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ABSTRACT

Three groups of traditional houses were insulated against aircraft noise by double glazing and installing sound attenuating ventilator units. For upper floor rooms of two story houses, overall insulations of 35-40 dB were obtainable, providing transmission through the roofs and down flues were also reduced. The noise levels caused by ventilator fans operating at maximum output varied from 45 to 33 dBA, and the noisier units should be quieted to not more than 35 dBA. The numerical values of sound insulation in dB averaged over the range 100 to 3150 Hz, and the level reductions, outside to inside, in dBA, agreed closely. The helicopter noise source spectrum used for testing typified many broad band noise spectra, so this close agreement may therefore find application in practical noise control. (TC)

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Insulation against aircraft noise

W E Scholes and P H Parkin

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THE INSULATION OF HOUSES AGAINST NOISE FROM AIRCRAFT IN FLIGHT

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Three groups of traditional houses were insulated against aircraft noise by (a) double glazing (with a 25 cm gap between panes), and (b) installing sound attenuating ventilator units. Provided that large numbers of houses were thus insulated, the cost for 3 rooms per house was estimated at £200.

For upper floor rooms of two storey houses, overall insulations of 35-40 dB were obtainable, providing transmission through the roofs and down flues were also reduced.

The noise levels caused by ventilator fans operating at maximum output varied from 45 to 33 dBA, and the noisier units should be quietened to not more than 35 dBA. The numerical values of sound insulation in dB averaged over the range 100 to 3150 Hz, and the level reductions, outside to inside, in dBA, agreed closely. The helicopter noise source spectrum used for testing typified many broad band noise spectra, so this close agreement may therefore find application in practical noise control.

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THE INSULATION OF HOUSES AGAINST NOISE FROM AIRCRAFT IN FLIGHT

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SUMMARY

This paper summarises the results obtained from a pilot scheme in which three groups of existing traditional houses were insulated against aircraft noise. The insulation measures were: (a) the addition of inner windows spaced about 25 cm from the existing windows; and (b) the installation of a sound-attenuating ventilator unit to each insulated room. The cost of insulating three rooms per house by these measures was estimated at two hundred pounds sterling per house, provided that large numbers of houses were insulated.

It was found that overall insulations of 35 to 40 dB could be obtained for rooms on the upper floors of two-storey houses. To reach these levels of insulation, it was necessary in some cases to reduce transmission through the roofs, for example by pugging the receiving room ceilings, and to reduce transmission down flues by blocking the fireplaces.

The noise levels in the receiving rooms caused by the ventilator fans operating at maximum output varied from 45 to 33 dBA. It is thought that the noisier units should be quietened to give a level of not more than 35 dBA. There was close agreement between the numerical values of sound insulation in dB, averaged over the range 100 to 3150 Hz and the level reductions, outside to inside, in dBA. The spectrum of the helicopter noise source used for the tests was typical of many broad band noise spectra and the measurements covered a wide range of insulation curves. It is therefore suggested that this close agreement may find application in practical noise control.

INTRODUCTION

When in 1962 the Wilson Committee was considering the problem of noise, it asked the Building Research Station to look at the feasibility of insulating houses and flats against aircraft noise, at reasonable cost. Experiments were made on laboratory buildings at the Building Research Station using a low-flying jet aircraft as a source, and the proposals seemed reasonable: in a room with 11-inch-cavity structural walls, no external doors, no flues, and on the ground floor, the installation of good double windows and a sound-attenuating ventilator unit gave an insulation against aircraft noise of 40 to 45 dB (average: 100–3150 Hz).[1]

On the basis of these results the Wilson Committee proposed that the Government should pay grants to householders near Heathrow Airport, London, to help them to insulate their houses in this way, the full cost (up to two hundred pounds sterling) to be paid in the areas most affected by noise, and a diminishing proportion of the full cost further away as the noise got less.

Following this recommendation, the Building Research Station and the (then) Ministry of Aviation, treated fifteen houses near Heathrow Airport according to the proposals, to see if there were any practical problems. The sound insulation of the treated houses was measured, and it is these measurements which are summarised here; the full details are available on request.

For administrative convenience the scheme proposed by the Wilson Committee was modified by the Government, which in 1966 authorised the British Airports Authority to pay 50 per cent of the cost (*i.e.* a maximum grant of one hundred pounds sterling) to householders in an area defined mainly by the local authority wards on or within the 1970 estimated 55 N.N.I. contour. The way in which the Wilson recommendation was implemented was given in a report to the International Conference on the Reduction of Noise and Disturbance caused by Civil Aircraft, and is due to be published as part of the proceedings of the conference.[2] The conditions for the grant were specified in a Statutory Instrument.[3]

DESCRIPTION OF HOUSES

All the houses in the p... experiment had solid external walls 25 to 30 cm thick. Ten of the houses were about thirty-five years old, and were of brick. The other five houses were about eighteen years old and were constructed of no-fines concrete. Thus the external walls were typical of traditional English housing, and similar to those in the laboratory at the Building Research Station where the sound transmitted through the walls was small compared with that through the windows and ventilator. The houses were all two-storey, semi-detached and had pitched tiled roofs. The sound insulating measures were confined to the upper storeys to assess the effects of transmission through the roofs. Some of the treated rooms had flues.

DESCRIPTION OF INSULATING MEASURES

(*a*) *Windows*

The existing windows were all of 32 oz. (4 mm) glass and some of the houses had wooden frames and others metal frames. The modifications were: (i) the existing opening elements of the windows were sealed by the use of foamed plastic draught excluding strip; (ii) the inner leaves of the double windows were 32 oz (4 mm) glass fixed in plastic framing on a wooden surround, airtight when closed, but both inner and outer leaves were openable for cleaning and natural ventilation, if required. The spaces between the inner and outer leaves varied between 18 and 30 cm, depending upon the type of house and the details of the individual window frames. The reveals were lined with 1-cm soft fibreboard.

(*b*) *Sound-attenuating ventilator*

The ventilators were of proprietary design and one was fitted to each insulated room. Each was sealed against a hole cut in an external wall through which air was drawn in by a built-in, variable-speed electric fan. Before discharge into the room the air passed along a folded, sound-attenuating duct and through a washable air filter. Laboratory measurements, between reverberant rooms, had shown an example of this type of ventilator to have a sound insulation of 44 dB (corrected to 0·5 seconds). The maximum ventilation rates provided in the test rooms with doors closed in the houses near Heathrow varied between 2·7 and 7·7 air changes per hour, depending on the room volumes and door seals.

METHOD OF MEASUREMENT

A low-flying helicopter was used as the noise source so that the roofs as well as the windows would be fully exposed to noise. The helicopter flight path was parallel to the window under test, about 90 metres horizontally from the window and about 90 metres high. Thus the elevation of the helicopter, at its closest position to the window, was about 45 degrees and measurements were made throughout each pass of the helicopter.

The outside noise levels were measured 1 metre from the external facades of the buildings at first-floor window height and the internal levels close to the centres of the furnished rooms, 1·2 metres above the floors. The insulations were defined as the differences in levels measured outside and inside at these positions. Some measurements were made of the insulations with the inner leaves of the double windows removed and others of opened single windows.

The reverberation times of all the receiving rooms were measured and also the internal noise levels due to the ventilator fans operating at maximum ventilation rate. In all, measurements were made in fourteen of the fifteen treated houses, at least two rooms per house.

RESULTS

(a) Sound insulation

The external and internal noise levels from at least 4 passes of the helicopter per room were analysed into octave bands centred on 125,250–4000 Hz. The average insulation values are not the simple averages of the values in these six octave bands but are weighted averages to cover the normal range of 100 to 3150 Hz.

(i) Double windows

There were wide variations between the sound insulations of the 33 rooms measured after the initial installation of double windows and ventilator units and before any further modifications. The initial installations gave insulation values, averaged over the range 100 to 3150 Hz and uncorrected for receiving room conditions, ranging from 42 dB down to 26 dB, this wide range justifying the whole pilot experiment. The available helicopter flight time was limited and so it was not possible to investigate thoroughly each example of low insulation. Insulations in the region of 40 dB were regarded as pleasingly high for first-floor rooms and under these essentially practical conditions and, where possible, rooms with insulations of less than 35 dB were investigated further. The two transmission paths most likely to reduce the insulations were via chimney flues, where fitted, and via roofs and ceilings. As the experiment progressed, the roof spaces of some of the houses were insulated either by pugging the ceilings of the treated rooms with mineral wool, or by laying lead sheet over the ceiling joists. Some of the rooms with flues had already had the fireplaces blocked or partially blocked by the tenants, for example, by the fitting of gas fires or by fitting sheets of blockboard. In some of the rooms where the fireplaces were open they were roughly blocked and measurements of the effect were made.

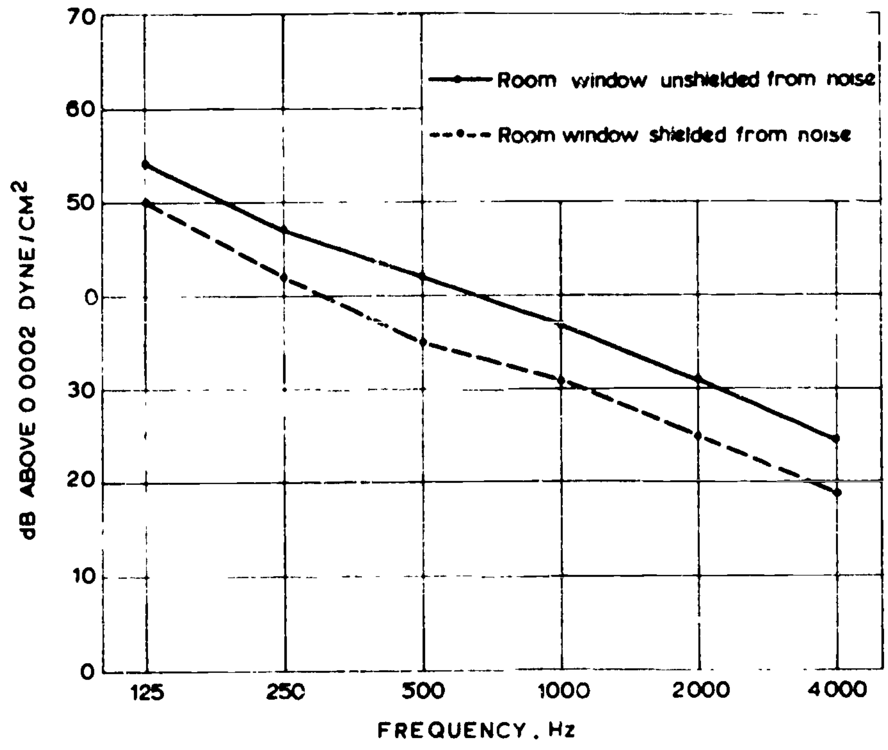

Fig. 1. Octave band pressure levels in front br of type B, no. 1.

A good indication of the contribution of secondary transmission, *i.e.* sound reaching the receiving rooms by paths other than through the windows and ventilators, was given by the levels in the receiving rooms. At each trial, the helicopter made several flights past the front of the house and these were used for the insulation measurements of rooms with windows at the front and several flights at the back of the house. Assuming that the main transmission was through the window and ventilator, the receiving room levels would be high with the room windows exposed to the helicopter noise and low with the windows shielded. For cases in which secondary transmission was appreciable, the differences between the exposed and shielded conditions would be less. This is illustrated in Fig. 1 which shows the octave band analysis with the room window exposed to and shielded from the helicopter, respectively. For this room the insulation was 42 dB and it will be seen from Fig. 1 that the shielded levels were about 6 dB lower than the unshielded levels, indicating that secondary transmission was not serious in this case.

Fig. 2 gives an example where the secondary transmission determined the insulation. The upper pair of curves in this figure show the receiving room levels with the chimney unblocked, corresponding to an insulation of 31 dB. Within the accuracy of the measurements these two curves are identical, indicating that secondary transmission made the major contribution to the receiving room levels. By blocking the fireplace to this room the insulation was increased to 37 dB. The receiving room levels corresponding to this increased insulation are shown as the lower pair of curves on Fig. 2 which again are practically identical. So even at this

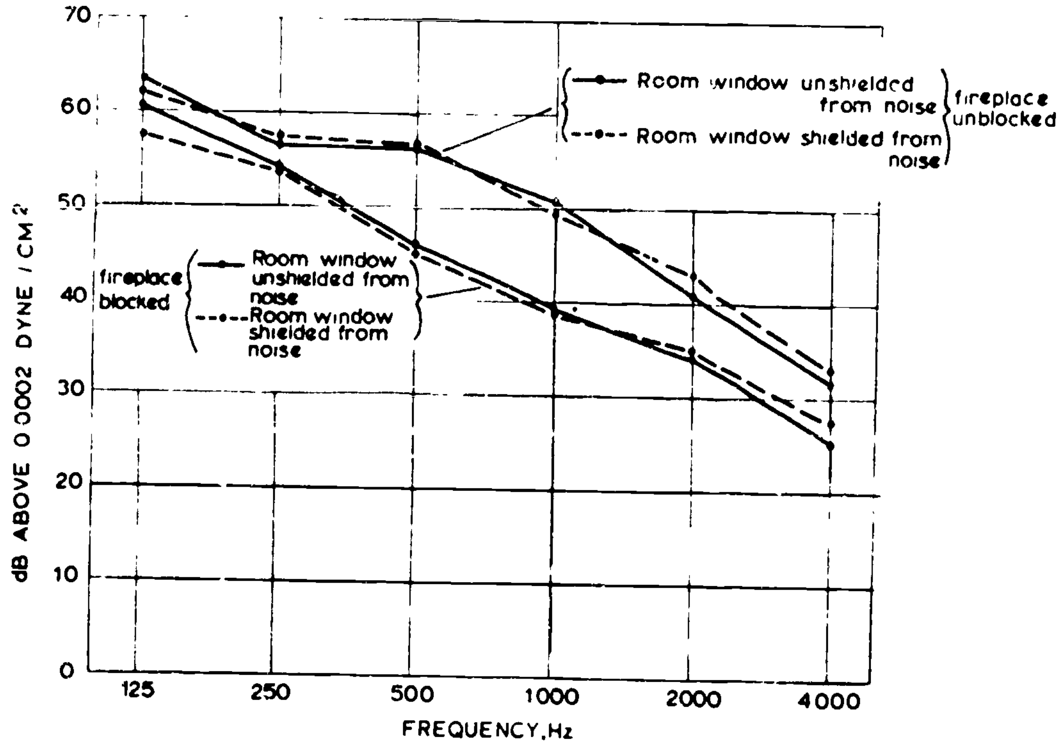

Fig. 2. Octave band pressure levels in front br of type C, no. 4.

increased insulation it is apparent that secondary transmission, most probably via the roof and ceiling, was a major factor in determining the levels in this receiving room.

In general it was found that secondary transmission via flues was more serious than secondary transmission by other paths. Examples of increases in insulation obtained by blocking a fireplace and by increasing the insulation of a ceiling are given in Figs. 3 and 4. Fig. 3 gives the insulation curves corresponding to the

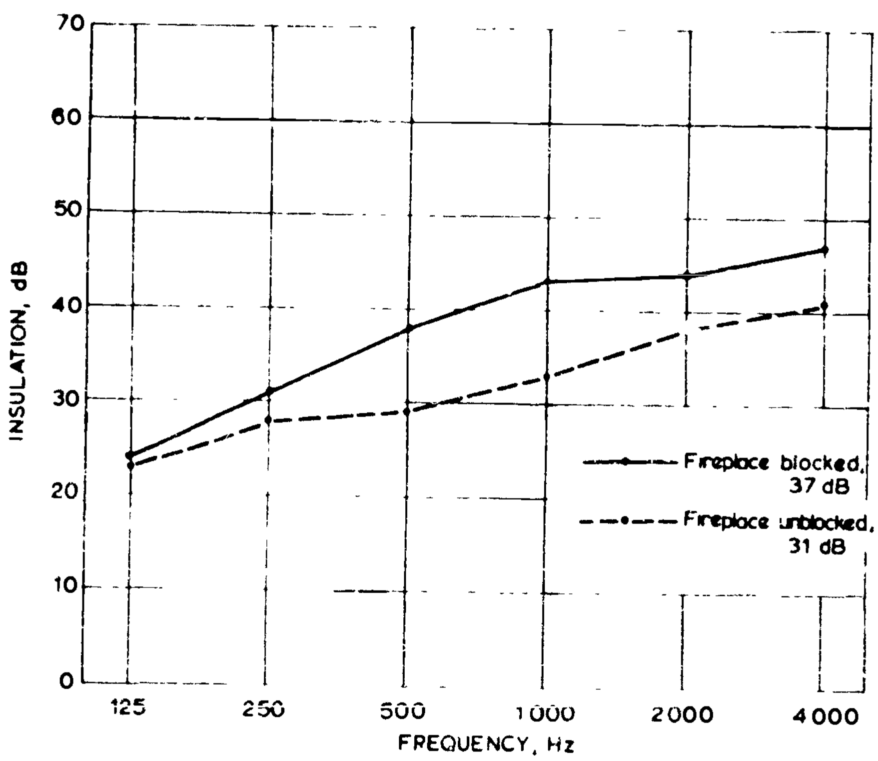

Fig. 3. Effect on insulation of blocking fireplace.

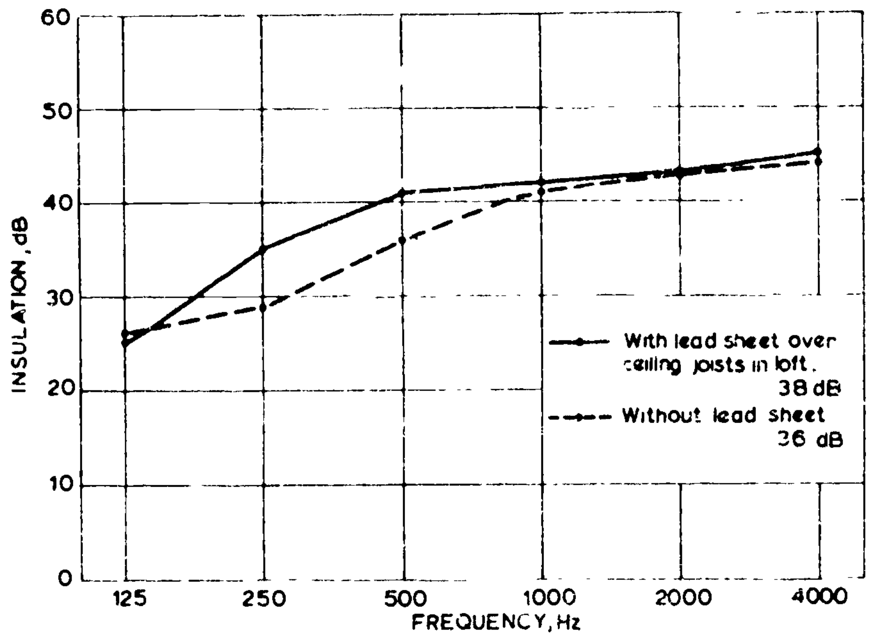

Fig. 4. Effect on insulation of lead sheet in loft.

receiving room levels shown in Fig.2. The average insulation values for the two cases of fireplace blocked and unblocked were, respectively, 37 dB and 31 dB. Figure 4 shows the insulation curves of a room, without a flue, with and without lead sheet over the ceiling joists. The lead, in this case increased the insulation by about 2 dB. Direct comparisons of given rooms with and without mineral wool pugging were not possible, but there are indications that the mineral wool pugging was slightly more effective than the lead sheet.

By making such modifications to the initial installations, usually blocking fireplaces and sometimes increasing the ceiling insulation, for rooms with particularly low insulations, these low insulations were increased so that the spread of initial insulations of 42 to 26 dB was reduced to a spread of 42 to 32 dB. There is little doubt that had sufficient time and helicopter flights been available the spread could have been reduced further. Even so, of the thirty-three rooms measured, only three had insulations lower than 35 dB after the modifications and the average was 37 dB. The average insulation curve for double windows and ventilator unit, with fireplace blocked or ceiling insulation increased for some of the rooms, is shown in Fig. 5, together with the spreads of the different frequency bands.

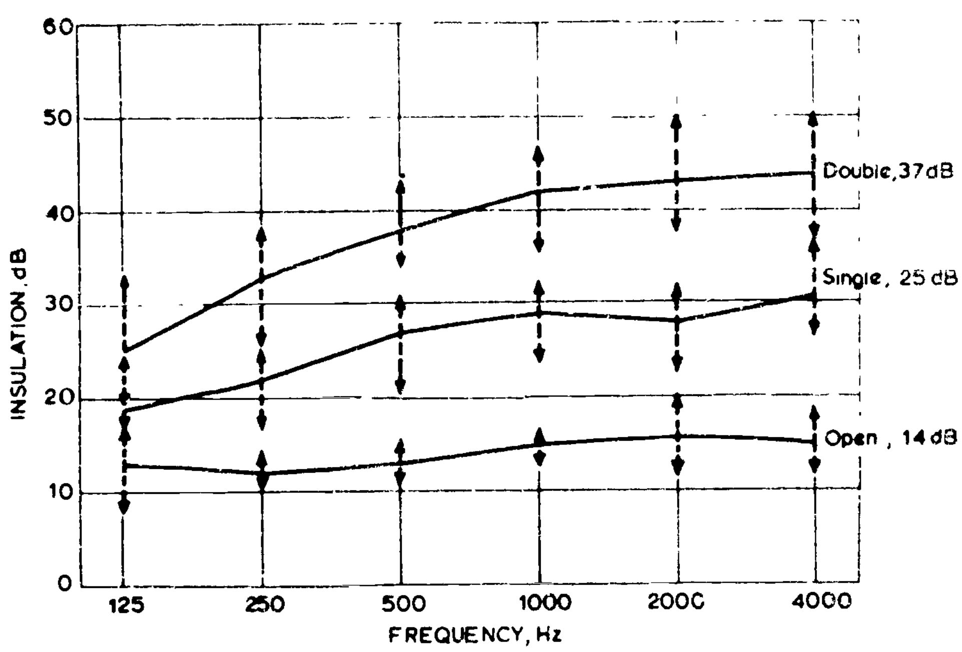

Fig. 5. Averaged, measured insulations and spreads for double, single and opened windows, all with ventilator.

(ii) Single and opened windows

In six of the rooms, measurements were made of the insulation of the existing single windows sealed with the expanded foam draught excluding strip and closed, and also of these same windows with one opening light fully opened. The average insulations for the closed single windows ranged from 28 to 21 dB, with an average of 25 dB and for the opened window from 12 to 15 dB, with an average of 14 dB. The average insulation curves are shown together with the spreads of the individual insulations in the different octave bands in Fig. 5.

(*b*) *Reverberation times of receiving rooms*

In general, the reverberation times of the receiving rooms were short, typically 0·3 seconds. All were less than 0·5 seconds at all frequencies—the value usually taken for "normally-furnished" living rooms. There are several reasons why the reverberation times were low, the main ones being the small floor areas and relatively heavy furnishing.

All the insulation values and also the noise levels from the fans given in this paper are actual measured values and have not been corrected to a reverberation time in the receiving room of 0·5 seconds at all frequencies. The correction 10 log $T/0{\cdot}5$ varied from room to room and also with frequency but in general was about -2 dB. Thus all the insulation values given, while being applicable to the upper floors of these houses, should be reduced by about 2 dB and all the internal noise levels should be increased by about 2 dB for receiving-room reverberation times of 0·5 seconds.

(*c*) *Noise from ventilator fans*

Again, there were wide variations between the different rooms. The ventilator fans were operated at maximum output and the sound levels measured near the centres of the rooms. The levels ranged from 45 dBA to 33 dBA and in each case the noise levels decreased rapidly as the fan speed was reduced.

(*d*) *Insulation measurements in dBA*

During each trial the outside and inside levels were measured directly in dBA so that rough indications of the insulations could be available during the trials and before the helicopter was released. In the subsequent analysis of the results it was noted that there was a remarkably close agreement between the numerical values of the sound level reductions in dBA from outside to inside and the insulations in dB. In all there were 49 measurements of insulation. This number includes repeat measurements on several rooms under different conditions, for example, fireplace blocked or unblocked and double, single and opened windows. It was found that the directly measured dBA differences agreed with the single figure (100–3150 Hz) insulations, derived from replayed tape recordings, within $+2$ and -3 and that the dBA differences derived from the tape recordings agreed with the average insulations within ± 2. In both cases the general agreement was much better than this. For example, the direct dBA differences agreed with the average insulations within ± 1 for all except twelve measurements and the replayed dBA differences agreed with the average insulations, ± 1, for all except three of the forty-nine measurements.

CONCLUSIONS

The measurements have shown that, with good double windows and a sound-attenuating ventilator unit, the first-floor rooms of houses with adequate walls can have a sound insulation against external noise of 35 to 40 dB, and possibly more without loss of ventilation. To reach these levels of insulation it may be necessary to reduce transmission via flues or roofs and ceilings, or both. Flues appear to be the weakest part of the insulation and in rooms where open fires are in use this seems to be an insuperable problem. However, in the majority of cases open fires are not used in first-floor rooms in houses and there were examples encountered in the trials where first-floor rooms with solid fuel fires still achieved insulations in excess of 35 dB. Presumably the quantity of soot in the flue has an influence on the sound transmitted. For rooms not directly under the roof, *i.e.* ground-floor rooms of two-storey houses or flats except the top storey, the flues will be longer and therefore may be expected to give greater attenuation.

Apparently, transmission through the roof and first-floor ceiling reduced the insulation in some cases and the measurements indicated that this effect could be reduced by either pugging the ceiling with mineral wool or by laying lead sheet over the ceiling joists. There were indications that mineral wool was the more effective.

The noise levels due to the fans operating at maximum output were high, unnecessarily high in some cases, and it is thought that with extra care in the manufacture and installation of such units, the noise levels need not exceed 35 dBA, measured at the centre of the room.

The consistently close agreement between the numerical values of the level reductions in dBA and of the 100–3150 Hz average insulations in dB, suggest that this relationship may have further applications in the field of practical noise control. The spectrum of the helicopter noise measured one metre from the house facades was typical of many broad band spectra encountered in noise control, increasing at about 4 dB per octave up to 250 Hz, remaining more or less constant up to and including 1000 Hz and decreasing at about 6 dB per octave at higher frequencies. The spectra in the receiving rooms in general decreased with frequency (see Figs. 1 and 2), but there were wide variations in inside spectra due, for example, to the differing slopes of the insulation curves for double, single and opened windows (see Fig. 5). Thus, the close agreement is likely to hold for other noise sources such as road traffic.

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