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THE SOUND ATTENUATION OF PASSIVE VENTILATORS

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1. INTRODUCTION

Background ventilation in new dwellings is provided by purpose designed ventilation openings. The Approved Documents supporting the Building Regulations [1] recommend the minimum size of such openings, and stress the need for such openings to be controllable and secure and located so as to avoid undue draughts. A common solution is to use a 'trickle' ventilator mounted in a window frame. Another method is the 'passive stack' ventilator, a vertical pipe venting a room from the ceiling to the roof-top by the stack effect.

However, any such opening in the external envelope is likely to have an adverse effect on the sound levels in dwellings, for example in relation to road traffic noise and aircraft noise. This paper reports some experimental investigations of the sound attenuation of passive ventilators. Stack ventilation was investigated in a test house subject to both traffic and aircraft noise. Trickle ventilators were investigated by measurements in the laboratory using two semi-reverberant rooms.

2. SITE DESCRIPTION AND EXPERIMENTAL ARRANGEMENT

No techniques appear to have been developed specifically for the measurement of the acoustic performance of stack and trickle ventilators. However, there has been much experimental work to measure sound transmission along ducts and through small apertures. Techniques range from the Standing Wave Ratio [2] method to modern signal processing that resolves the incident and reflected wave components by wave decomposition of steady broad-band noise [3] or by the use of impulses [4].

2.1 Stack Ventilators

Stack ventilation was investigated directly in a test house in which different sizes and configurations of stacks were installed between kitchen and roof-top. The site was chosen as there is an airfield nearby so light aircraft pass over fairly frequently.

The stacks tested consisted of four types of circular pipes. They were made either from a smooth rigid plastic or from a flexible plastic and wire composite, having a spiral ribbing of wire covered by plastic fabric ('spiral wound'). This maintained circularity but allowed the pipe to flex and extend slightly. Each type of tubing came in nominal six and four inch diameter sizes. Two stack configurations were tested. The pipe passed either directly up from the ceiling of the kitchen to an outside stack of the same diameter on the roof slope, or, in the attic space, it was diverted sideways to the central ridge line to vent outside through a terminal put in place of a ridge tile. The small diameter pipe passing straight up to the roof lean was capped with a 'mushroom' type ventilation terminal for cover against rain and to act as a wind-break. The larger diameter pipe had a 'chinese hat' type terminal. Thus eight permutations of a stack ventilator were available.

2.2 Trickle Ventilators

The wall used to mount the ventilators was in between two semi-reverberant rooms. A block of wood, sealed into a slot cut through the blockwork in the recess, was used to mount each ventilator. Four blocks were installed in turn; two with a row of circular holes but differing in number and radii and two with slots of different sizes cut in them. With a total width of about 12 cm, this arrangement was nevertheless still wider than the average window frame that could fit a trickle ventilator.

The ventilators were of typical design [5] with the openings controlled either by a sliding cover or by a self-clamping cover that can be screwed up to or away from the window frame. They were tested mounted on the blocks of wood having in turn both types of openings; a line of holes or a slot.

3. PROCEDURE AND ANALYSES OF DATA

3.1 Stack Ventilator

Assessments of the sound attenuation in stack ventilators of noise from aircraft overhead into the vented room were obtained from the arithmetic sum of two measured level differences. The first was obtained from the mean reduction of aircraft noise from outside the top of the stack to its other end in the kitchen which was then corrected using the mean reduction with the stack blocked off to give the stack transmission. The second was the reduction of loudspeaker noise from the stack end into the whole room. This was obtained by disconnecting the stack at the join in the attic, transmitting noise down the stack with a loudspeaker placed over the open end of the stack in the attic and measuring the levels just below the stack as before and then in the room as a whole. Reverberation times in the room were measured to normalise the room level measurements to standard receiving room times of half a second.

3.2 Trickle Ventilator

The insulation of the transmission wall alone was measured before the recess and aperture were made in its centre. The measurement taken was the Sound Reduction Index, R, of the whole wall, defined by BS 2750: Part 3 [6]. Each ventilator was then assessed in terms of the insulation of the combined partition of wall and ventilator. The transmission loss, R, of the partition due to transmission through the ventilator only was then calculated. Assuming no transmission through the wall, the ratio of areas of the maximum opening (a slot of 6960 mm^2) and the wall would predict insulation no worse than 30 dB. Thus evaluation of the ventilators would be restricted to frequencies above which the wall insulation exceeded 30 dB (and so likely to be beyond a frequency in the Mass Law region of its domain).

4. RESULTS AND DISCUSSION

4.1 Stack Ventilator

It is clear from figure 3 that the combination of stack material and configuration that provided the least attenuation was the smooth and rigid plastic tubing which went straight up to the roof without bends. The most attenuation was provided by the ribbed and flexible plastic tubing which went up to the ridge of the roof by bending across the attic space. Intuitively, hard smooth bore pipes are more efficient waveguides than pipes with soft spiral ribbing inside.

However, for a given material and configuration, it was the smaller diameter stack that invariably let in more sound overall than its larger diameter equivalent. This was particularly pronounced for the frequencies above 630 Hz. This is evident in the constituent measurements both of pipe transmission as well as radiation from the end of the pipe into the whole room. For each pair, one might expect the pipe of larger diameter to transmit more sound energy through the other end. However there are other factors that could be involved, as follows.

a) Only the plane acoustic mode can occur below about 1.8 kHz for the smaller diameter pipes and below about 1.1 kHz for the larger. This limits the extent of modal coupling of the wall with the sound waves. Above these cut-on frequencies, more coupling can occur in the larger pipe. However, the larger diameter pipes also have a higher transmission loss in the two octaves below the cut-on frequency.

b) This effect will be compounded if the distortion in the circularity of the cross-section of a pipe throughout its length increases with radius. An increase in distortion can increase the coupling of the wall with the sound waves as the internal sound field can then excite higher structural modes. This can occur as the lack of symmetry results in the sound pressure introducing an uncancelled resultant force in the wall of the pipe.

   Below the cut-on frequency classical theory predicts that transmission through the wall will fall by 9 dB per halving of frequency with a corresponding decrease in transmission loss between the ends of the pipe. This is rarely shown in measurements. Here, a decrease is indeed shown from the cut-on down to about 630 Hz, but then there is a levelling-off and a increase before a further general decrease down from 100 Hz. Previous experiments [7] have supported these findings by showing an increase in wall transmission loss below the cut-on frequency but then a decrease further down reaching a low between typically 20-100 Hz. Modal coupling due to the distortion in cross-sectional circularity has been given as one explanation of this discrepancy [7].

c) The generation of pipe bending modes has also been offered as an explanation of the higher wall transmission in the lower frequencies of plane mode propagation [8,9]. The excitation here is limited to areas of the pipe where a net sideways force can be exerted on the wall, such as at bends. The mass and stiffness of the rigid pipes increases with the radius. Therefore the smaller pipes would be expected to transmit a higher sound intensity through its walls in both stiffness and mass domains. The pipes having a side-arm in the attic and venting to the ridge are more likely to exhibit this effect and thereby have a higher transmission loss between their ends. Though they do, these pipes are also longer and have different terminals on the roof.

d) Below the cut-on frequency, the radiation of sound from the pipe appears to change in character depending on the frequency and overall length of the pipe [7]. Below a certain frequency, shorter pipes - not surprisingly - radiate more sound through the end. Above this though, the pipe becomes increasingly more efficient as a waveguide as it gets longer. This may be due to the greater amount of cancellation, per unit length of a longer pipe, of the higher structural modes. The smaller pipes have a higher ratio of length to diameter. Thus at lower frequencies, more sound is radiated from the end of the large pipe whilst at the higher frequencies, greater cancellation occurs along the length of the small pipe so the sound intensity radiated from the end of the small pipe is higher.

4.2 Trickle Ventilators

Due to transmission through the wall, the attenuation of most ventilators can only be assessed from around 250 Hz. The performance of each type of ventilator is consistent with their physical dimensions. The larger ventilators let in more sound; for a given ventilator, holes in the wood attenuate sound more than a slot - due to the greater area of the opening; when closed a ventilator attenuates by at least 5 dB more than when open. The ventilators that control the opening by a screw that moves the cover in and out can be closed tightly by clamping against the window frame. However, when it is open, sound has an easier passage through the ventilator compared to the other design that has a boxed-in tilting-flap shutter operated by a slider.

For a ventilator in the open position, some additional impedance to the normal free field air impedance is evident from the low end of the measurable range at 250 Hz up to a resonance dip. Above this, the sound reduction of the wall is determined by the ratio of the areas of ventilator opening to the whole wall, since at these frequencies the rest of the wall can be treated as perfectly insulating compared to the complete transmission provided by the open ventilator. Figures 5 and 6 indicate resonances due to half and quarter standing waves in the slot or holes corresponding to the ventilator open and then closed. Such resonances for ventilators in a real window frame would occur at a higher frequency than those in the test rig due to the narrower width. However, comparison with the insulation of different types of window when closed [10] indicates that trickle ventilators can cause an increase in noise level indoors from above 630 Hz when used with single pane windows and from above 315 Hz for the more attenuating secondary pane double windows, as shown in figures 5 and 6. This would be no worse, though, than if the window were opened to meet the ventilation requirement.

Figure 7 shows that the average sound transmission of open ventilators is roughly proportional to the area of the opening in the block of wood, that is, an increase of 3 dB per doubling of area. There is little evidence of viscosity reducing the transmission further for the smallest holes of 12 mm diameter (the values at resonance - where viscosity would have the greatest effect - are included in the frequency range over which the mean is calculated). This was contrary to expectation and the results of previous measurements [11]. The test method may not have been sensitive enough. On the basis of these results, therefore, a slot or holes would be equally suitable to make up the required opening with the attenuation determined solely by the total open area.

5. CONCLUSIONS

Measurements of the acoustic insulation of passive ventilators showed that they could increase indoor noise levels at the higher frequencies. This is due to the decrease in impedance of openings with frequency. However, they provide a quieter indoor environment and an otherwise more satisfactory means of controlling background ventilation than is met by opening windows. Where noise levels outside require additional sound insulation, for example by the use of thermal double glazing or secondary double windows, sound attenuating ventilators should be used instead. Such ventilators are specified in Schedule 1 of The Noise Insulation Regulations [12].

Resonance effects were exhibited by trickle ventilators due to standing waves through the depth of the opening. They provide lower sound attenuation than stack ventilators, in general. In addition, stack ventilators are less vulnerable to the incidence of traffic noise. However, the most efficient stack ventilator provided the least sound attenuation of the stack types tested. There was also the apparent anomaly of higher transmission through four inch diameter pipes than through the equivalent six inch pipes, above 630 Hz.

6. REFERENCES

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[6] BS 2750 Methods of measurement of sound insulation in buildings and of building elements. Part 3 : 1980 'Laboratory measurements of airborne sound insulation of building elements' (Identical to ISO 140/III-1978)

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[12] The Noise Insulation Regulations 1975, S.I. 1975 No. 1763

7. ACKNOWLEDGEMENT

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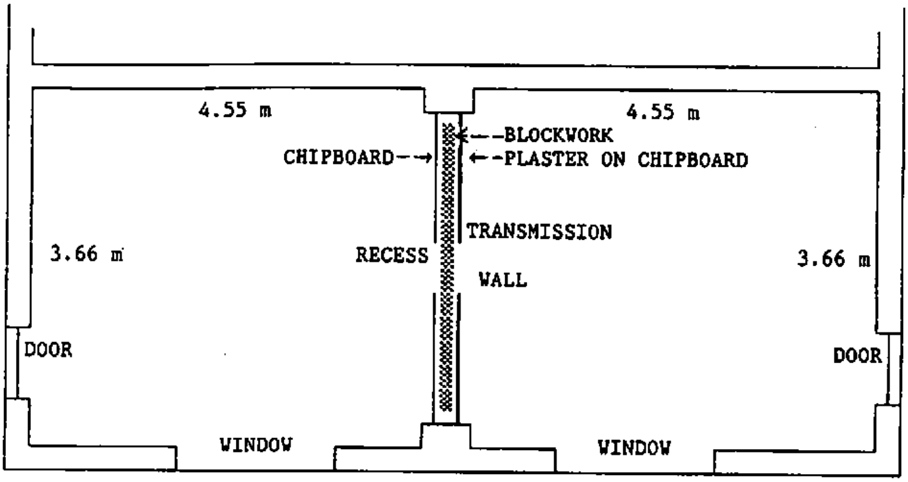


Figure 1 Plan of transmission suite

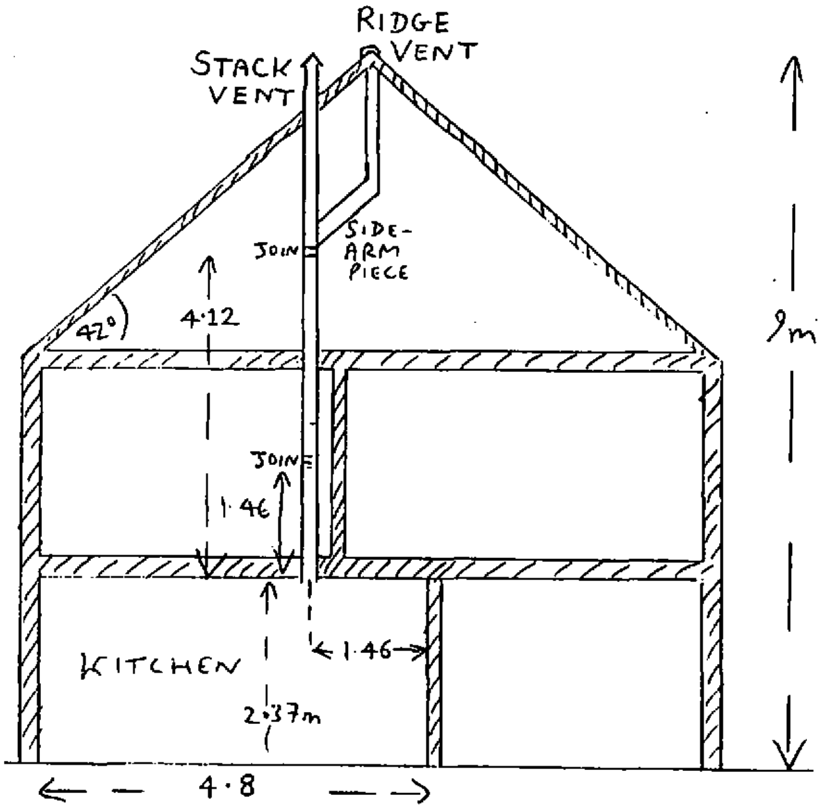


Figure 2 Location of stack pipes
(all dimensions in metres)

FIG.3 INSULATION OF SEVEN STACK TYPES - LEVEL DIFFERENCE OF AIRCRAFT NOISE AT ROOFTOP AND IN ROOM (DUE TO STACK TRANSMISSION), STANDARDIZED FOR 1/2s.REV.TIME

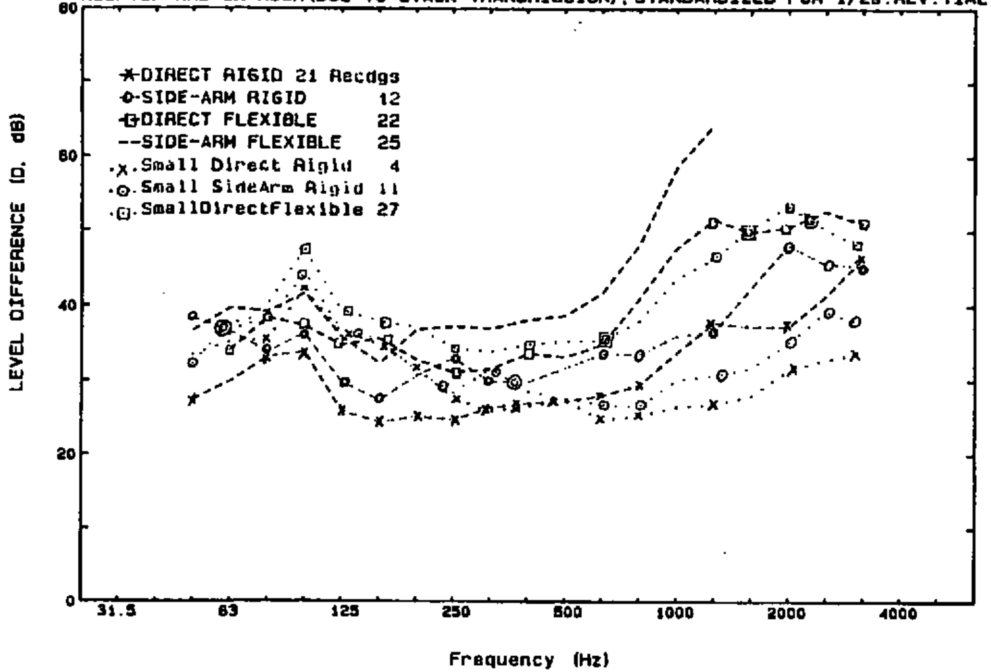


FIGURE 4 DIFFERENCE IN INSULATION PERFORMANCES BETWEEN STACK DIAMETER SIZES FOR STACKS OF THE SAME CONFIGURATION AND TYPE OF PIPE

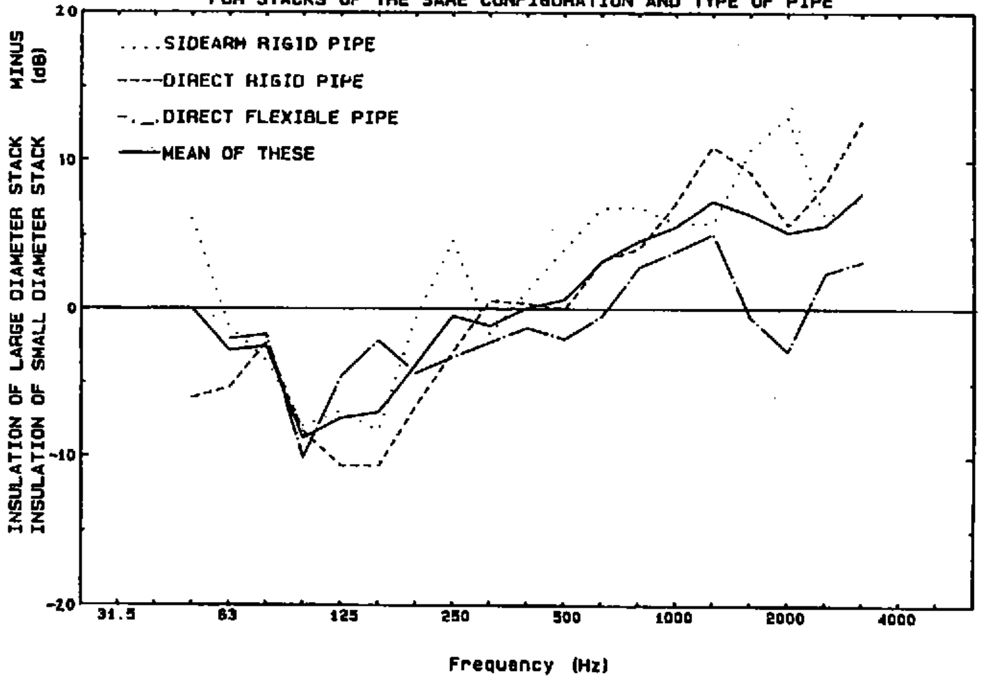


FIGURE 5 BEST & WORST TRICKLE VENTS v AVERAGE SINGLE PANE CASEMENT WINDOW

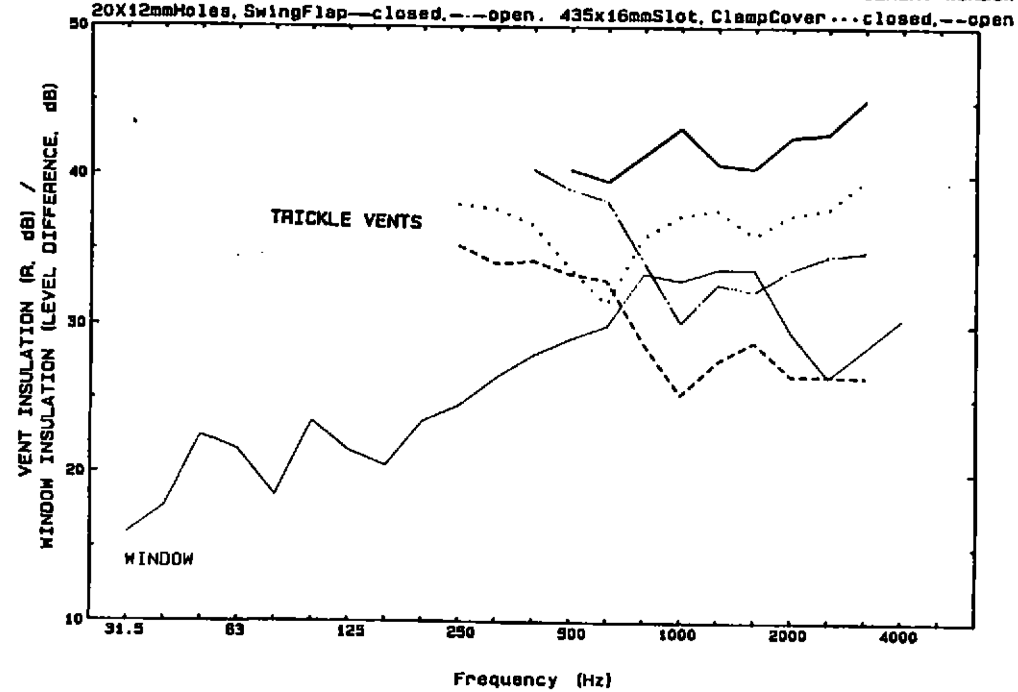
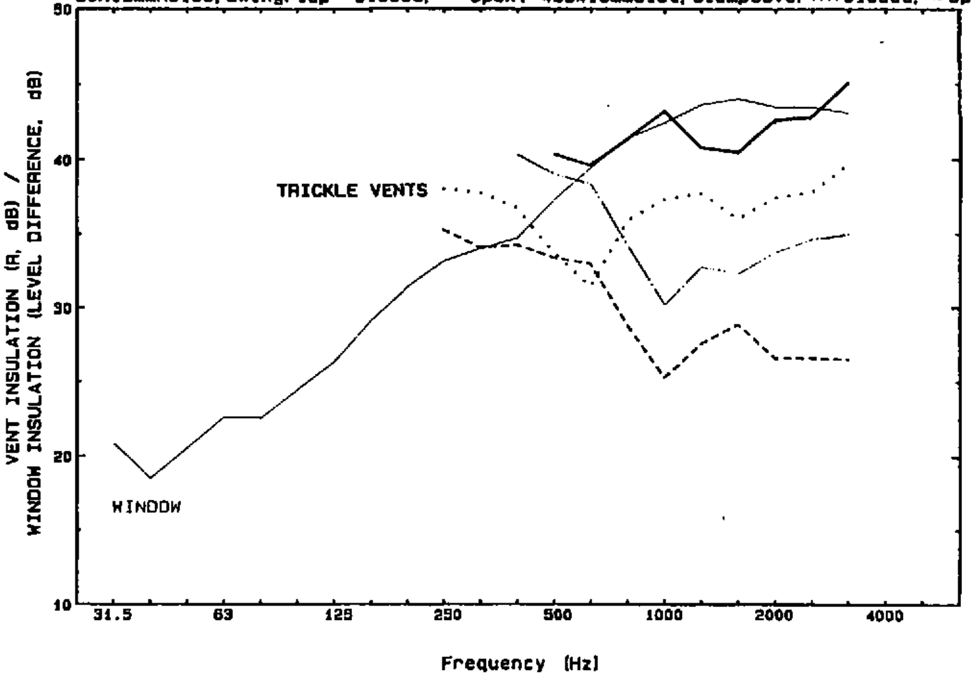


FIGURE 6 BEST & WORST TRICKLE VENTS v AVERAGE SECONDARY PANE DOUBLE WINDOW

20X12mmHoles, SwingFlap—closed,-·—open. 435x16mmSlot, ClampCover····closed,---open



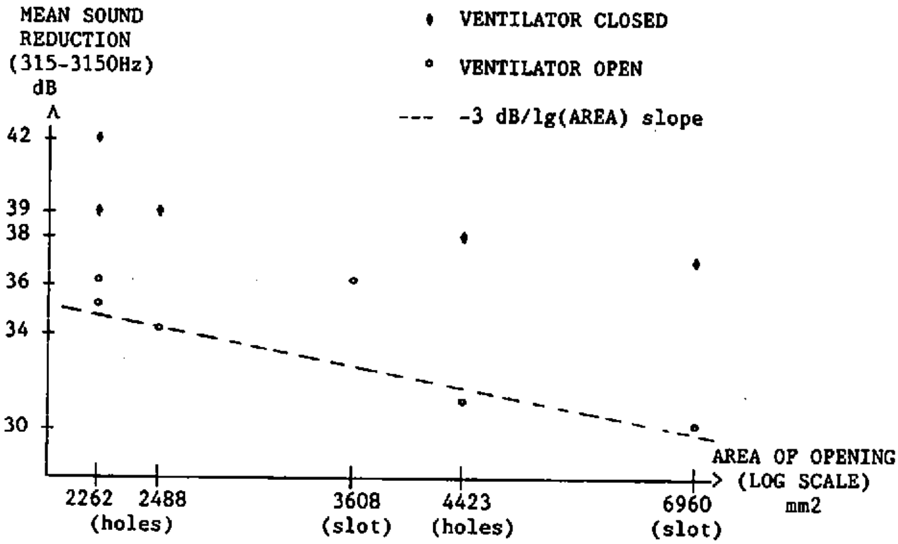


Figure 7 Mean sound reduction of ventilators by total area of opening(s)