of their studies of T234 Environmental Control and Public Health. Data collected by the students has been shown to be a reliable and accurate source of information [6]. Students are provided with an integrating sound level meter which meets the requirements of BS5969 Type 3 [7]. They are asked to measure

$L_{Aeq,10minutes}$ of television news broadcast, excluding commercial breaks. The mean level recorded by 297 students was 56 dBA, with a standard deviation of 7 dBA. The range of television listening levels was from 35 to 76 dBA. Similar means and ranges have been obtained each year during the period 1985 - 1988.

A typical spectral analysis of this source was determined by recording 10 minutes of a news broadcast. The equipment used has been detailed in section 3.1. The recording was replayed into an Ono Sokki 910 FFT analyser and one-third octave band spectrum was obtained. The spectrum shows little acoustic energy below 160 Hz and a fall off after 2.5 kHz. Between these frequencies the spectrum is quite flat.

3.3 AMPLIFIED MUSIC

Amplified music constituted 34 % of all noise sources which were reported to EHOs. Data relating to amplified music listening levels has been abstracted from other data collected by Open University students. They are asked to measure three $L_{Aeq,2minutes}$ samples of amplified music from records, radio, cassette or compact disc. The three measurements should represent the loudest, quietest and a typical level at which they listen to amplified music in their dwelling. The mean listening levels for 85 students were: loudest level - 74.4dBA (s.d. 7.8 dBA), typical level - 63.5 dBA (s.d. 6.3 dBA) and quietest level - 53.5 dBA (s.d. 7.1 dBA) (see Figure 1).

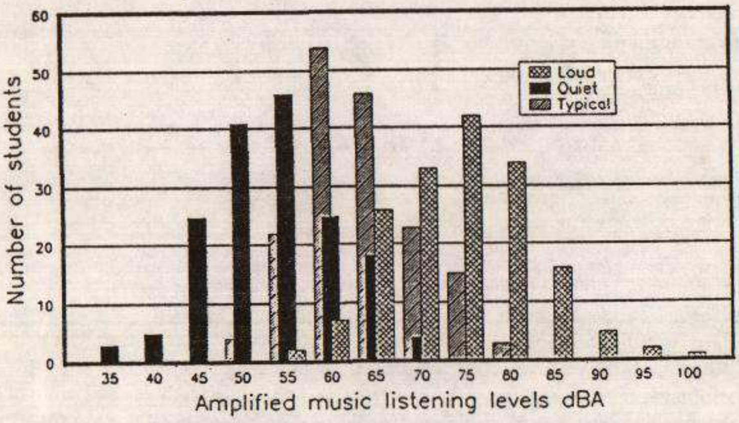

Figure 1: Range of amplified music listening levels.

Spectral information about amplified music has been abstracted from two sources. Recordings of different types of amplified music have been made in the living room of a semi-detached dwelling (using the equipment detailed in section 3.1), at normal listening levels. The microphone was positioned at the ear level of a listener, seated in a chair. One-third octave band spectra were obtained by replaying the calibrated recordings into an FFT analyser (Ono Sokki 910). Measurements of L_{Aeq} were made for each track of music using a CEL 393 precision computing sound level meter. Most of the acoustic energy was centered between 315 Hz - 1.25 kHz for a selected piece of classical music. However, selected tracks of popular music had a good deal of acoustic energy centered between 80 - 250 Hz.

One-third octave spectra have also been abstracted from recordings made in dwellings where the occupants are disturbed by the amplified music from an adjoining dwelling. The calibrated recordings are made by the Environmental Protection Unit for the City of Birmingham Environmental Health Department, and by the first author, using the equipment previously described (section 3.1). The microphone is mounted on a tripod at a height of 1.2m and situated at least 1m from any reflecting surface. The recordings are replayed into an Ono Sokki 910 FFT analyser to obtain one-third octave band spectra. Most of the acoustic energy is centered around 80 - 250 Hz bands, but with significant amounts up to 3.15 kHz band. Transmitted levels range from 28 to 50 dBA, with a mean level of 41.3 dBA (standard deviation 6.0 dBA). Sixteen of the seventeen cases of amplified music disturbance had noise levels in excess of 30 dBA. Eleven cases examined had levels in excess of 40 dBA, and five had levels in excess of 45 dBA. Assuming insulation model 2, these transmitted levels imply listening levels of 72 to 92dBA. These levels are representative of the typical and loud listening levels of the Open University students, and thus can not be described as unduly extreme.

Two listening levels and representative spectra have been extracted from these data: a typical spectrum corresponding to an overall level of 67dBA, based on a recording of popular music; and a loud spectrum with an overall level of 92dBA, corresponding to a recorded transmitted level of 49 dBA and an assumed insulation model 2. The assumption has been made that amplified music disturbances are reported to EHOs when music is being played loudly, through a party wall offering poor insulation. The two levels chosen for this analysis are representative of typical and loud levels recorded by Open University students. (See Figure 1).

Amplified classical music as a source will not be discussed further in this paper as typically if does not give rise to complaint.

4 INTERNAL AMBIENT NOISE LEVELS

To assess whether any of the internal noise sources investigated will be audible in an adjoining dwelling, a comparison has to be made with the internal ambient noise level.

4.1 MEASURED AMBIENT NOISE LEVELS

The Open University students have also measured levels of ambient noise inside their homes. These measurements were made when the room was free from any sound sources. One limitation of the data is that the sound level meters used by students could only measure noise levels down to 30 dBA. 24% of students had ambient noise at or below this level. The range of internal ambient noise levels can be seen in Figure 2. 50% of students recorded a level of 34 dBA or less.

4.2 INTERNAL AMBIENT NOISE SPECTRA

The threshold at which sound becomes audible will vary from individual to individual. According to Utley et al [8] when the spectrum of the received sound is similar to that of the ambient noise, the sound will probably be inaudible if its overall level is similar to or below the ambient level. However, if the transmitted sound spectrum is markedly different from that of the ambient noise, the sound may be audible even when the overall level is as much as 10 dBA below ambient. Measurements of the internal ambient noise have been made in the living room of two dwellings: a timber-framed,

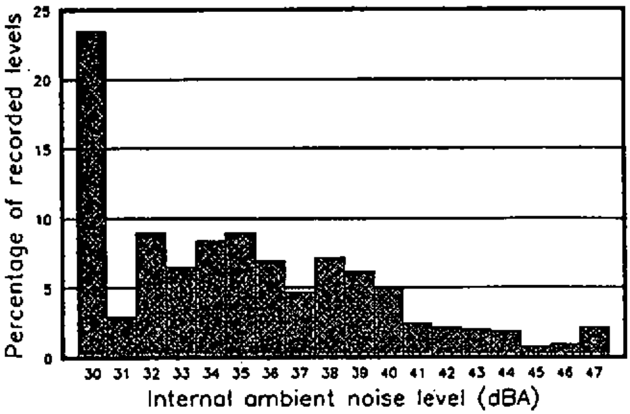

Figure 2: Range of internal ambient noise levels recorded by students (n=238).

semi-detached dwelling; and a breeze-block detached dwelling, in the absence of any sound source, using a CEL 393 precision computing sound level meter. $L_{Aeq,5minutes}$ was found to be 27.4 dBA in the semi-detached dwelling and 25.7 dB in the detached dwelling. These values are consistent with 24% of the values presented in Figure 2. Calibrated tape recordings of the ambient noise were also made, using the equipment previously detailed (see section 3.1). The microphone was positioned on a tripod, 1.2m high and at least 1m away from the nearest reflecting surface. One-third octave band spectra were obtained by replaying the recordings through an Ono Sokki 910 FFT analyser. By superimposing the transmitted noise spectra onto the ambient noise spectra, one can identify the transmitted noises for which ambient noise is exceeded. Since the resulting spectra had similar shapes, that corresponding to the higher overall level has been used in the rest of this paper.

4.3 INTERNAL AMBIENT NOISE SPECTRA DEDUCED FROM NOISE RATING CURVES

It has been recommended that the noise levels inside bedrooms and living rooms should not exceed the NR 25 and 30 curves respectively. It is possible to compare the octave band transmitted spectra of the internal noises assuming the three model insulations with these curves to identify any sources that result in NR values being exceeded.

5 TRANSMITTED NOISE ASSESSMENT

5.1 CALCULATED TRANSMITTED NOISE LEVELS

Table 2 presents the calculated A-weighted transmitted noise levels, assuming three models of insulation.

Transmitted levels varied from 4 to 42 dBA with insulation model 1, 13 to 42 with model 2 and 20 to 56 with model 3.

Table 2: A-weighted transmitted noise levels

NOISE SOURCE	Source level L_{Aeq}	Received noise level Good insulation L_{Aeq}	Poor insulation L_{Aeq}	Partition insulation L_{Aeq}
TV news	56	04	13	20
APPLIANCES:				
Hair dryer	73	17	22	27
Vacuum cleaner	82	32	42	50
Food mixer	77	24	32	39
Liquidiser	78	32	41	50
Food processor	82	23	31	39
AMPLIFIED MUSIC:				
Typical level	67	16	26	29
Estimated loud level	92	42	49	56

5.2 COMPARISON WITH MEASURED BACKGROUND SPECTRA

Table 3 presents the one-third octave band frequencies for which the transmitted noise levels exceed the internal ambient noise level by at least 3 dB.

Table 3: One-third octave band frequencies for which transmitted noise exceeded internal ambient noise

NOISE SOURCE	Good insulation One-third octave frequency band - Hz	Poor insulation One-third octave frequency band - Hz	Partition insulation Octave frequency band - Hz
TV news	-	-	125-500
APPLIANCES:			
Hair dryer	-	100, 160	125-1000
Vacuum cleaner	200-800, 1250-2500	100, 160-2500	125-1000
Food mixer	160, 400, 1600-2000	125-800, 1600-2000	125-1000
Liquidiser	250, 500-630, 2000-3150	160-3150	125-1000
Food processor	250-630, 2000-3150	125, 800, 2000-3150	125-1000
AMPLIFIED MUSIC:			
Typical level	-	100-200	125-500
Estimated loud level	100-3150	100-3150	125-2000

Figure 3 presents one-third octave band spectra of the internal ambient noise and transmitted noise of the estimated loud amplified music, assuming the three insulation models. The transmitted noise levels of amplified music exceeded internal ambient noise in several bands which depend on the insulation characteristics. The transmitted noise levels of the appliances investigated exceeded internal ambient noise over the whole frequency range of interest. Television noise only exceeded internal ambient noise when assuming model 3.

In the absence of other noise in the receiver dwelling, all the transmitted noise spectra, assuming insulation models 2 or 3, would exceed a typical ambient spectrum. Moreover, it should be noted that the one-third octave band spectra of the transmitted noises are rather different from the internal ambient spectra. Consideration should also be given to a higher overall ambient level. 95% of

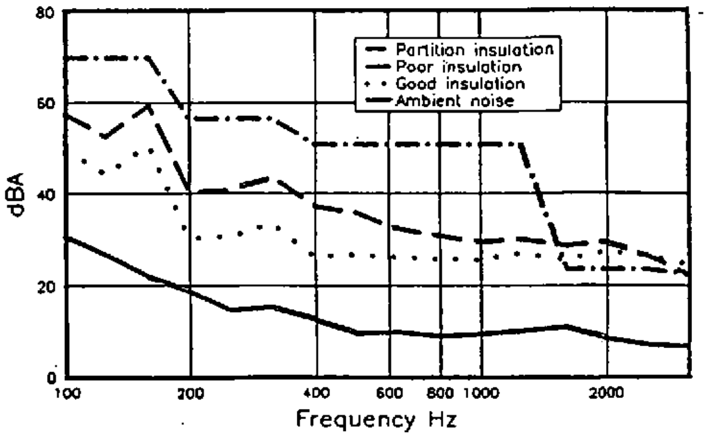

Figure 3: One-third octave band spectra of transmitted loud amplified music compared with a typical internal ambient noise.

Open University student data fell below 42 dBA. Assuming the same spectrum shape as in Figure 3 then the domestic appliances (except the hair dryer) and loud amplified music will still give rise to transmitted levels that significantly exceed the ambient spectrum and in low frequency bands.

5.3 COMPARISON WITH NOISE RATING CURVES

Octave-band spectra of the transmitted noises were compared with NR 25 and 30 curves. Table 4 presents calculated NR values for the transmitted noises.

Table 4: Noise Rating values of internal noise sources in an adjoining dwelling.

NOISE SOURCE	Good insulation	Poor insulation	Partition insulation
TV news	0	1	15
APPLIANCES:			
Hair dryer	11	16	21
Vacuum cleaner	26*	34*	46*
Food mixer	18	23	35*
Liquidiser	23	33*	47*
Food processor	14	22	35*
AMPLIFIED MUSIC:			
Typical level	7	16	25*
Estimated loud level	31*	39*	55*

The NR values for the transmitted noise of the vacuum cleaner and amplified music (extreme listening level) exceed the recommended NR values for living rooms and bedrooms, for all insulation models. With the exception of transmitted noise from television news and the hair dryer, all noise sources exceed recommended NR values when transmitted through model 3.

Discussion of Results and Conclusions

The transmitted noise levels of the television news broadcast did not constitute a noise problem. Through all the models of insulation, the transmitted level was below the internal ambient noise level. Even though the transmitted level through model 3 was calculated to be within 10 dB of internal ambient noise, the one-third octave spectra was not markedly different from that of background noise. Indeed, the transmitted noise exceeded the internal ambient noise only with model 3 insulation and at low frequencies. Calculated NR values were small. However, it must be emphasized that these calculations are based on a typical listening level, and extremely high listening levels may cause disturbance even with model 2 insulation.

Unlike televisions relaying news, the domestic appliances investigated had relatively high source levels. With the exception of the hair dryer, their transmitted noise levels were high when compared to the internal ambient level for all models of insulation. The transmitted levels exceeded a typical internal ambient level over the whole frequency range. All the transmitted noise levels exceeded recommended NR values through the partition wall. However, only the transmitted level of the vacuum cleaner exceeded recommended NR values with model 1 and 2 insulations.

Despite the relatively high transmitted noise levels, when one considers the amount of time the selected appliances are in use, they can not generally be considered to constitute a noise nuisance. This conclusion is consistent with the results of the BRE survey, which revealed that they are not generally reported as a source of neighbourhood noise disturbance.

Amplified music, however, has been found to constitute a noise problem. Transmitted noise levels for both the typical and loud listening levels were sufficiently great for them to be audible above internal ambient noise level with insulation models 2 and 3. Moreover, their frequency spectra are markedly different from those of internal ambient noises, especially at low frequencies. This low frequency effect is noticeable in all recordings.

Use of NR values for the transmitted noise would suggest that amplified music is only a source of disturbance when the listening level is high. However, this conclusion is not consistent with Tables 2 and 3, or with the results of the BRE survey. NR curves discriminated against low frequencies, and this discrimination may be inappropriate for the assessment of disturbance by amplified music.

The results of the analysis confirm the need for careful internal planning. Calculations of transmitted noise levels through a model partition wall produced significant levels from all sources considered (with the exception of television news). The calculations in this paper also suggest the need for good insulation at low frequencies to reduce amplified music disturbances.

References

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