Electret microphones in the field; care and the effects of the environment and damage

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Much technical literature exists regarding the performance of pre-polarized electret microphone capsules, yet information regarding their practical use in the environments typical of noise measurements is often overlooked. Considering the fragile nature of these devices and their susceptibility to damage, or at least detrimental effects to their performance by the operating environment, such information is vital to the user in order to ensure reliability of measurements.

Physical design features

One of the most affecting design features of the electret condenser microphone is the pure Nickel membrane, which is typically 0.003mm thick, highly tensioned and, consequentially, very fragile. Functionally, the membrane presents a physical barrier between the outside air and the capsule inner chamber and must be thin enough that even a minuscule 0.0002Pa (20dBA) pressure differential between the two spaces causes deflection of the membrane. A 20-25μm air gap, roughly four times smaller than the width of a human hair, separates the membrane and the backplate inside the capsule. Variation in the membrane displacement then alters the distance between the two surfaces and therefore the capacitance. While a flexible membrane material would give a high displacement per unit pressure and thus a higher sensitivity, such a material would have a poor response to high frequencies.

Common causes of physical damage

It is of utmost importance that the membrane is never P30

Figure 1a & 1b (left, centre): Capsules with torn diaphragms used in tests. Figure 1c (right): Capsule with obvious wrinkling, most likely caused by dropping

◄P28 touched, even for cleaning. By simple analysis, placing one's finger evenly over the membrane of a ½" capsule (working diaphragm area c. 50mm²) with a force of 1N (100g) would exert a pressure of 0.02N/mm². Working in more typical acoustic units, this is 20000Pa; the equivalent of an 180dB peak acoustic wave! In practice, with this level of force, the membrane would in fact be pushed onto the surface of the backplate. Any significant contact force upon the membrane can cause permanent deformation of the membrane and thus tension; capsule sensitivity will then increase at the detriment of the high-frequency response. The only cleaning procedures recommended are the use of very light blasts of air, then liquid solvents and, when absolutely necessary, very gentle use of solvent-soaked cotton wool to remove stubborn particles.

The unavoidable fragility of the membrane and the high shear forces exerted upon it due to the manner in which it is attached and tensioned result in tears being quite commonplace following rough handling or accidental damage. Overly quick removal of a calibrator is enough to cause the membrane to be torn; it is also commonplace for such tears to be invisible to the naked eye. Even more surprising is that the capsule will still function as a microphone, producing quite believable measurements. The charts seen in figure 2 are capsules with entirely torn membranes, measured acoustically at 94dBA using a B&K 4226 multi-frequency acoustic calibrator.

Due to the relatively unchanged response at mid frequencies, users may experience an apparent successful calibration. When performing measurements, if low frequencies are measured lower than might be expected and eccentric measurements are seen in the high-frequency ranges, a visual inspection of the membrane is the first point of call; however, while severe damage is easy to spot, slight damage is not. A torn membrane of any size can be detected by pressure testing, although it is readily appreciated that the sensitivity and accuracy of the pressures involved requires specialist equipment.

In order that the membrane is held as ideally flat and parallel to the backplate as possible, the top surface of the body to which the membrane is attached is extremely flat, on a par with that of optical surfaces. Dropping the capsule can cause deformation of the body, possibly resulting in clear wrinkling of the membrane, as seen in figure 3, which displays a 25μm trough depth. While these features are obvious (the capsule failed to attain type-2), visual inspection may fail to realise similar defects from lesser levels of damage. For example, take the visually perfectly flat membrane of a good capsule... now consider figure 4... that 3μm 'bowing' is perfectly normal, caused by the electrostatic attraction of the electret upon the membrane and essentially undetectable to the naked eye; visual inspection sometimes is not sufficient to determine whether damage has been caused.

More severe cases of damage from dropping can cause the sapphire – the component providing electrical insulation between the casing and contact pin – to crack. This can also occur from over-tightening a capsule onto the pre-amplifier contact (although using properly-designed, IEC-specification equipment, this should never be possible). This does not necessarily render the capsule entirely non-operational; the major problem is the increase in air leakage through the sapphire. Capsules incorporate a very narrow 'bleed' capillary to allow for pressure equalisation; sub-10Hz waves are of sufficient period for the pressure wave to propagate through the bleed during the wave period; hence, low frequency response tails off toward zero. Hairline fractures in the sapphire 'could' have very little effect, but a shattered one would be expected to exhibit poor response below 100Hz. As the sapphire is the mounting for the backplate, the air gap distance could also have altered, which could decrease or *increase* the sensitivity.

Outdoor applications can see a capsule being placed in a harsh, dirty environment and regular cleaning is often required; the effects of dirt and corrosion are of current investigation.

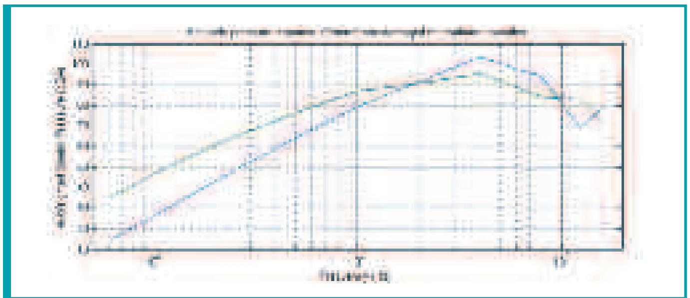

Figure 2: Performance of membrane-damaged capsules

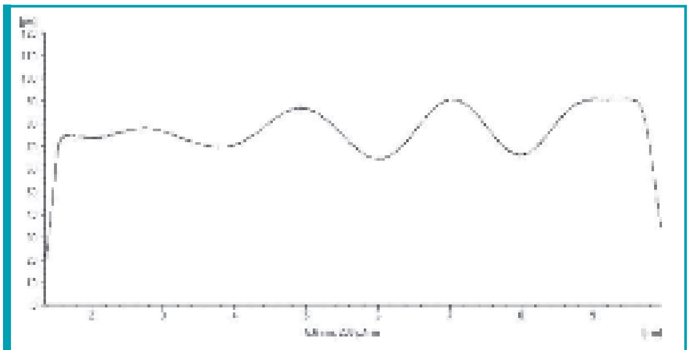

Figure 3: Membrane profile of a dropped capsule

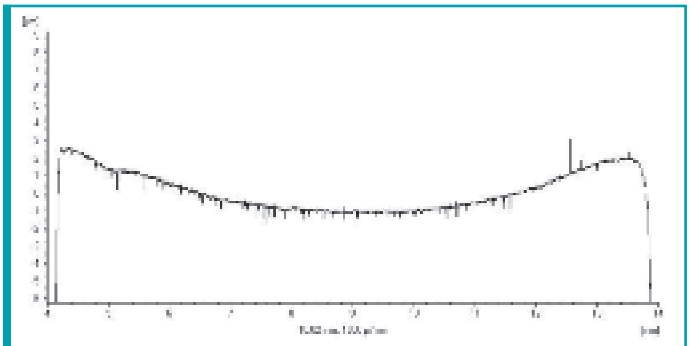

Figure 4: Displacement of the membrane on a good capsule

Conclusions

Much older sound level meters, with entirely analogue electronics, will exhibit drift over time; while this is slightly less of an issue with modern, digitally-controlled equipment, the microphone capsule remains fundamentally the same design. Regular calibration is intrinsic to the use of sound level metering equipment to ensure that the stringent specifications of IEC 61672-1:2002 are being held to. With the increased reliability over time of the electronics, it is generally more common for the cause of an out-of-specification metering system to be the capsule.

Microphone capsules are devices that require high levels of care in use. Typical damage caused to a capsule may not be immediately visible, nor detectable by a basic 1kHz calibration on a SLM and consequent measurements following damage to a capsule will have dubious reliability. It is highly advisable that, after any suspected damage, the frequency response of the capsule is investigated for the characteristics of damage as described; this should at least indicate that there may be reasonable worth in having the capsule properly tested.

This article continues in the next issue when it will look at the effects upon performance, and the problems that can arise from various environmental conditions.