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'Some Practical Aspects of Sound Conditioning'

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There is now a good stock of installed sound conditioning systems in the UK and elsewhere as a result of development of the concept of introducing masking sound using electro-acoustics. The aim of this paper is to relay some of the main points arising from experience with sound conditioning, with particular emphasis on the practical aspects. The scope is limited to the use of electro-acoustic systems to provide speech masking i.e. to improve privacy. Incitement to efficiency or to buy e.g. in supermarkets by sound (often music) systems is not considered. There are three main areas for discussion of sound conditioning in practice - (i) applications for sound conditioning and the techniques used, (ii) client/building occupant reactions to the concept and (iii) particular problems which tend to arise frequently.

Applications and Techniques

To date the author has experience in sound conditioning mainly for offices, with occasional use of systems for hospital consulting rooms, banks and doctors /dentists surgeries. A feasibility study has been carried out for its use in hotel bedrooms and we are aware that, in Australia, it has been used for such diverse purposes as reduction of startle (which apparently affects the health of poultry) and masking of quarry noise by the use of an outdoor system.

The basic principles of sound conditioning are well known. Fig 1 shows a target spectrum zone of continuous broad band masking sound derived from our research and the work of others in this area. Means are found to distribute sound with such a spectrum throughout the area to be conditioned. As there is a relatively narrow 'window' for useful speech masking (usually between about 40 and 48dBA) a fairly even sound field is usually needed in large areas.

Where speech masking cannot be achieved by other means (e.g. from mechanical services systems, which tend to offer the advantage of association with a known building component or from relatively steady occupational noise), the use of loudspeakers to distribute masking sound is an option.

Fig 2 is a schematic diagram of the main components of a typical sound conditioning system. Broad band sound is generated filtered and amplified, then fed via a 100 volt line distribution system to an array of loudspeakers. On a large system, zone control units are used at each floor of the building and loudspeakers are grouped into zones (the size of which is determined by the needs of the conditioned area).

What Sort of Sound?

The spectrum zone in Fig 1 is not an adequate specification. Comparisons have been made between many potential sound sources - from shaped broad band electronic noise, mechanical noise, the sound of the sea, the wind, waterfalls, fountains, air leaks, and 'scrambled' occupational noise to frying pans.

Dependant on the amplitude/frequency/time base characteristics sounds can be "friendly" or "threatening/aggressive". The former is likely to be more success -ful provided it does not carry a sedative effect. There is also a danger that the sound becomes boring and limited modulation may be useful, but mixture with occupational noise tends to counter this. If occupational noise levels are relatively steady, sound conditioning is unlikely to be appropriate anyway. If it is sporadic or absent (e.g in an office after normal working hours) the presence of sound conditioning can be oppressive if some adjustment is not made to the level. We are currently looking at improvement of electronically generated sound. To date a random non-clipped broad band signal of relatively even spectral density (i.e. white noise) filtered to produce the target spectrum has been used.

Sound Conditioning Generation, Filtering and Amplification

Sound is generated preferably by a digital random noise source on a stable regulated power supply. Octave band filters (say six) rolling away at 12dB/ octave have been used, but the target spectrum suggests that 1/2 or 1/3 octave filters or a steeper filter skirt at the top end of the frequency range covered is required. If this is not done, the interaction between the filters limits the control at high frequencies.

Amplifiers clearly need to be of reasonable quality sized to match the scope of the system, perhaps covering a frequency range 50Hz - 15KHz $\pm$ 2dB with THD $<$ 1%. The normal considerations of stability, life, accessibility apply.

Distribution

Wiring is generally screened multi-core as far as zone control boxes and then simple twin cable out to the loudspeakers. Adequate screening to avoid r.f. pick up and separation from high voltage runs are important. In two cases in Central London, the use of loudspeakers in a suspended ceiling void - which was also a return air plenum - led to a requirement from the fire authorities for all distribution wiring to be run in conduit, which of course produces a major cost increase. Often wiring is carried out by an electrical sub-contractor and the system supplier makes the connections - the relative responsibility of each party must be clear in this case. Connection to loudspeakers in phase is of course important.

Zone control switching or pin matrices should have a controlled crosstalk performance (say 40dB) and the use of 2dB steps appears to work well.

Loudspeakers

A wide range of loudspeakers configurations has been tried. Most commonly for large systems 150-200mm diameter simple cone units have been used. Larger units are preferred but the need for even distribution, in combination with the economics tend to produce a compromise.

In suspended ceilings, with a reasonably deep void above, units can be laid on the ceiling (subject to having adequate support), hung on wire or chains or fixed to the structure (see Fig 3). Excitation of lightweight suspended ceiling or services components has to be avoided and the effect of suspended ceilings on sound transmission and distribution is very important. The common suspended 15mm mineral fibre tile or board (with surface weight about 6Kg/m²) presents no problem for sound penetration, but heavy plaster tiles or unperforated metal tiles or plaster on expanded metal are more difficult. In these cases, the masking sound tends to emerge from weak areas in the ceiling such as light fittings, which may not be a bad thing if they are not too far apart.

Field measurements during commissioning show that ± 2dB can be achieved with loudspeakers at approximately 3.5 metre centres (if they are set on top of tiles). Where larger units are used in the ceiling void upturned to direct sound at the soffit of the structural slab above, fewer loudspeakers are generally needed. However, this may not be the case if the ceiling void is shallow (< 400mm) or ductwork/pipework/downstand beams etc. hinder the distribution of the sound.

Where a suspended ceiling is not available surface mounted units can be used. In this case, source location tends to be easier and occupant reaction less favourable. Source location is likely to be more acceptable if loudspeakers are built into mechanical services which people expect to produce such sound e.g. into perimeter services casings, behind light fittings.

If building occupants accept blatant use of masking sound, individual desk mounted units are available. Office furniture systems are beginning to offer individual units as features. The use of these types of units has however been limited. The use of drive units attached to partitions or other potential sound radiators has been investigated a little. Colouration of the sound tends to occur, but there is scope for more work in this area.

Optional Extras

There are many ways to improve basic systems. For example, time clocks can be used to introduce the system and switch it out gradually. Stepped attenuation can be incorporated. It is often difficult to decide the on/off times and the rate of change of level with time. Introduction over a two minute period is practical, although five minutes is more appropriate where background levels are very low. Other items are signal modulation, secondary spectrum input (useful if ceiling attenuation varies), individual loudspeaker control and monitor speakers. These items are rarely justified but again are available using well established principles.

Variation in Amplitude

Early systems included provision for gradual increase in background level as one approached the main conditioned area. This was done using loudspeakers on a slightly lower output in lift lobbies/entrance halls. However, this has not proved necessary unless the access is part of the same area. Presumably, people entering a new space expect a new thermal, visual and aural environment.

Equally early systems which covered only parts of large rooms tended to suffer from comparison between different areas unless grading of the sound level and evenness in the main conditioned area could be assured.

The flexibility of sound conditioning systems, allowing variation in level and spectrum from area to area seemed a considerable asset. The narrow 'window' in which it is effective has tended to limit this aspect. Nevertheless, adjustment of levels, for example, in and around conference areas in open offices can prove useful.

The Client's View

Introduction of masking sound interferes with communication patterns (that is its purpose if privacy is to be improved). It also goes against the grain to attenuate noise and then feed sound back in again. If we take the definition of noise as unwanted sound, the masking of unwanted sound by a more acceptable sound is effectively noise reduction. That is why it is done. Unfortunately, such a concept is difficult to convey to clients. Experience suggests that clients accept the concept as a result of the influence of practical and cost benefits compared with improvement of partition insulation, or as a direct result of experience of a system, or on trust. The advantage of control of part of the aural environment and some flexibility is often appreciated.

It is helpful to be able to justify the cost of a sound conditioning system (e.g against control of flanking around partitions). But in the case of open office areas, justification is more closely related to amenity which is difficult to cost. The combination of a system with P/A, fire alarm and perhaps music in selected areas tends to make more sense of the cost. If an area is served from above, there is usually a need for more loudspeakers for sound conditioning than would be needed for the other systems.

A sound conditioning system currently tends to cost in the range £2.00 - £6.00 per m^2 of conditioned area dependant on the size of the installation. Of course, much of the cost is the generator and wiring installation. The principles are simple and prices need not be high. There are currently too few firms with experience in this area.

Occupant Reaction

An important question to be considered is the extent to which occupants are made aware of the system. Sometimes people have been fully informed of the presence and purpose of the system. Equally systems have been installed without the knowledge of the occupants. Although it is preferable to inform occupants as, on occasions, this has caused unnecessary alarm. The concept of controlling the aural environment in a similar manner to control of the visual or thermal environment is still not commonly accepted. Offering control of the system to occupants is also very tricky. A period of exposure to the wrong sound level or spectrum or even excessive switching tends to breed antagonism towards a system. There seems to be an uncontrollable urge to blast all the disturbing intermittent noise out of existence by setting sound conditioning too high. The result is that it is offensive in itself. Gradual introduction and strict control has proved very effective to the point where, with a system temporarily switched off, occupants ask for it to be put on again.

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The Main Problems

Perhaps the most difficult practical problem with sound conditioning is knowing when to use it. Frequently mechanical services systems are designed to maximum noise limits. A minimum noise limit is an onerous requirement for the services engineer, where airflow, throw etc. must take priority. We can design services systems with adjustable perforated plates behind grilles (with a penalty of additional system pressure) but this is expensive. If this is not done it is difficult to predict the final services noise level - it may be under e.g NR35 as specified but over the speech frequency range it may well be much lower and of little value for masking. Do we control the background sound level because we cannot guarantee a suitable level from services? If sound conditioning goes in and is not effective when switched on (as the ventilation system or copying machines in an office are already doing the job) it would be embarrassing to say the least. Should all sound conditioning therefore be retro-fit? Experience is beginning to tell us when it is a sensible move to include sound conditioning in a design e.g. where occupational noise is sporadic and natural ventilation is intended, particularly where partitions for good practical reasons offer lower than preferred sound insulation. Nevertheless, several of our systems have gone in as retro-fit where access to ceilings is good and wiring routes are not complex.

A second difficult area is restraining the use of sound conditioning to "cure the problems of open plan offices". It is not difficult to show by reference to speech dot fields/articulation index that achieving privacy in open offices by general masking sound alone is not practical since the levels needed to mask the speech are too high to work with. In conjunction with other controls (e.g good screening, zoning, boundary treatment) sound conditioning can make a contribution - perhaps a 5-10dB improvement in the face of a 20dB problem.

Conclusion

The potential of sound conditioning is considerable if it is carefully handled. The range of applications is limited but important. The danger is that poor systems, using perhaps incorrect spectra, bad sound distribution, or overstretched where other noise control measures would be more appropriate, will damage the development of effective systems.

Whereas introduction of masking sound is not a preferred approach to many of our current noise problems, it has proved a means of solving problems which are very difficult to solve in other ways. As such the author would wish to encourage the development of the practical techniques where there is considerable scope for improvement.

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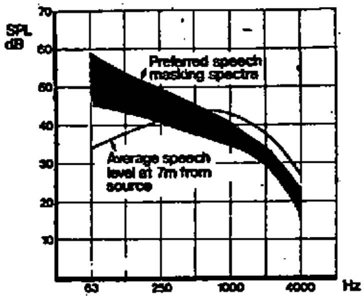

Fig 1 Speech-masking spectrum

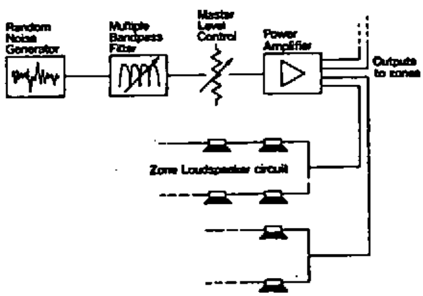

Fig 2 Diagrammatic representation of a typical sound conditioning system

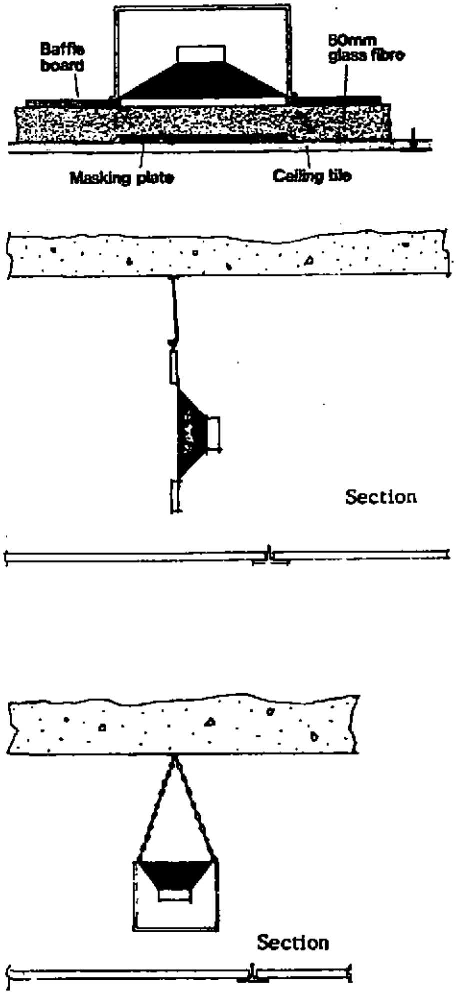

Fig 3 Examples of Loudspeaker arrangements.