SOME CURRENT AND FUTURE APPLICATIONS OF ACTIVE ATTENUATION

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INTRODUCTION

Active noise control is now a well proven solution to many low-frequency industrial and HVAC noise problems. Industrial applications, including fans, vacuum pumps and compressors, often involve wet and corrosive environments, and very high amplitude noise sources. The outstanding advantages which have been recognized over conventional silencers include superior low-frequency attenuation with negligible flow restriction. Low restriction to flow leads to significant energy savings. Additional benefits are low weight and the ability to be fitted into existing duct arrangements.

For commercial office buildings, hybrid active/passive silencers give attenuation over eight octave bands from 31.5Hz to 4kHz. Active noise control systems also have the ability to "shape" the noise entering a room by selective attenuation and thus control its quality and comfort.

BASIC CONCEPTS

The basic concept of active noise control is to create an "anti-noise" acoustic field in a space in order to cancel the existing noise and result in a quieter space. The cancellation of three-dimensional fields is currently under development in a number of laboratories, but the best results obtained so far are by cancelling plane waves travelling down ducts. As shown in Figure 1, a fan, for example, generates an undesired noise wave which travels down the duct. The input microphone picks up the pressure variation and the controller generates a signal to the loudspeaker which will create an opposing pressure precisely when the noise wave reaches the loudspeaker. An "error" microphone downstream from the loudspeaker monitors the residual acoustic pressure after cancellation and signals the controller to adjust itself for optimum results. The controller estimates the delay and amplitude changes from the input microphone to the loudspeaker, including delays in the microphones, loudspeaker and electronics. A widely used control system is the filtered recursive LMS (least mean square), which is described in detail elsewhere.(1)

Once the delay and amplitude changes from the input microphone to the loudspeaker hve been found (formed the 'model'), any pressure wave which reaches the input microphone will be cancelled when it arrives at the loudspeaker. This technique cancels both periodic (tonal) and random plane waves, with preferential attenuation of tones.

The controller also assumes that any pressure fluctuation appearing at the input microphone represents a plane wave which will appear after a delay at the cancelling loudspeaker. A convenient measure of the amount of plane wave energy compared to local pressure fluctuations, is the coherence function of the two microphone signals. Coherence of 0.95 or greater usually ensures good broadband cancellation in excess of 10dB.

A final important requirement for cancellation of random noise is that the acoustic delay from input microphone to cancelling loudspeaker is at least as long as the electrical delay from the input microphone to the radiated cancelling noise of the attenuating loudspeaker. Periodic signals (tones) are a special case where such causality is not required and shorter systems are possible.

HVAC APPLICATIONS

Typical HVAC noise spectra are broadband with low frequencies emphasized, plus a few moderate amplitude tones. The overall noise level is low, usually less than 100 dB, mainly contributed by low frequencies. Air flow velocities are moderate, around 7.5 m/sec, but this requires shielded microphones to reduce incoherent wind noise. HVAC duct cross sections are large, with dimensions typically greater than 1 m. Active noise cancellation is usually limited to below the first cross-modal frequency, so hybrid active/passive techniques are needed to attenuate noise over the full eight octave-band range. Duct break-in and break-out effects must be considered to ensure plane wave noise propagation within the active noise control system. In addition, space constraints often make it necessary to place the active noise control device near abrupt changes of duct geometry, causing regions of turbulence, reflected waves and non-planar acoustic fields, which can limit performance.

Figure 2 shows a hybrid active/passive silencer designed to work in HVAC systems. The unit is typically 2.4 to 3.0 m long, 0.6 m x 0.6 m to 0.6 x 2.0 m cross section and has 25 mm of sound absorptive lining. Both input and error microphones are designed to reject flow noise. Heavy duct wall material (18g steel) reduces break-in and break-out effects, allowing the unit to operate in both noisy and quiet external environments. The systems are also available for round ducts up to 1 m diameter, which have superior break-in, break-out characteristics at low frequencies. Since there is no restriction to air flow, the pressure drop across the silencer is negligible. The electronic unit mounts either on the duct or on a nearby wall.

Figure 3 show typical in-duct measurements of the performance of the hybrid silencer on a forward-curved (FC) type fan. The active part of the silencer works in the first three octave bands, whilst the passive lining works from the third to the eighth band. Only a modest amount of mid-to high-frequency noise attenuation is normally required and this is easily achieved with acoustic lining inside the duct.

Active silencing of HVAC systems not only provides greater low frequency attenuation, it also reduces the load on the fan by up to 40%. Passive silencers with internal splitters typically have pressure losses ranging from 60 to 250 N/m^2. On a typical 7 m^3/s air handler, energy savings amount to up to 2.5 kW. Running, say, 12 hours a day for 250 days a year saves 7500 units of electricity a year on this one air handler, giving good payback of capital costs.

INUSTRIAL APPLICATIONS

Air moving devices used in industrial applications (centrifugal and vane-axial fans, vacuum pumps, compressors or blowers) typically generate tonal noise of high amplitude with in-duct levels greater than 140 dB. Gas flow is high, typically 25 m/s, and there are often suspended solids in the flow stream. Temperatures range from ambient to about 250°C, and the gas stream is sometimes wet and/or corrosive. These ducts are generally unlined due to the nature of the gas stream, permiting a prominent standing wave structure.

Industrial applications have required the development of a range of high-power loudspeakers. Protection of the loudspeakers and microphones from a wet, dirty stack environment is essential for long term performance. A protective membrane material is used to allow transmission of the sound energy into and out of the stack while maintaining a clean, dry environment for the loudspeakers to ensure long component life. Two or four loudspeaker modules, to provide both extra output power and for redundancy, might typically be used.

Whilst the high gas flow rates would, at first sight, seem to require sophisticated flow probes to reduce flow noise, the high amplitude of the tonal noise makes this unnecessary. Also, because the only requirement is to cancel the tonal component, the system length can be reduced.

Some examples of industrial applications are:-

Dust control fan. In a system of in-plant ventilation for dust control, air was drawn from the plant through dust-collecting bags before discharge to atmosphere through a 600mm diameter duct. The radial blade paddle wheel fan which moved the air had a high tone at 120Hz, causing neighbourhood disturbance, especially at night. The solution to the problem was an active attenuator system employing two loudspeakers as indicated in Fig 4. The performance is shown in Fig 5, giving a pure tone reduction of 32dB. This installation has been in operation since January 1987.

Vacuum pumps. These are used in the paper industry to draw water from the paper slurry. Two pumps with a combined capacity of about $10m^3/s$, discharging to atmosphere through a 450mm diameter pipe, caused noise at harmonics of 30Hz, with highest levels at 120Hz. An active attenuator reduced the level at 120Hz by 37dB. The system is shown in Fig.6 and its performance in Fig.7.

Other industrial applications include:

Incinerator. In a 500mm diameter discharge stack at 82°C, a 27dB reduction of the 235Hz blade passing frequency was achieved.

Material handling fan. 20dB far field reduction of 198Hz fan tone was obtained for a cyclone handling paper scrap.

Rotary pumps. Vacuum pumps at a paper mill, discharging into a 1320mm vertical stack, produced tones at 89Hz and 94 Hz. Active attenuation gave a 20dB reduction of the two tones.

These examples have shown that active attenuation is now an established technique for HVAC and industrial applications, but in order to develop further, and finance continuous work, attention must be given to a wider range of applications.

THE FUTURE DEVELOPMENT OF ACTIVE ATTENUATION

The future of active attenuation must lie in its development for large volume products. In some senses the future is already here. Active attenuator headsets and ear defenders are available from several companies in the USA and Europe for military, aviation and industrial use. It will not be long until active attenuator vehicle mufflers are a standard option, whilst car interior active noise control has recently become available as an option on a production vehicle.

Further developments will be towards active control of consumer products, whilst not neglecting improvements in present systems, e.g. control of higher order modes in ducts. The large volume products to which active control is likely to be applied include:-

Vehicles	-	exhaust mufflers interior noise control, including aircraft vibration control active seat and other suspensions road tyre noise
Fans	-	a large number of small fans are in use including for: extracts e.g. kitchen air blowers e.g. fan heaters room air conditioning e.g. wall units
Domestic equipment	-	clothes washers dish washers refrigerators freezers central heating
Horticultural equipment	-	mowers trimmers
Leisure equipment	-	jet ski motor boats
Industrial	-	machinery noise and vibration protected zones for workers

In addition to these applications, active noise and vibration control will continue to make steady development in the building services industry. The energy efficiency of "straight-through" hybrid silencers has already been recognised and it cannot be long before there is a major installation. The application of active mounts to plant room machinery, or to floors, will reduce many of the current building vibration problems.

The technical and commercial effort which has been put into active attenuation over the past five years is showing results. The active attenuation industry continues to be progressive and confident. The next few years will show considerable further progress.

REFERENCES

(1) L J Eriksson, M C Allie System considerations for adaptive modelling applied to active noise control. Vol 3 p 2387 Proceedings IEEE ISCAS '88

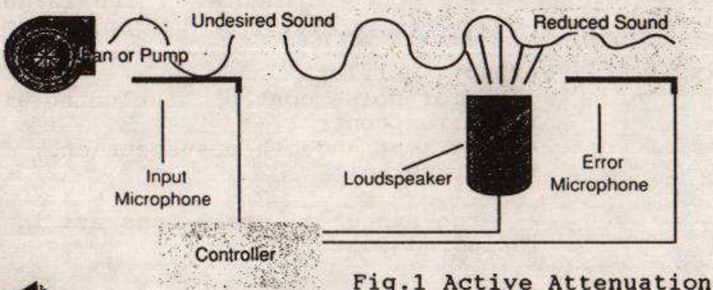

Fig.1 Active Attenuation Duct System

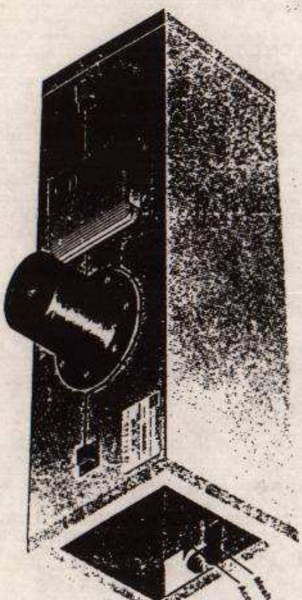

Fig.2 DIGIDUCT

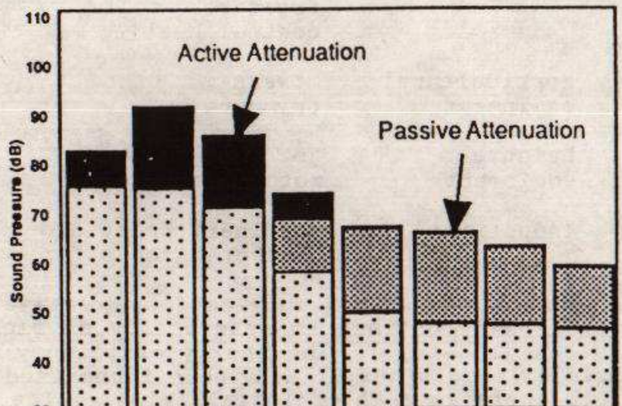

Fig.3 Attenuation of DIGIDUCT

APPLICATIONS OF ACTIVE ATTENUATION

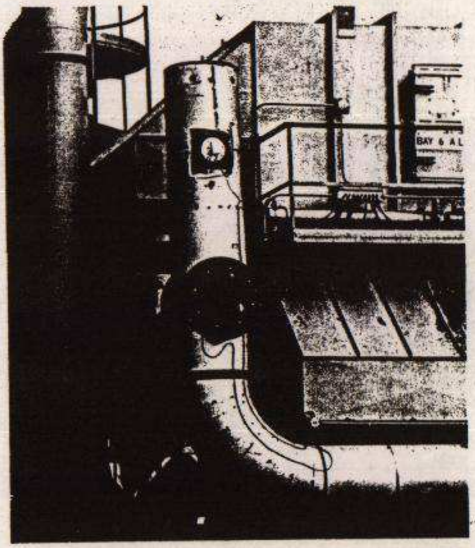

Fig.4 Dust control fan installation

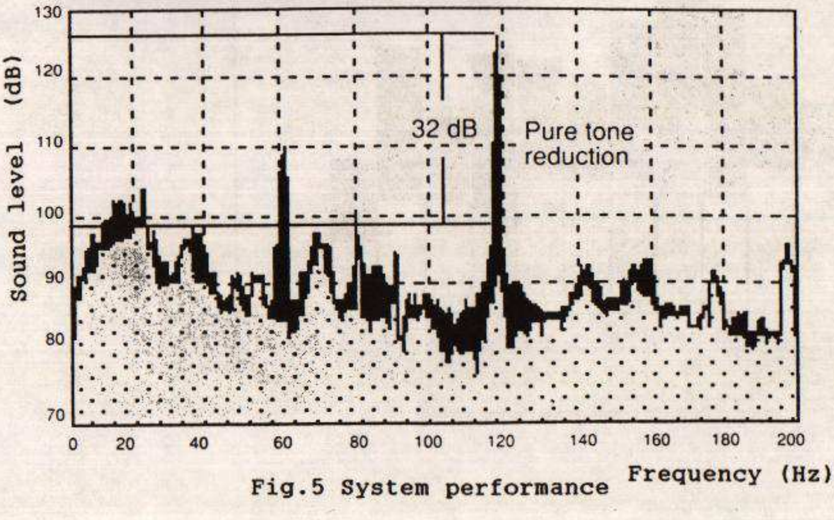

Fig.5 System performance

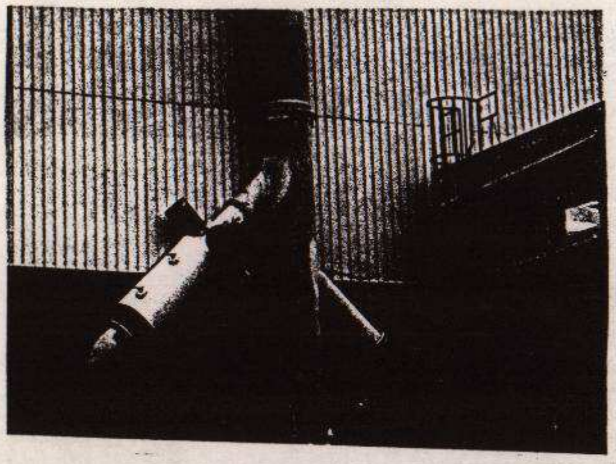

Fig.6 Vacuum pump installation

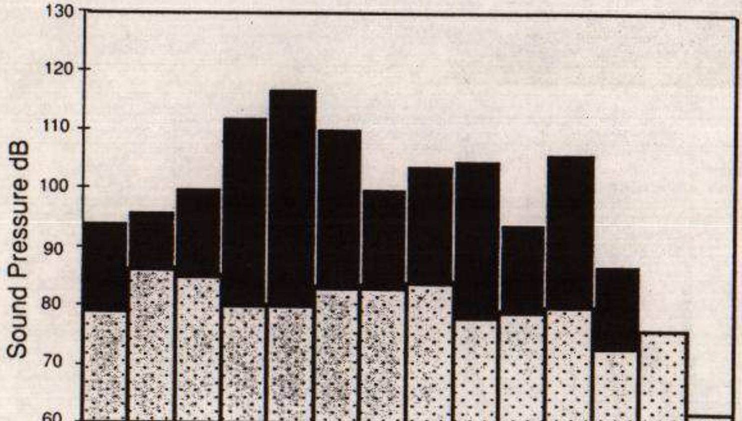

Fig.7 System performance