Proceedings of the Institute of Acoustics

THE ELECTRONIC PISTONPHONE CALIBRATOR

Ole-Herman Bjor (1) and Ian Campbell (2).

(1) Norsonic AS, PO Box 24, N-3408, Tranby, Norway.
(2) Gracey and Associates, Chelveston, Northamptonshire, NN9 6AS.

1 - SUMMARY

This paper describes the improvements made to conventional electro-acoustic calibrators by using active compensation techniques to adjust for the changes caused by both the loading volume of the microphone and changes due to environmental factors. The development of these algorithms has now reached a level of sophistication that it is possible to ensure performance that rivals that of the traditional electro-mechanical pistonphone calibrator. As a direct result it is possible to construct a laboratory standard device that is no larger than traditional field calibrators and at a considerably lower cost than the older style of electro-mechanical device. There is also the added advantage that the "smart calibrator" techniques employed considerably reduce the need for manual corrections to be applied to the results. The next step in the improvement in the accuracy of sound level calibrations is now available to the acoustics profession.

2.- INTRODUCTION

When making sound level measurement it is necessary to ascertain that the measurement accuracy is within the standardised requirements. Procedures for periodic verification have been proposed but these do not remove the requirements for pre and post measurement calibration checks to be carried out on the instrumentation. A reliable sound calibrator is required to undertake these tests. A sound calibrator is a device which generates a sinusoidal sound pressure of a specified level and frequency when coupled to a microphone for which it is designed. The generated sound pressure must be stable and not dependent on variations in the ambient conditions such as temperature, humidity and atmospheric pressure as well as resisting the effects of electromagnetic fields. The technical requirements for sound calibrators have been standardised in an International Standard [1] which has also been confirmed as a British Standard [2].

The use of acoustic calibrators goes back to the days when it was easier to design a stable calibrator than sound level meter. Modem acoustic instruments are fortunately inherently more stable than those available in the early days, but at the same time there is a much deeper understanding of the errors associated with the calibration of microphones in closed couplers. These uncertainties derive from the physical loading of the calibration cavity by the actual microphone that is being calibrated, mostly between types but also to a lesser extent with different microphones of the same design due to manufacturing tolerances. There are also variations that follow from the basic rules of sound generation and propagation over the normal range of environmental conditions in which we are required to make sound level measurements.

These basic factors have resulted in the need to apply a wide range of correction factors to the nominal sound pressure level generated by the sound calibrator in order to obtain the correct sound level to which the meter being calibrated has to be set. The extent of these corrections has been dramatically demonstrated in the Institute work shops [3] and can comprise five individual corrections, of varying sign, that could result in an error of over a dB if incorrectly applied. It also follows that it is necessary to have all of the input data available to allow the corrections to be calculated. It was to overcome these operational limitations that the Norsonic "smart calibrator" project was initiated.

3.- DESIGN CONCEPTS

As most of the corrections that have to be applied are functions of the basic physics of sound they can not be avoided and the only approach therefore is to apply the corrections automatically. This brings the first break with the traditional approach of having highly stable electrical drive circuits feeding a transducer of well defined characteristics by introducing a level of control into the system. With this facility available it would then be possible to programme the calibrator with information as to the correction necessary for each type of microphone and environmental condition that it is required to cope with. Although this approach would meet the design requirement it places on the operator the need to input information on each occasion that the device is to be used. If the calibrator could ascertain for its self the correction that is necessary this inconvenience, and possible source of error, could be avoided. As the calibrator is required to generate a set sound pressure level within its calibration cavity the preferred approach must be to monitor the generated pressure level to produce a delta signal that can be used in a control loop to ensure that the required level is maintained irrespective of the loading volume applied by the microphone being calibrated.

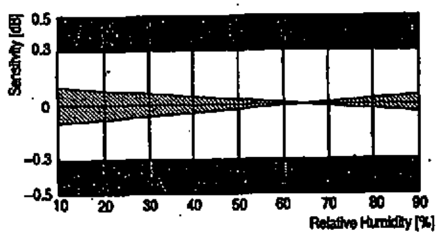

Fig 1 - Production spread for N-1251 - humidity

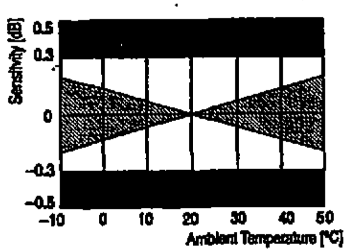

Fig 2 - Production spread for N-1251 - temperature

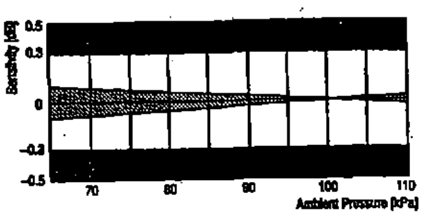

Fig 3 - Production spread for N-1251 - atmospheric pressure

The obvious weak link in this approach is the monitor microphone that is to be used to determine the pressure level in the cavity as it has to be clearly more accurate and stable than the microphone being calibrated. Measurement microphones are delicate and expensive transducers because they are required to behave in a stable and predicable manner over a wide range of frequencies and amplitude levels, as the accepted practice is to undertake field calibration checks at a single frequency and level all the design compromises in the monitor microphone can be directed to optimising the performance at these conditions. By limiting the performance requirements to a single level and frequency a considerable improvement in the stability of the monitor microphone is possible.

Careful design has also minimised the influence of atmospheric pressure variations by means of a venting system that also ensures that external noise levels are adequately attenuated and that humidity is also controlled within the required limits. The addition of an active temperature compensation arrangement completes the elements that are required to produce the smart calibrator.

A sound calibrator based on these concepts was fully described in an earlier paper [4] that meets all the requirements of the International Standard for a type 1 device over the full range of environmental conditions without the need to apply any correction factors. As a result of these active volumetric compensation arrangement the Norsonic NOR-1251 will also produce the correct pressure level in its cavity for most of the measurement microphones in current use as it has an effective cavity volume some 100 times larger than its actual physical dimensions. Experience has shown that the design targets have been exceeded in the production units and the spread is well within the 0.3 dB required by the standards. Figures 1 through 3 show the typical production spread against the tolerances for humidity, temperature and pressure. Using devices of this accuracy allows measurement technicians to considerably simplify the procedures used to control their measurements as the need to calculate and apply correction factors has become a thing of the past.

4.- THE ELECTRONIC PISTONPHONE.

Reviewing the data obtained in the audit checking of the production calibrators raised the possibility of improving the performance to the highest level of accuracy required by the standard.

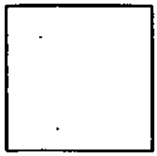

Fig 4 - Typical performance for N-1253 - humidity

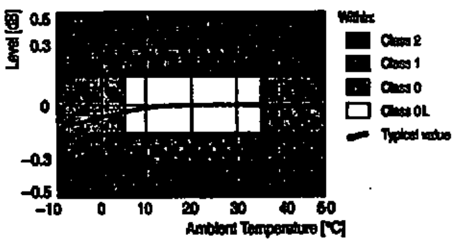

Fig 5 - Typical performance for N-1253 - temperature

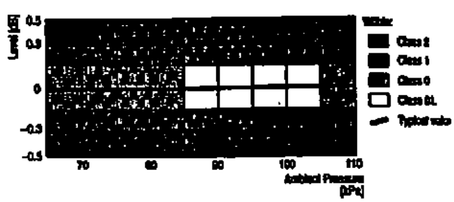

Fig 6 - Typical performance for N-1253 - atmospheric pressure

Analysis of the control algorithm shows that with some refinements the 0.15 dB tolerances required by the standard for class 0 devices can be achieved This work shows that, at the present time, the control of the environmental parameters indicates that the device will easily meet the 0_L requirements making it ideal for use in the laboratory and over the range of environmental conditions that are found in most measurement locations.

As a result the Norsonic NOR-1253 Calibrator has been developed and is now entering into production. Tradition has established that laboratory calibrators operate at 250 Hz and produce a level of 124 dB, the electronic pistonphone has therefore been designed to produce these values. Typical performance of the early production units are shown in figures 4 through 6 and in this case the tolerance requirements for all three classes of calibrator have been shown. All the requirements for a type 0 device in respect of ambient pressure and humidity are met and it is only at the extremes of low temperatures that the system produces results that are approaching the permitted tolerances. As further experience is gained from the production control process a fuller understanding of the concepts employed in this new generation of acoustic calibration will further contribute to the improvements that modem electro-acoustic engineering can contribute to the calibration of sound level measuring instrumentation.

5. - CONCLUSIONS

The use of active volumetric compensation and environmental corrections has produced an acoustic pressure level calibrator that will operate without the need for manual corrections that is suitable for field use with precision sound level meters. Development of this work has produced a laboratory standard calibrator that also offers these advantages over a wide range of conditions that are typical of the environments where field measurements are undertaken.

6.- REFERENCES

[1] International Standard IEC-942:1988. CEI Geneva Switzerland.

[2] British Standard BS-7189:1989. BSI London.

[3] R Tyler FIOA CEL Instruments Ltd. IOA Meeting London 14th February 1996.

[4] Bjor and Campbell. "Sound Calibrator based on a Silicon Reference Transducer". Proceedings of the IOA, Volume 18 Part 1 (1996), pages 29-32.