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LOUDSPEAKERS IN ACTIVE ATTENUATION

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INTRODUCTION

Loudspeakers used in active attenuation may be required to operate outside the regimes for which they were designed. This is particularly so for electromagnetic loud speakers, where bass units developed for reproduction of sound in normal environments have been employed at their power limits in adverse conditions.

LOUDSPEAKER SELECTION

Standard bass units are a popular choice for active attenuation and are satisfactory in both power output and reliability for many applications. If a duct of 1m area has an internal noise level of 120dB, this corresponds to an intensity of $1W/m^2$ and the cancelling source must radiate a power of 1W. Many low frequency units have a power handling capacity of 200-400W, so that only a small efficiency is required to give the output level.

Arrays of loudspeakers are used to couple into large, high power sources. For example, if additional low frequency attenuation is required on a gas compressor stack, which might have an outlet several metres in diameter, a large number of cancelling loudspeakers are required to give both the output power and source configuration for attenuation. The estimation of the number of loudspeakers required is shown below, but more than the minimum number must be used, since the life of a loudspeaker is shortened if it is run at its maximum deflection.

If conventional loudspeakers are to be operated in difficult environments e.g. high temperature or humid, special precautions must be taken in the design. For example, high temperature, water resistant adhesives are used at the cone/coil connection and a paper cone sprayed with a protective layer. Cyclic heating and cooling of loudspeakers enclosures located in the open will result in condensation, and drain holes must be provided to prevent build-up of water in the enclosure. In cases of extreme heat e.g. a hot gas compressor silencer, the loudspeaker cones must be protected with a heat shield, whilst a flow of cooling air past the shield. may also be necessary. However it is also possible to use a loudspeaker on a stub to remove it from the extreme conditions, although the space required for this is not always available.

POWER AMPLIFICATION

The sound output from the loudspeaker depends on the cone deflection, but the amplifier power required to achieve this deflection depends on both the deflection and the enclosure volume. At very low frequencies, the speaker will be working in a stiffness region controlled by the enclosure volume, V, which has stiffness proportional to 1/V. Thus, a reduction in enclosure volume increases the stiffness against which the power amplifier has to work, leading to greater current drain from the power amplifier, increased heat dissipation, in the loudspeaker coil and the problems of reliability which result from this. There may be a further economic penalty in the need to use a larger amplifier than would have been necessary with a greater enclosed volume. Therefore, every effort should be made to maximise the enclosure volume, particularly in high power applications.

NUMBER OF LOUDSPEAKERS REQUIRED

Consider each unit as a monopole source. The r.m.s. pressure at a distance, r, for frequency, f is

$$p = \rho \pi f^2 (Ad)/r$$

Where A is the effective cone area and d is the r.m.s. displacement. (Ad) is the swept volume. The power of the source is

$$W = \frac{\rho}{c} 4\pi^3 f^4 \ (Ad)^2$$

which leads to a sound power level

$$SWL = 40 \log f + 20 \log (Ad) + 117 \text{ dB} \ldots\ldots (1)$$

This gives the required value of swept volume, which by comparison with that of a single loudspeaker, gives the number required. Here, SWL, in equn.(1) is assumed to be the power of the noise source, which is an averaged value. For a typical random source the peaks may be 5-10 dB above this, which must be allowed for in choosing the number of sources i.e. increase the number calculated from equation (1) by 2 to 3 times.

LOUDSPEAKER ACTION IN PRESENCE OF AN EXTERNAL FIELD

It can be shown that the electrical impedance of a loudspeaker is.

$$V/I = Z_E = Z_{EB} + (Bl)^2/(Z_{mo} + Z_r)$$

Where Z_{EB} is the blocked electrical impedance, Z_{mo} the open circuit mechanical impedance, Z_r the radiation impedance, B the field in the air gap and l the coil length. The last term is the motional impedance.

Changes in radiation impedance affect the motional impedance and hence the total electrical impedance. If a loudspeaker is radiating into free space and moves to produce a compression whilst a compression is passing the speaker, the forces are in opposition and greater current is required to maintain the motion (Fig 1). Assuming constant voltage, the increased current leads to a reduced electrical impedance. Conversely, if a loudspeaker generates a rarefaction when the passing wave is a compression, the external wave assists the motion, leading to a reduced drive current and increased electrical impedance. The passing wave gives energy to the loudspeakers and is 'absorbed'. Active attenuation has occured. The absorbing action leads to a pressure 'zero' at the loudspeaker which does not radiate and, ideally has zero radiation impedance whilst acting as an active attenuator.

In a small loudspeaker (0.08m diameter) the impedance change was about 0.2ohm in 4ohm at 300Hz, whilst acting as an active attenuator. The impedance can vary more widely, and even go to infinity. This occurs with high external sound fields and low drive currents when the back e.m.f. caused by generator action just balances the drive current and the current drawn goes to zero (Fig 2)

ALTERNATIVE SOURCES

Air Modulated. These have high power, but require large amounts of high pressure air, and are normally used in high intensity acoustic testing, discharging into an enclosed chamber.

Servo drive. This is a recent development in low frequency high power loudspeakers, in which the conventional coil and magnet are replaced by a high speed servomotor driven by the power amplifier. Motor rotations are converted to a linear motion which drives the radiating cones. Peak to peak deflections are about 30mm, compared with 10mm for a typical bass unit. The sensitivity below 125Hz can be 105 dB per watt at 1m, whilst a bass unit might give 95-100 dB.

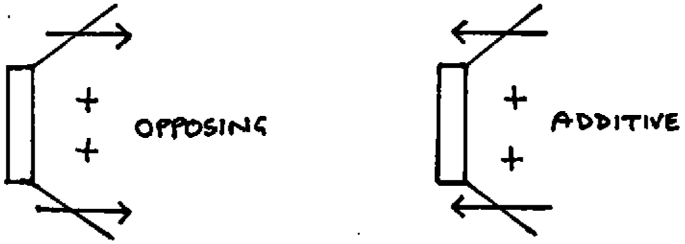

FIG 1. LOUDSPEAKER AND EXTERNAL FIELD

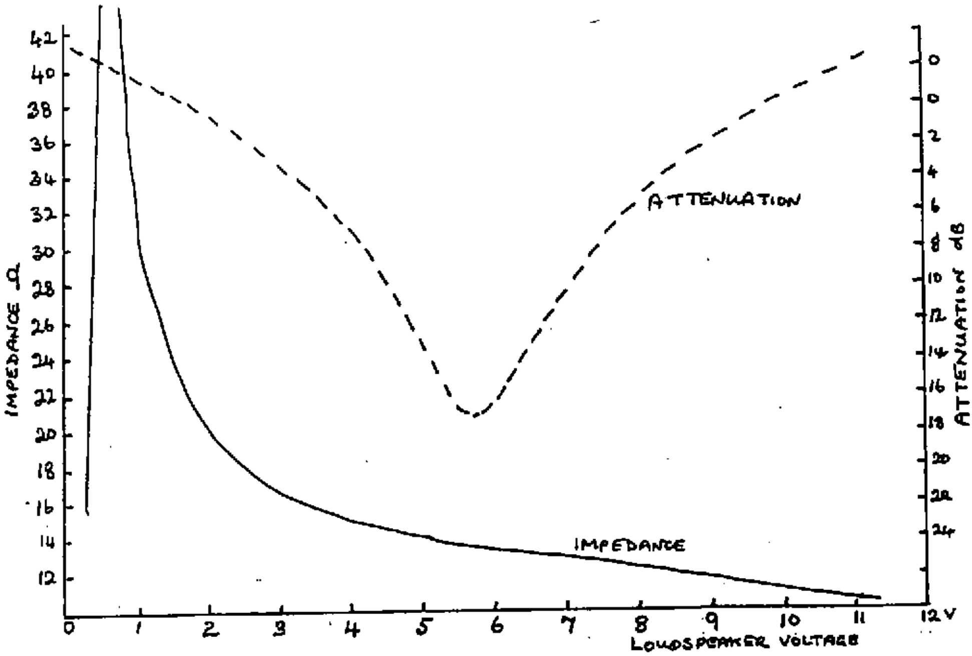

FIG 2 IMPEDANCE, ATTENUATION
AND INPUT LEVEL AT RESONANCE
(104 Hz)