# Low Frequency Calibration of Measurement Microphones

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The calibration of measurement microphones below 100 Hz is not very well covered by the present IEC standards. The uncertainty increases rapidly and for very low frequencies it goes toward infinity. This paper approaches this issue and presents a unique way to verifying and calibrating the low-frequency response of measurement microphones. Using a small isolated calibration volume and applying a constant force to a large piston inside this volume, you obtain a direct proportional relation between force and sound pressure, allowing calibration of measurement microphones down to 0.01 Hz.

## 1. LOW FREQUENCY MEASUREMENTS

Modern technology has caused a more frequent occurrence of low frequency sound phenomena. Thunder, water-falls and wind are sources in nature, but human activity has added many more sources causing distress and annoyance among people sensitive to low frequency sound. Heavy machinery and traffic often produce sound of a continuous cyclic character while aircraft take-off, sonic boom, pile driving, and blasting produce single events of an often startling nature.

The very long wave length associated with low frequency waves e.g. 170 m (500 feet) at 2 Hz, makes it very difficult to absorb the energy of the travelling wave. Very low frequencies may travel thousands of kilometers. Free field conditions do not exist and in dosed volumes isothermal to adiabatic conditions play an important role.

The measurement of low frequency sound pressure levels calls for special instrumentation not described in the present standards for sound level meters. Sound level meters are only specified for use in the frequency range above 20 Hz. At 20 Hz the tolerance of the weighting is ±2.5 dB and proper standardized calibration procedures including the microphone are non-existing. The consequence is the jump in standardized hearing threshold curves based on discrepancies in measurements reported over many years. Fig.1

In order to measure perceived sound pressure levels at the threshold of human hearing, one should cover the frequency range down to 2 Hz and a dynamic range from 120 dB at 2 Hz and up to the maximum level one is interested in. As seen from fig. 2, the equal loudness level contours cover a range of more than 140 dB for full coverage of measurements involving humans.

The instrumentation used to measure the sound pressure in the infrasound range 2 - 20 Hz must be able to measure correctly in this frequency range. A normal type 1 sound level meter is not well suited. The tolerance on the frequency weighting alone below 20 Hz is ±3 dB and at 16 Hz it is +5 - ∞. This does not include the microphone in most calibration situations. The database on which the ISO 226-2003 is based may thus be rather vague at 20 Hz, which may explain the lack of continuity in the

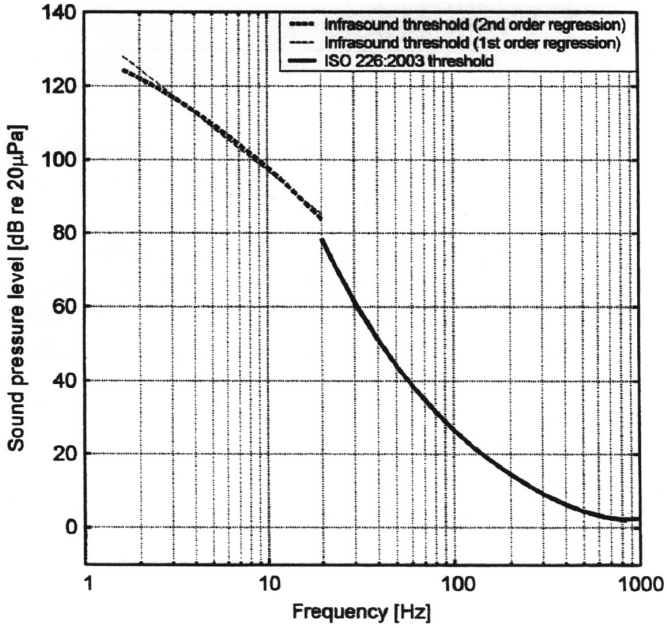



*Figure 1. Stndardized hearing threshold above 20 Hz (IS0 226:2003) and proposed normal hearing thresholds for frequencies below 20 Hz*

equal loudness contour curves shown in fig. 1. The data trace for the infrasound equal loudness contour level may be considered more realistic, as the experimenters may have been more aware of the instrumentation requirements.

Sound measurements are nearly exclusively made by use of condenser microphones. The operational principle makes this microphone type ideally suited for sound measurements. When calibrated at a single frequency - preferably 250 Hz - one may have a high degree of confidence in the performance over a wide frequency range from 20 Hz and up. The required tolerances for sound level meters are easily obtained by simple mechanical means and by easily controlled normal production tolerances. Obtaining an extra decade in the low frequency range is more critical.

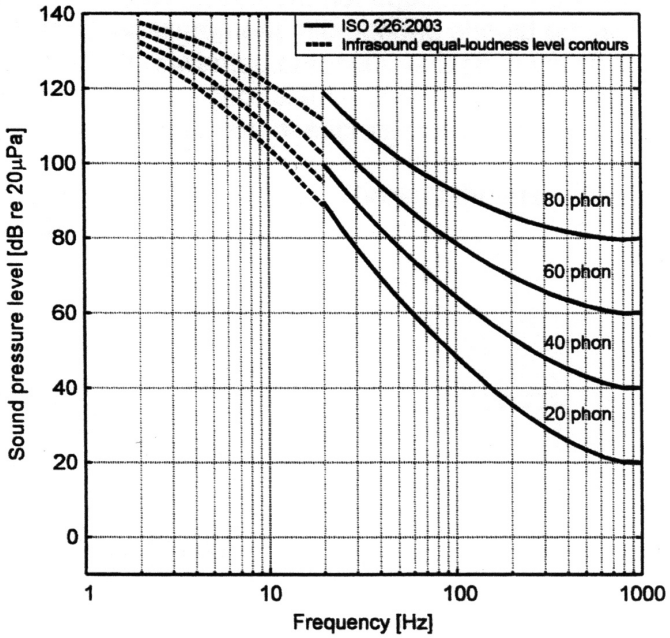



*Figure 2. Proposal of equal-loudness-level contours for the infrasonic region together with standardized contours above 20 Hz*

The lower limiting frequency of a condenser microphone is acoustically controlled by the internal volume of the microphone and air equalization vent which ensures that small atmospheric variations are equalized while fast sound pressure variations are not equalized because we want to measure them. A good measurement microphone should equalize as fast as possible in order to cut off unwanted pressure variations which surround us in many ways. Wind turbulence - door slam - floor movements etc. The normal cut off for many high quality measurement microphones is 3 - 5 Hz.

For infrasound it should be 0.1 - 0.5 Hz. The way the microphone is used is also important. See fig. 3.

Infrasound microphones would normally be specified to be linear in the frequency range 1 - 20 Hz. However, special microphones like some intensity microphones may be linear in the 0.2 - 20 kHz range or simply convertible from equalized to the front - to the rear - or closed.

This would enable a 1" microphone with large sensitivity to withstand large variation in atmospheric pressure and yet allow it to be used for near static pressure variation and calibration with a simple change in configuration.

High quality analog preamplifiers with an input impedance of 40 GΩ may be used to measure to below 0.2 Hz. For near static measurements a carrier system should be used.

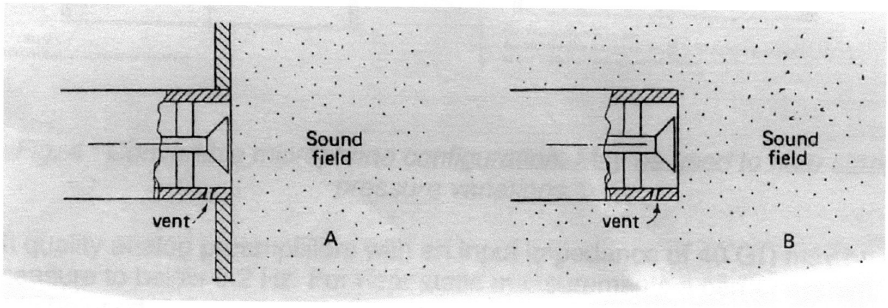



*Figure 3. A. The equalization vent screened from the sound field. B. The equalization vent open to the sound field*

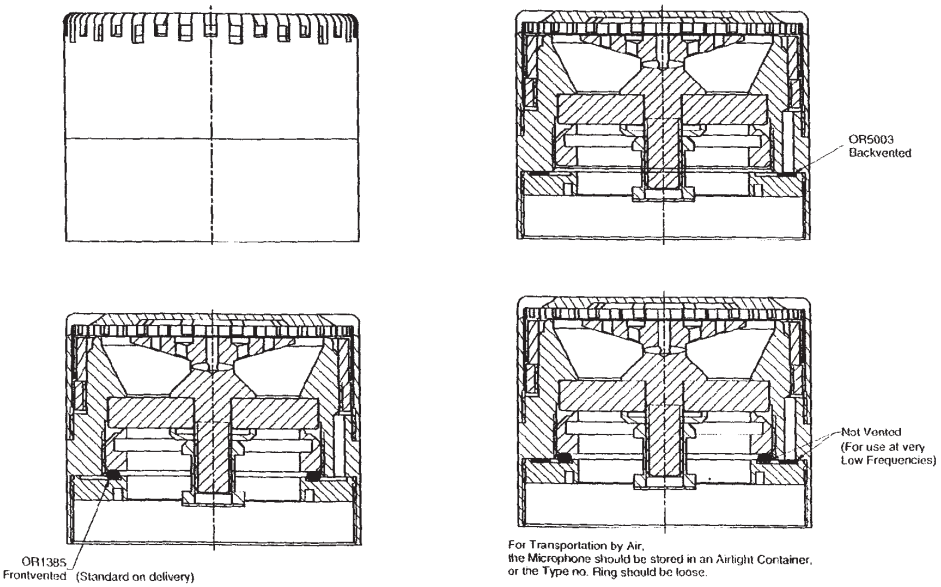



*Figure 4. Convertible microphone configuration. May be used to near static pressure variations*

## 2. CALIBRATION OF MEASUREMENT MICROPHONES

For calibration of low frequency systems it should be kept in mind that 1 m of shift in altitude represents a change of 12 Pa = 106 dB 10 cm or 4 inches are equivalent to 97 dB.

The calibration of a complete low frequency system is carried out by using a pistonphone at 250 Hz together with a measurement microphone and a low frequency calibrator like e.g. G.R.A.S. 42AE for calibration from 100Hz down to any desired low frequency limit.

A typical response of a 1" measurement microphone is shown in fig. 5.

The low frequency calibrator which nominally allows calibration to below 0.01 Hz is shown in figure 6. The calibrator will deliver a constant level of Pa independent of thermal heat exchange and system leaks over a wide frequency range up to above 100 Hz.

When measuring low frequency noise the selection of transducer is very important. The 1-inch microphone capsule can be sealed tightly to make measurements near static pressure variations, but today the most common

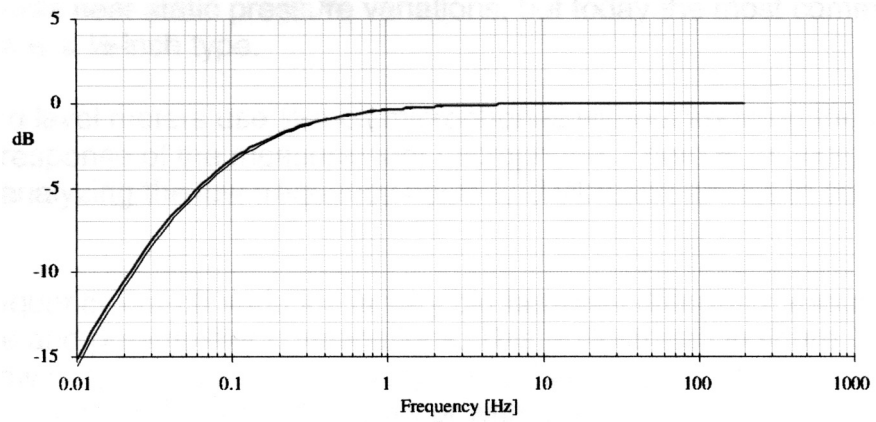



*Figure 5. Microphone and preamplifier combined cut-off measured with a sealed 1-inch microphone and with a 50pF dummy*




*Figure 6. Low frequency calibrator, Type 42AE*

microphone is a 1/2-inch type.

Many sound level meters use 1/2-inch microphones without knowing the low frequency response of the measurement microphone. There is an increased interest in analyzing the low frequency noise and vibration effects in our modern society.

The low frequency cut-off variation is very big between different measurement microphone and preamplifier combinations. This is illustrated in figure 7. When using the low frequency calibrator, every microphone type from 1-inch and down to 1/8-inch can be calibrated individually or with a preamplifier combination.

The low frequency response is given by the electrical cut-off by the preamplifier and the acoustical cut-off by the microphone capsule. It is possible to separate each of these contributions. The results are shown in figure 8 below. The preamplifier is measured with a 20pF load equal to a standard 1/2 inch measurement microphone.

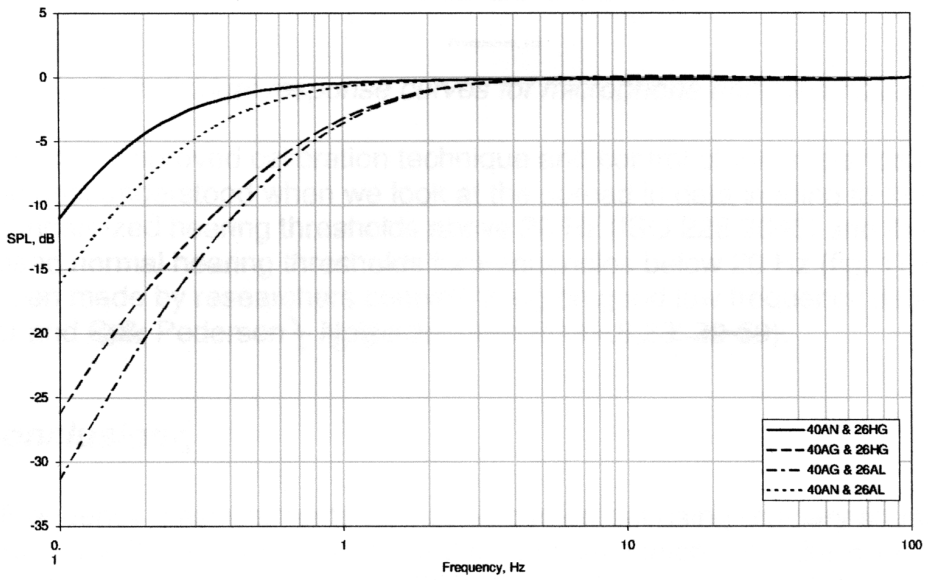



*Figure 7. Microphone and preamplifier combined cut-off for different combinations*

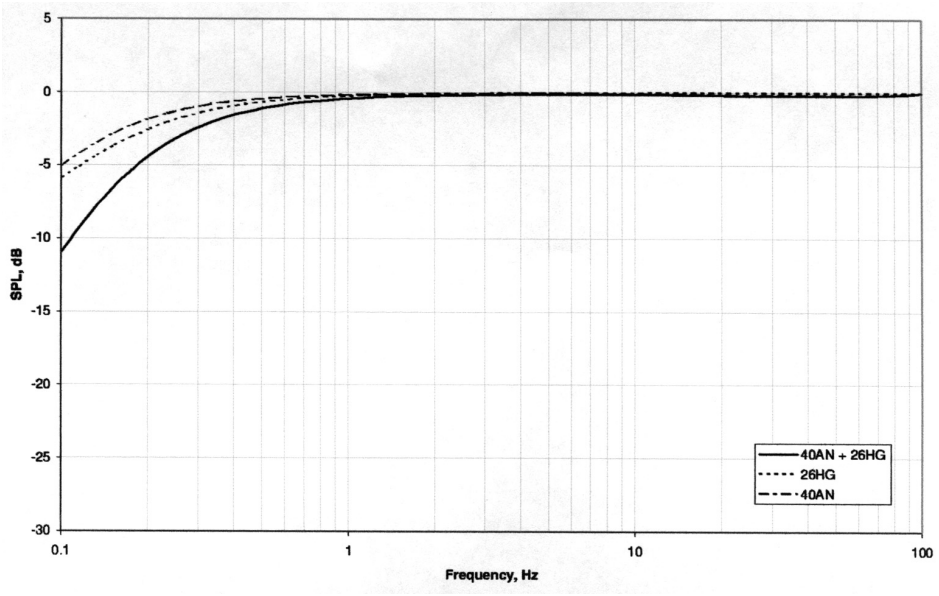



*Figure 8. Individual response curves for microphone and preamplifier*

The need for improved calibration technique and control of the tolerances is maybe best understood when we look at the spread in data leading to the jump in the standardized hearing thresholds above 20 Hz (ISO 226:2003) and the proposed normal hearing thresholds for frequencies below 20 Hz (fig. 1 ) which has been made by researchers concentrating on good low frequency data (Møller and Pedersen)

## CONCLUSIONS

Low Frequency measurements cannot be carried out using ordinary sound level meters below 20Hz. The present standardized calibration procedures do not cover the frequency range below 100Hz. Free field measurements below 100Hz require careful calibration using a low frequency calibrator.

## REFERENCE

Møller H and Pedersen, C. S., Noise and Health, 6:23, 39-50 (2004).

**WIND POWER: POPULAR BUT NOISY-SURVEY**

A survey in Rhode Island shows that 89% have positive opinions on the use of wind turbines to generate electricity, but 50% rate the cost of wind as an important issue and 44% say noise is an important consideration.

**TOILET NOISE BOMB SCARE**

Patients were evacuated from a ward in Royal Perth Hospital (Australia) after a suspicious noise coming from a female toilet sparked a bomb scare. A staff member reported hearing the noise coming from the ward's female toilets and police were called. Patients and ward staff were evacuated while the bomb squad investigated the source of the noise. A police spokesman has confirmed nothing suspicious was found and patients

**NOISE PAYS FOR POLICE**

Drivers in the northern Indiana city of Elkhart may want to think twice about pumping up the volume on their car stereos. The city is aggressively enforcing its noise ordinance, which carries a fine of up to $2,500 for repeated violations. More than 1,100 citations have been issued so far this year. Police Lt. Ed Windbigler says the department is using two unmarked Mustangs to catch violators and has created a full-time position to enforce the ordinance. The city has also spent $16,000 on billboards warning drivers of the rule. Money from noise ordinance tickets has paid for police cars and enforcement efforts. Windbigler says the city is cracking down on noise because it's one of the biggest complaints from residents.