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AIRFLOW GENERATED NOISE AND THE QUALITY OF DESIGN AND MANUFACTURE

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The most significant noise problems encountered in today's ventilation systems are those caused by air flow generated noise. This has probably been brought about by a combination of greater awareness of noise, the provision of better standards of ventilation and hence more air, and the pressure on space available for services in buildings.

The services engineer has a great problem in acquiring enough space in a building for services. Time and again ceiling heights are squeezed and plant room space allocated in "spare" areas of the building which are neither in the best location, nor of the best size and shape. The acoustic consultant is just as interested as the services consultant in these difficulties because they are the root cause of too many noise problems.

It is probably more accurate and certainly more logical to consider air flow generated noise to be related to pressure drop rather than velocity. A drop in total pressure represents a loss of energy and a proportion of that lost energy is released as noise. Realistic pressure drop is difficult to calculate because the standard methods do not allow for the proximity of fittings one to another, nor do they allow for variations in the quality of manufacture. To calculate the pressure drop across a silencer and damper in close proximity or across a diffuser on a short spur from a main duct by standard methods will give greatly misleading results. So while noise levels generated by air flow can be reasonably accurately calculated where pressure drops are known, this is of little practical value at the design stage.

What we can say is that in designing a system we must attempt to reduce pressure drops along it if we are to keep air flow generated noise down. Poorly manufactured ductwork, tortuous duct geometry, system design requiring much use of dampers and simply trying to get too much air down too small a duct are the most frequent causes of excessive pressure drop and excessive noise.

It is probably more useful therefore to examine how velocity and velocity gradients generate noise. Noise is created by turbulence within the air flow. To be strictly correct all air flow in duct systems is turbulent and will always create some noise. The turbulence can be created by air passing over or past a constriction in the duct whether this is a simple constriction such as an orifice or a complex one such as heater battery. Probably the best way of viewing the production of noise in this way is to consider that it will occur where two parts of the airstream are travelling at different velocities. The air just downstream of a silencer will be travelling at different velocities, a high velocity in line with the airways and a low - or even negative - velocity in line with the splitters. After about three duct widths down the duct the air has mixed sufficiently to be considered as travelling with the average velocity over the whole duct cross section. We can consider that the level of noise generated is directly related to the velocity differences or more accurately to the velocity gradients in the duct.

Velocity variations across and downstream of one fitting can have a dramatic effect on a following fitting. The placing of a second fitting - for example a damper - immediately after the silencer, means that the localised high velocities, and the velocity gradients which would be created by the damper on its own will be considerably increased because of the high velocity of air from the silencer airways. Consequently the velocity variation in the duct and the noise generated will be increased. Aerodynamically designed components will ensure that the mean velocity is re-established more quickly than with plain steel sheet components - such as basic turning vanes.

Air flow generated noise is highly sensitive to changes in velocity, on average about 16dB per doubling of velocity. Where air flows vary in a fitting, the noise created is determined not by the mean velocity but by a velocity of between 75% and 100% of the maximum and so to all intents and purposes it can be considered dependent on the maximum velocity. At bends without turning vanes air near the outside of the bend may be travelling at twice the mean velocity, so the noise level created by the bend may be 16db greater than that where good quality turning vanes are used. But poor quality turning vanes can make the situation even worse by creating additional turbulence. If the bend is followed by a branch on its outside, the air on the outside of the bend will be travelling faster than the mean and when it reaches the branch, the noise generated will be that expected from the local air velocity, not the mean.

In summary, it is important to select fittings which do not generate high local velocities, and more particularly to arrange fittings so that increased local velocities have a chance to even out to near the mean before the next fitting is encountered.

- Avoid abrupt changes of section.
- Avoid sudden changes of direction at bends and branches and use long radiussed bends and swept branches. Mitre bends give better attenuation of noise but they are rarely a critical factor in fan noise attenuation.
- Don't place fittings less than three major duct dimensions apart.
- Don't follow branches closely on bends - particularly if the branch leads to a diffuser nearby.
- Take a lot of trouble to ensure that the system is self balancing.
- Don't run a long duct from one end of the room to the other spurring off diffusers as you go, particularly if the face velocity of the diffuser is low.

<u>Case Study 1</u>

New ventilation system for existing large hall with NR25 criterion, 24m long by 15m wide by 6m high.

The hall was bounded on three sides by external walls and was a listed building so no ducts were permitted on the outside of the building. The consulting engineer had to supply air at one end of the room and it was extracted at low level in the stage front and elsewhere at the other end.

In order to obtain the required throw, a series of aluminium bar diffusers were selected for the end wall to throw across the 24m room dimension. These diffusers each had their own plenum box which was fed by a flexible connection from a header duct. On acoustic analysis it was concluded that the bar diffusers would only be suitable if they had no integral dampers or dampers to individual plenums and if each of the diffusers carried within ± 10% of it's design volume. In other words, only if the system was self balancing. Because the header duct was fed from one end it was considered that balancing without dampers to the close limits required could not be achieved. Two alternatives were examined: The first was to feed the header duct from the centre and thence in two directions, the second was to enlarge the header duct to form a long plenum and then place the diffusers directly in the side of the plenum.

The second option was selected and achieved NR25. It was calculated that the use of balancing dampers and turbulence created at the spigots leading to the diffusers would otherwise have produced a level of around NR35.

Case Study 2

This was a new office building with a criterion of NR35. The space available in the ceiling void was limited and at an intermediate level the main supply duct had to cross to the other side of the building to feed the lower levels. $4m^3/s$ of air were required and a rectangular duct of 1500mm x 450mm gave a velocity of about 6m/s. However, because of the lack of space this duct adopted a tortuous route and had several changes of section, in one case increasing the velocity to about 8m/s. It was calculated that air in this duct would produce a noise level in the order of NR45. The solution adopted was to form a plenum at the bottom of the duct from the plant room and discharge through an aerodynamically shaped bell mouth into a flat oval duct 900mm x 400mm. Although this gave a velocity of 12m/s, the size enabled the duct to pass from the discharge plenum to a receiving plenum at the other end in a straight line and the criterion of NR35 was met.

A duct system with fittings placed well apart and with high manufacturing quality reducing sharp edges and incorporating aerodynamically shaped components can take air velocities of twice that of poor quality ductwork with fittings close together. Noise levels can be greatly increased by poorly made ductwork. In particular, sharp edges can generate mid to high frequency noise - usually in the range of 1 to 2kHz which dominate the sound spectrum. These edges occur most frequently in plenum boxes or duct spurs containing grilles and diffusers. Careful specification and control on site can keep noise levels down.

Grilles and Diffusers

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The selection of the right grille or diffuser is an important factor in the achievement of the correct noise levels. Some types of diffuser are inherently more noisy than others. The conflict between the Acoustic Consultant and the Building Services Engineer here is that gaining sufficient throw of air often leads to higher than acceptable noise. The acoustic consultant wants face velocities reduced while the services engineer wants them increased. This conflict can often be overcome by the careful selection of a diffuser type and duct geometry leading to it. Noise data provided by grille and diffuser manufacturers has improved in recent years, but such data is simplistic - it has to be to avoid it becoming unweildy from the large number of combinations of components and conditions. Noise is dependent on the ductwork configuration and on the degree of use of integral dampers. The manufacturer cannot know all the conditions under which his equipment will be used and so it is the designers responsibility to obtain all the relevant data and to satisfy himself that the equipment selection is suitable. Taking an example of a particular situation in which the throw required is 10 metres and the air volume flow $4m^3/s$ we can achieve noise levels as follows:

Single slot diffusers in plenum box	NR67
Single slot diffusers without plenum box	NR55
Aluminium bar diffusers	NR48
8-slot sidewall diffusers	NR41

These figures on their own are sufficient to show what a wide variation is possible, but the noise levels can be reduced even further by other selections. Annular ring diffuser fed from a large common plenum can achieve less than NR25 and levels even lower than this can be achieved by using specially adapted aerodynamic eyeball jets.

Where supply diffusers are placed in a plenum with a spigot entry either at the top or the side which has a higher inlet velocity than the face velocity of the diffuser the noise generated at the diffuser is increased. For a typical plenum box, the diffuser noise can be approximately calculated by assuming that the diffuser face velocity is the mean of the actual face velocity and the spigot inlet velocity. The increase in level is dependant very much on the construction of the plenum and it can be designed so that the level is hardly increased at all. Since the increase in grille noise can be very substantial in this type of combination, it is important to keep the spigot velocity low and the distance between the diffuser and the spigot high.

Finally, a word about plant room problems. Lack of space is common and because of this fans, silencers, bends and dampers are often in very close proximity. If you are forced into this position it is often worth considering keeping velocities high in the plant room and hence ducts small, to allow a straighter longer entry into the silencer. Alternatively, use a plenum box as large as possible instead of a silencer, cutting out the number of bends. If the air is then taken out of the plenum via a bell-mouth into the duct through the plant room wall, a reasonably smooth air flow should be possible.

Another method is to simply accept the tortuous ductwork and put a low free area silencer in. This will reduce low frequency noise efficiently, but probably gererate even more mid and high frequency noise. But low frequency noise is the most difficult to attenuate and the mid and high frequencies can be reduced with a high free area silencer or by lined ductwork.

In preference we obviously want to avoid measures such as this. The design of self balancing systems, and careful specification for manufacturing of ductwork, can both help avoid them.