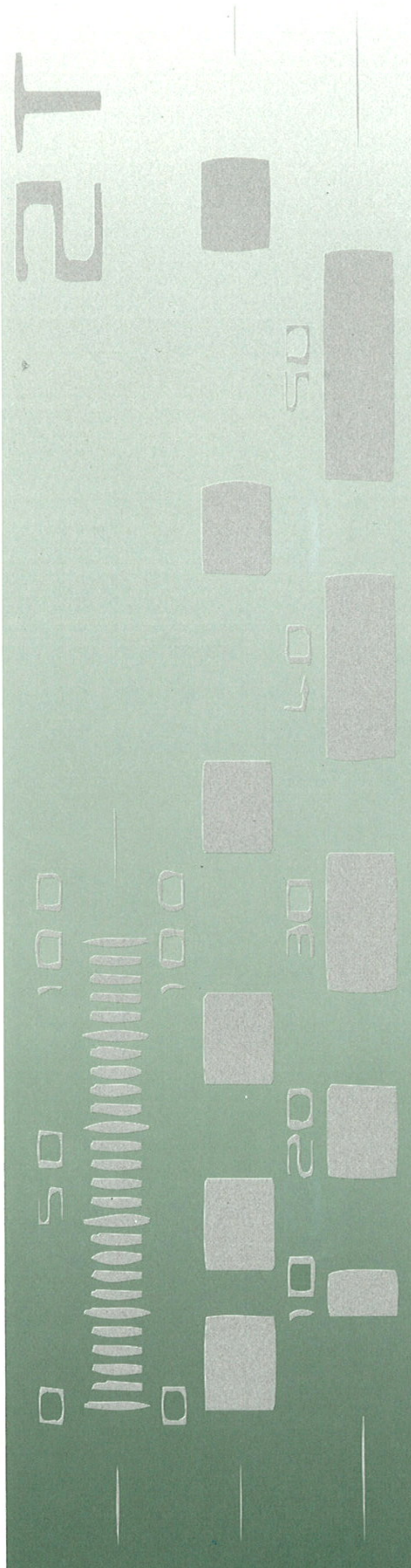
NPL REPORT CMAM(EXT) 007

REPORT

A method for determining the accuracy of sound level meter peak pressure measurements

David Aldridge

September 1997



NPL
National Physical Laboratory

NPL Report CMAM(EXT) 007

September 1997

A method for determining the accuracy of sound level meter peak pressure measurements

David Aldridge
Centre for Mechanical and Acoustical Metrology
National Physical Laboratory
Teddington
Middlesex
United Kingdom
TW11 0LW

ABSTRACT

The accurate measurement of peak sound pressures is important for the audiological protection of workers exposed to high sound pressures and both British and European legislation imposes requirements on employers to measure high level impulsive noise and to take remedial action where necessary. However no test exists to verify the performance of the measuring equipment used at these high levels and to ensure that the measurements are consistent across Europe. This report describes the basis for a method of determining the accuracy of sound level meters when exposed to acoustical impulses from minor explosions (blank-firing pistols) by comparing the response of the meter to that of an accurate and well calibrated microphone exposed to exactly the same pressure.

Results are given for a Brüel and Kjær type 2135 sound level meter exposed to sound pressure impulses with peak pressures in the range 6 to 650 Pa (about 110 to 150 dB peak). These results show that, with its normal microphone, there is a drop-off in sensitivity of at least 2 dB between 130 and 150 dB SPL, such that a peak pressure of 200 Pa would read 138 dB peak on the meter display instead of 140 dB peak. When a low sensitivity microphone is attached to the meter this drop-off is not seen. If this meter were being used in industry, peak pressures of up to 250 Pa might not be recognised at being over the 200 Pa peak action level specified in legislation.

It is recommended that an amendment to current international Standards is sought so that type-tests for sound level meters include tests similar to those presented here.

ISSN 1369-6785

National Physical Laboratory,
Teddington, Middlesex, UK, TW11 0LW.

Approved on behalf of Managing Director, NPL,
by Dr G R Torr, Head, Centre for Mechanical and Acoustical Metrology.

CONTENTS

1 INTRODUCTION

The accurate measurement of the peak pressure of impulsive sounds, and the subsequent protection of workers from potentially harmful peaks, is important for maintaining the audiological health of those who are exposed to such peaks. Recognising this, current British[1] and European[2] legislation includes a 'peak' action level of 200 Pa (equivalent to a peak-hold reading of 140 dB on a sound level meter), requiring employers to measure peak sound pressures and take action if employees could be exposed to such pressures. However, the sound level meters used to make these measurements are not usually calibrated at such high levels, and verification tests on the meters only use electrically simulated signals and not real acoustical inputs to the microphone.

A method of assessing the accuracy of a sound level meter when measuring peak sound pressures around 200 Pa from impulsive sources was sought. Initially it was hoped that a reproducible impulsive source could be found but after exploring many options[3] no practical source could be found and it was decided that any calibration would have to be by simultaneous comparison with a well characterised measurement microphone.

Comparison techniques for the pressure calibration of working standard microphones have been under development at NPL and other national metrology institutes recently[4]. Simultaneous methods (ie those where both test and reference microphones are exposed to the sound field at the same time) have proved useful and accurate for determining the *pressure*[a] sensitivity of microphones but are less useful for determining the *free-field*[b] sensitivity because the diffraction around one microphone would influence the pressure at the other microphone.

When calibrating a sound level meter it is usually the free-field response that is required, however for measuring the peak pressure of an impulsive sound, the pressure response is more appropriate. This is because, for normal incidence, the peak of the sound pressure will arrive at the microphone and be registered by the meter before any reflection of that peak can arrive from the body of the meter and influence the measurement. A reflection from the body may arrive at some time later but by then the direct sound will be less and the combination is unlikely to be greater than the peak already recorded. Therefore the pressure response is more likely to represent the true peak pressure in the field and a method based on a simultaneous comparison with the pressure sensitivity of a working standard microphone was chosen.

An arrangement for simultaneous comparison of a sound level meter against a reference microphone is shown in Figure 1. Such a method requires both a well characterised reference microphone and a high level impulsive sound source. Two calibration methods[5,6] were developed for microphones used at high sound pressures and a measurement microphone type WS2 was characterised in order to establish its accuracy and linearity up to 150 dB re 20 μPa. Impulsive sounds were generated by a range of blank firing pistols.

In this method the microphone and sound level meter are both used with their respective microphone grids. There will be some uncertainty caused by the presence of the grids but as the microphones are not enclosed in a small cavity this will be small compared with other uncertainties. Many microphones fitted to sound level meters do not have removable grids so any other arrangement would be impractical.

---

[a] The pressure response gives the sound pressure on the diaphragm while the microphone is in the sound field.

[b] The free-field response gives the sound pressure, at that point in the field, in the absence of the microphone.

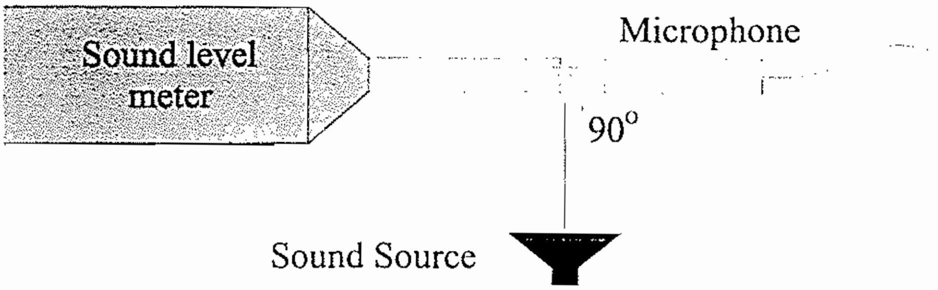


Figure 1. Microphone and sound level meter configuration

2 METHOD

To demonstrate the method a sound level meter (a Brüel & Kjær type 2135, fitted with an attenuator type ZF0020 where necessary) was calibrated by comparison with a working standard microphone (a Brüel & Kjær type 4134). The two devices were mounted in a free field room on a jig which suspended them in mid-air and allowed alignment of microphone relative to the sound level meter. A photograph of this jig is shown in Figure 2.

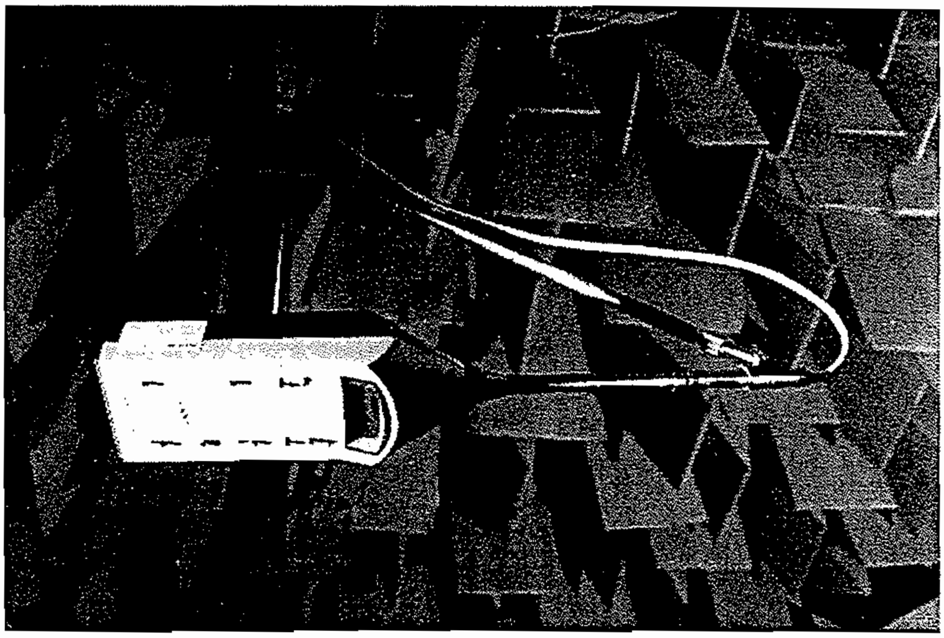


Figure 2. The sound level meter and microphone mounted on the jig and suspended in a free field room.

The free-field environment was not strictly necessary but provided a convenient working location and prevented the sound disturbing others. The room has a floor which is usually retracted during measurements but to demonstrate the effect of not using a free-field room some tests were carried out with the floor left in. The results were unchanged because the reflection from the floor arrived much later than the original impulse and, although it was noticeable on voltage traces, it did not affect the peak measurements of the first pulse.

The impulsive sounds were generated by three blank-firing pistols, ranging from a children's cap gun for low levels, through a starting pistol, to an imitation police pistol for high levels. By slightly varying the distance between the sound source and the sound level meter (and there being an inherent non-repeatability involved in any explosive sound source) a range of peak pressures from 110 dB to 150 dB re 20 μPa were created.

The impulsive sounds from the pistols contain the whole range of audio frequencies, with typical rise times in the order of 40 µs. Figure 3 shows a typical microphone voltage output trace from one of these impulses as measured by the microphone.

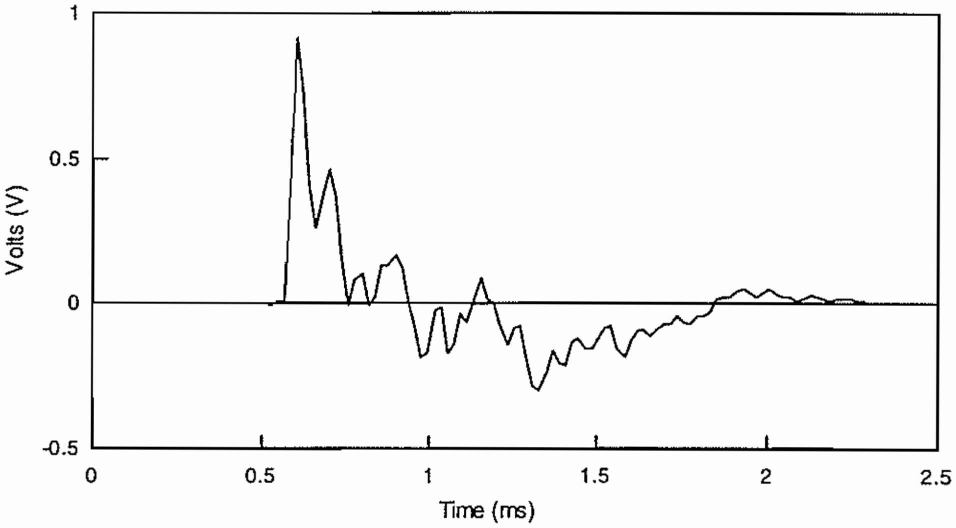


Figure 3. Typical microphone output voltage trace from pistol shot

The microphone was connected through a measuring amplifier to a data capture card sampling at 51.2 kHz in a PC. The system was then calibrated by applying a calibrated sound calibrator to the microphone, and measuring the RMS voltage as given by the software after data capture. The signal was C-weighted in software.

The sound level meter was set to C-weighting, peak-hold mode, and the meter display was read after each impulse and then reset. The sound level meter also had an AC voltage output (giving 1 V for maximum indication on the meter), and this was connected to the second channel of the data capture card and recorded.

Both meter and microphone traces were C-weighted because this is common practice when taking peak sound pressure measurements to ensure reproducibility between different meters. (There is no standardised specification for a 'flat' response).

For each impulse the output from the microphone, the display on the sound level meter and the output from the sound level meter were recorded. Measurements were made with both a high sensitivity WS2 microphone (Brüel & Kjær type 4176) and a low sensitivity WS2 microphone (Brüel & Kjær type 4133) fitted to the sound level meter.

3 RESULTS

3.1 With a high-sensitivity WS2 microphone (Brüel & Kjær type 4176) on the meter

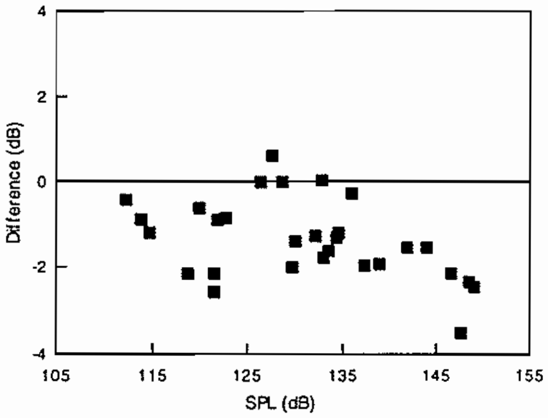


Figure 4. The difference between the meter display and the actual level as measured by the reference microphone, plotted against the sound pressure level.

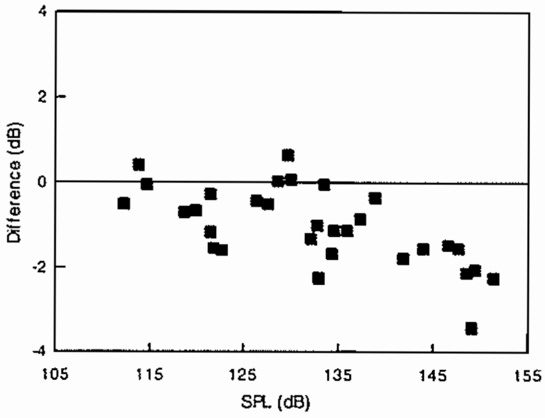


Figure 5. The difference between the meter output level and the actual level as measured by the reference microphone, plotted against sound pressure level

Figures 4 and 5 show the difference between the output from the sound level meter and the actual level as measured by the reference microphone, plotted against sound pressure level. Figure 4 shows the results taken from the meter display, while Figure 5 shows those taken from the AC output.

A drop-off in sensitivity of at least 2 dB between 130 and 150 dB SPL can be seen on both graphs. This is consistent with the manufacturers specification that the maximum peak level to be measured in this configuration is 153 dB.

3.2 With a low-sensitivity WS2 microphone (Brüel & Kjær type 4133) on the meter

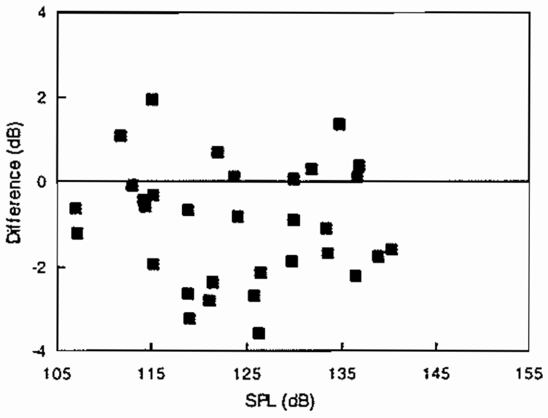


Figure 6. The difference between the meter display and the actual level as measured by the reference microphone, plotted against the sound pressure level

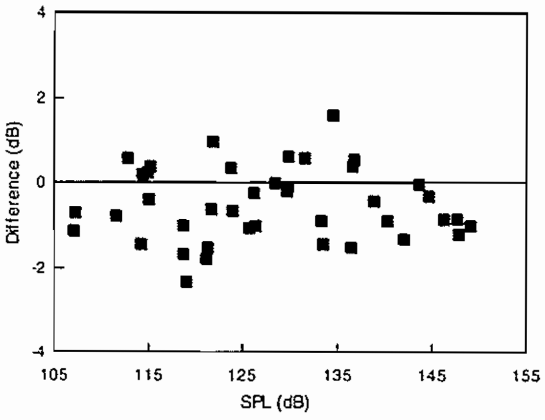


Figure 7. The difference between the meter output level and the actual level as measured by the reference microphone, plotted against the sound pressure level

Figures 6 and 7 are from similar measurements to those in Figures 4 and 5 except that the meter is now fitted with a low-sensitivity microphone instead of a high sensitivity microphone. Figure

6 does not cover the full range of pressures from 110 to 150 dB peak because the meter display went over range at this point. However, the AC voltage output continued to function normally to 10 dB above the display, so Figure 7 does include these results.

It is seen from these figures, though less well from the meter display results, that when fitted with the low-sensitivity microphone, the sound level meter is linear right up to 150 dB peak pressure. This being true, it shows that the high-sensitivity microphone is the non-linear part of the meter system when it is used to measure impulsive peak pressures..

The drop-off in sensitivity when using the high-sensitivity microphone is probably due to harmonic distortion created in it when exposed to high sound pressure with a wideband frequency. This is in keeping with similar results that were found when the newly developed high-pressure calibration method[1,2] were used on this microphone.

It is interesting to note that the meter display results for both microphone types show more variation in repeat measurements than the AC output does. This may imply that the real time peak detector in the sound level meter is not as accurate as the PC based peak detector.

4 CONCLUSIONS

The method outlined here, when combined with the previous work reported in references 5 and 6, provides the basis for a test of sound level meter performance at peak sound pressures of 140 dB and above and particularly the action levels defined in the Noise at Work regulations and the current draft of the physical agents directive.

A B&K type 2135 sound level meter was tested and was found to have a drop-off in sensitivity of at least 2 dB between 130 and 150 dB SPL when used with its normal microphone. Using sound level meters which consistently measure such peak pressures inaccurately will inevitably lead to the incorrect application of legislation. In the case of this specific meter, a measurement of 140 dB peak (200 Pa) could result from an actual sound pressure of 142 dB peak (250 Pa), an error of 25%.

It is recommended that, once the physical agents directive is finalised, an amendment to current sound level meter standards is sought, to include a section requiring a type-test for peak pressure measurements at the relevant regulatory levels, based on this method.

According to these findings, a sound level meter used for peak sound pressure measurement may consistently give inaccurate peak readings at the peak pressures which it may be required to measure. A type test for peak pressure measurement, if applied, could significantly help to protect human hearing in the industries where noises of this type and level are a regular occurrence and ensure that legislation in this area is applied uniformly across the EU.

5 ACKNOWLEDGEMENTS

The author wishes to thank the UK Engineering and Physical Sciences Research Council for his EngD Research Studentship, his supervisors (Duncan Jarvis at NPL, Barry Jones and Richard Rakowski at Brunel University) and also to acknowledge the financial support of the National Measurement System Policy Unit of the UK Department of Trade and Industry.

6 REFERENCES

1 HMSO, 1989. The Noise at Work Regulations 1989, SI 1989 No.1790

2 EUROPEAN COMMUNITY, 1986. On the protection of workers from the risks related to exposure to noise at work, Council Directive No. 86/188/EEC

3 ALDRIDGE D C, 1997. The calibration of microphones and sound level meters for the measurement of impusive noise, Engineering Doctorate in Environmental Technology thesis-portfolio, Brunel University.

4 JARVIS D R, 1996. Methods for determining the pressure sensitivity of working standard microphones - a report on Euromet project A311, NPL Report CIRA(EXT) 010

5 ALDRIDGE D C, JARVIS D R, JONES B E, and RAKOWSKI R T, 199?. A pressure-step method for determining the low frequency sensitivity of measurement microphones at high sound pressures, Acta Acustica (awaiting publication)

6 ALDRIDGE D C, JARVIS D R, JONES B E, and RAKOWSKI R T, 199?. A method for demonstrating the linearity of measurement microphones at high sound pressures, Acta Acustica (awaiting publication)