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BUILDING ACOUSTICS AND SICK BUILDING SYNDROME

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ABSTRACT

The acoustic environment was examined in an office building with a high prevalence of symptoms typical of the sick building syndrome (SBS). Levels of ventilation noise exceeded 70 dB in many rooms. The peak was often found in the region below 20 Hz, which is the infrasound region and generally regarded as inaudible at these levels. Symptoms attributed to exposure to low frequencies include nausea, headache, choking, coughing, visual blurring and fatigue, which appear to overlap with some of the symptoms of SBS. Reducing fan speeds provided reductions in noise levels mainly in the audible region. Closing windows and doors to the rooms gave more effective reductions, but interfered with working routines.

KEYWORDS

Sick building syndrome, ventilation noise, infrasound

INTRODUCTION

Ventilation systems produce noise of fairly low frequency, extending into the infrasound region below 20 Hz. The noise comes from the fan unit, the ductwork and the terminal devices. Most ventilation noise is due to turbulent flow acting on blades, vanes and casings (Neise 1992). The fan unit is the biggest noise source. The fan should be selected to operate at the point of maximum aerodynamic efficiency, which is also the optimum point acoustically (Iqbal et al 1977, Graham et al 1991). Designers often try to use large, slow-moving fans to reduce noise. But fan noise is not just a function of the rotational velocity, it is also a function of the tip speed, which increases with increasing diameter. Undersized fans with high shaft speeds are noisier than fans operating at maximum efficiency; oversized fans with low shaft speeds produce more low-frequency noise.

Ventilation noise levels vary, but occupants can be exposed to 80-90 dB. Whether long exposures to such levels is harmful is still not known; most research into the biological effects of infrasound has been carried out at higher levels. The first experiments (Mohr et al 1965) showed that exposures up to 150 dB could be tolerated for short periods (two minutes). Sources included loudspeakers in a reverberation chamber and a J57 turbojet engine with afterburner in an F102A aircraft. Exposure to frequencies below 100 Hz resulted in mild nausea, headaches, choking, coughing, visual blurring and fatigue. Although there was much individual variation, all subjects reported severe post-exposure fatigue that could only be resolved by a night's sleep. Levels below 120 dB may have a depressive effect, and higher levels an arousal effect (Broner 1978). A typical office environment has the lower levels. The depressive effects at lower levels could account for symptoms such as fatigue and lack of concentration.

Studies showed that infrasound is transmitted poorly via air to the body organs (von Gierke and Nixon 1976), and that any possible effects are mostly due to pressure effects in the ear (Westin 1975). Comparisons of deaf people with normal people indicated that low-frequency noise affects the cochlea (Yamada et al 1983). Some people, such as those with balance disturbances or other middle ear problems, may be more susceptible to the effects of infrasound (Tempest 1976). People with a cold can experience nausea and vomiting when exposed to infrasound (Okai et al 1983). People who develop allergy, where they become sensitive to very low levels of a stimulus, frequently have a spill-over effect and become sensitive or allergic to other stimuli. Allergic people should therefore be considered a risk group for sensitivity to infrasound, until more information is available.

There have been very few studies about the effects of longer durations of infrasound at more moderate intensities, such as those encountered by many office workers. One study tested subjects for two working weeks (8 hours a day for 10 days) at levels of 70-125 dB, and frequencies of 3-24 Hz, both pure tone and band. Measurements were made of several physiological parameters such as ECG, blood pressure, respiration, epinephrine and norepinephrine in urine. The physiological parameters were not significantly altered, but several subjects reported subjective effects such as reduced concentration, increased tiredness, headache and tenseness (Ising 1983).

Sick building syndrome has some symptoms in common with those due to infrasound exposure. It also has symptoms that are unlikely to be produced by infrasound and to have other causes. The complete spectrum of SBS symptoms is therefore probably due to multiple causes, acting both independently and interdependently.

The aim of this study was to examine the acoustic environment in a building that was known to have a high prevalence of occupant symptoms and high levels of infrasound in the rooms. Remedial measures tested were reducing fan speeds and closing windows and doors. These provided some reductions in infrasound levels, but did not represent practical solutions.

METHOD

Noise levels were measured with a Precison Sound Level Meter (B&K 2203), and the signals recorded on a portable Digital Audio Tape (DAT) recorder (Sony TCD-D7). Recordings were made at the occupants' desks, the supply ventilation grilles, and the exhaust ventilation grilles. These were done with the ventilation fans running at full speed and 2/3 speed, and with all combinations of the windows and doors open and closed. The recordings were analysed with a Tunable Band Pass Filter (B&K 1621) to cover the frequency range 2-2000 Hz, and spectrogrammes were made with a B&K 2305 Level Recorder.

RESULTS

The results from a questionnaire study showed that people who reported ventilation noise as a problem, and people who were allergic in some way, also had a high prevalence of SBS symptoms, Burt (1998). Fig. 1-4 show some tracings made in individual rooms. Note that all the readings are unweighted, as the commonly used A-weighted scale (dBA) attenuates the signal by over 50 dB in the infrasound region.

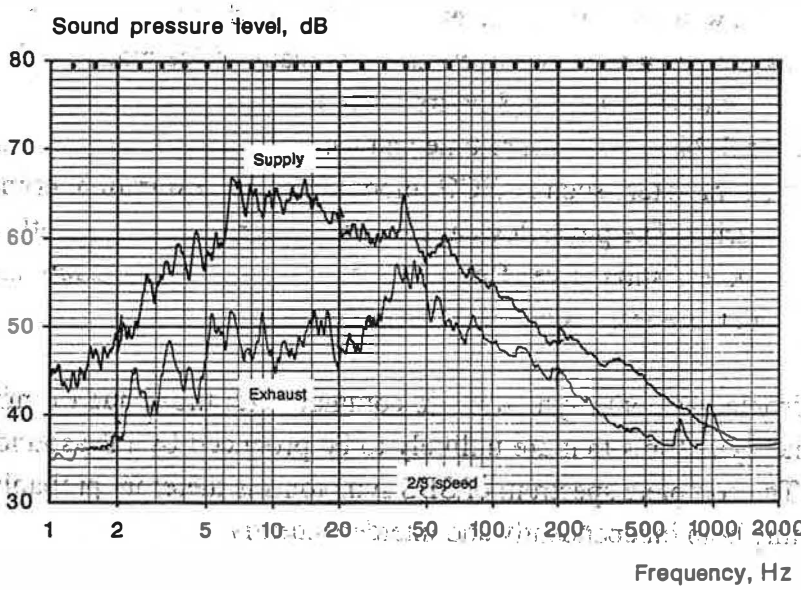

Fig. 1. Supply and exhaust grilles.

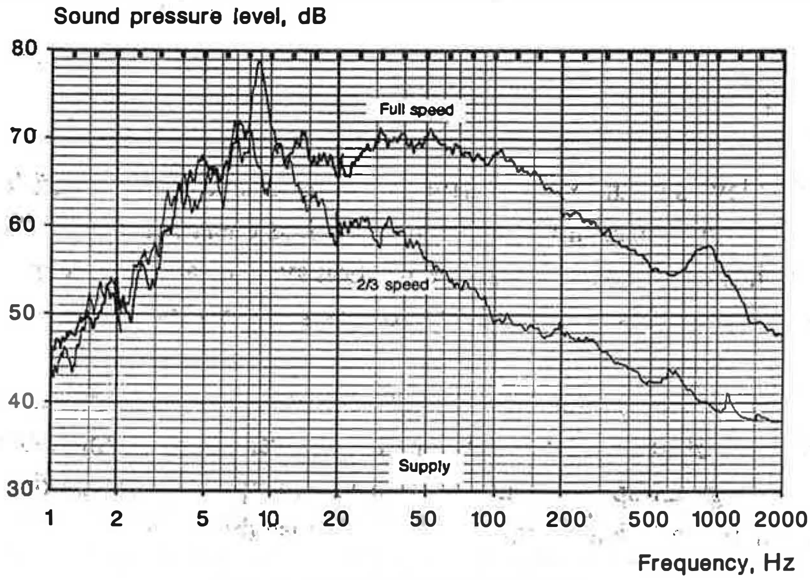

Fig. 2. Reducing fan speeds.

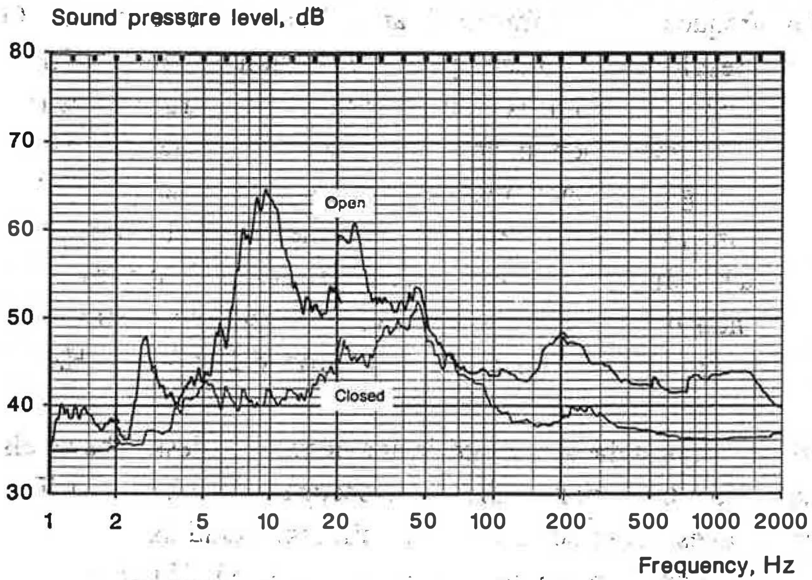

Fig. 3. Closing windows and doors.

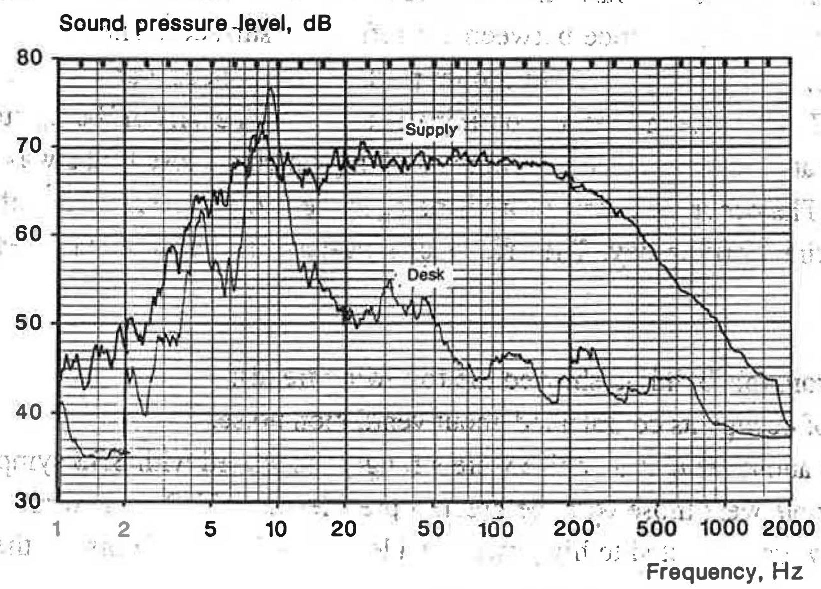

Fig. 4. Supply grille and desk.

DISCUSSION

Fig. 1 shows that levels at an exhaust grille are lower than at a supply grille in the same room. Furthermore, the spectrum is different, with less energy in the infrasound region. Experience has shown that exhaust-only ventilation systems are usually more acceptable than supply-and-exhaust systems, and this is one possible reason.

Fig. 2 shows the effects of reducing fan speeds. There is some noise reduction that could be beneficial, although the effects in the infrasound range are slight. The effect is not general, as reducing fan speeds may cause a fan to operate outside the range of its optimum aerodynamic efficiency, which would increase the noise.

Fig. 3 shows the effects of shutting the windows and doors to a room. Large reductions occur in the low-frequency and infrasound range. There are two reasons. One is that an open window can result in a room acting like a Helmholtz resonator. This effect occurs when a closed volume (the room) is connected to a much larger space (outdoors) by a duct (the window). Air movement in and out of the window causes a resonance to be set up in the room. Closing the window reduces the effect. The other reason is that the entire building can be acting as a resonance chamber for the noise. The wavelength of a 10 Hz wave is 34 m, so a building with this internal dimension will emphasise this frequency. Closing the door shuts the room off from rest of the "resonance chamber". The result of closing both windows and doors is a reduction of around 25 dB at 10 Hz.

Fig. 4 compares tracings at the supply grille and occupant's desk. The levels at 10 Hz do not decline much from the supply grille to the occupant's work station. This is probably due to standing waves being set up in the building. Standing waves (as opposed to travelling waves) occur when sound waves are reflected. If two waves travelling in opposite directions are in phase, they will reinforce each other. The wavelength of the reinforced wave is the distance between the reflecting surfaces. The effects are seldom noticed in ordinary buildings, but unexpected resonances can be set up at low frequencies. The total length of this building is 66 m, with each half being supplied with air by a separate fan. Thus each fan supplies 33 m, which is close to the wavelength of a 10 Hz wave. The occupant in this room is being subjected to a 10 Hz wave of over 70 dB of for the entire working day. The effects of long-term exposure to such levels are still unknown.

The results from this building showed the following trends:

- Over 20% of occupants complained about ventilation noise.
- Complaints about ventilation noise were strongly associated with SBS symptoms.
- Allergic people were those with the greatest prevalence of SBS symptoms.
- Occupants were subjected to high measured levels (> 70 dB) of noise in the infrasound region.

Research in this field has not progressed enough for it to be possible to say if these four trends are linked. If they are, the implication is that people can become sensitised or "allergic" to infrasound. This could happen in the same way as other allergies arise, i.e. repeated or long-term exposure to infrasound might drastically reduce the individual's threshold for the stimulus. The individual then reacts to infrasound levels that do not affect non-allergic people. This kind of exposure pattern would explain the epidemiology of sick building syndrome, in which people moving into a building are initially unaffected but begin to react after several weeks or months of occupancy.

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REFERENCES

Broner N. (1978). The effects of low frequency noise on people - a review. J Sound Vib.; 58(4): 483-500.

Burt TS. (1998). Dusty, dry air and sick building syndrome (this conference).

Graham JB, Hoover RM. (1991). Fan Noise. In: Handbook of Acoustical Measurements and Noise Control. Harris CM (Ed). 3rd Edition, McGraw-Hill Publishers.

Iqbal MA, Willson TK, Thomas RJ. (1977). The Control of Noise in Ventilation Systems: A Designer's Guide. Atkins Research and Development. E & F.N. Spon, London.

Ising H. (1983). Effect of 8 h exposure to infrasound in man. Proc. 4th Int. Congress on Noise as a Public Health Problem: 593-604. Turin, Italy.

Mohr GC, Cole JN, Guild E, von Gierke H. (1965). Effects of low frequency and infrasonic noise on man. Aerospace Medicine; 36(9): 817-824. September 1965.

Neise W. (1992). Review of fan noise generation mechanisms and control methods. Fan Noise, An International INCE Symposium: 45-56. Senlis, France.

Okai O, Taki M, Saito M, Nishiwaki N, Mori T, Fujio N. (1983). Infrasound generated by human body. Inter-Noise 83: 239-242.

Tempest W. (1976). Infrasound and Low Frequency Vibration. Academic Press.

von Gierke H, Nixon CW. (1976). Effects of intense infrasound on man. In: Infrasound and Low Frequency Vibration, Tempest W (Ed). Academic Press.

Westin JB. (1975). Infrasound: a short review of effects on man. Aviation, Space and Environmental Medicine: 1135-1140, September 1975.

Yamada S, Ikuji M, Fujikata S. (1983). Sensation of low frequency noise of deaf persons. Inter-Noise 83: 823-826.