

The feasibility of using calibration methods recently developed for working standard microphones in the calibration of audiometric reference couplers and artificial ears

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ABSTRACT

The use of an active coupler in the calibration of working standard (WS2) microphones at NPL has greatly increased the efficiency of the measurement procedure for those devices. This report considers whether the method can be adapted for use in the calibration of artificial ears used in audiometry, since they contain a WS2 microphone. For this type of calibration to yield worthwhile benefits it is also necessary to have a similar method of calibrating reference couplers containing an LS1 microphone. The Brüel and Kjær active coupler type WA 0817 cannot be used with this device, but an alternative calibration method is considered. The report concludes that while these methods are technically feasible, the commercially available hardware is not yet suitable to implement them practically.

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ISSN 1369-6785

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

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1. INTRODUCTION

Ear simulators are used extensively to study earphone characteristics and in particular to make objective measurements of their acoustic output. This is particularly important in the field of measurement of hearing where the measured hearing level of the ear of a test subject depends on the calibration of an ear simulator. The calibration methods used at NPL for such devices have traditionally been adapted from methods developed for microphone systems. This is understandable since the receiving part of the ear simulator is essentially a simple microphone system.

The calibration of a microphone system usually involves some form of comparison technique against a reference microphone with known sensitivity. A comparison calibration can be performed in two basic ways. In a sequential comparison calibration the microphones are exposed to the sound field in turn and any change in the sound field is sensed by a monitor microphone. In a simultaneous comparison calibration both microphones are exposed to the sound field at the same time.

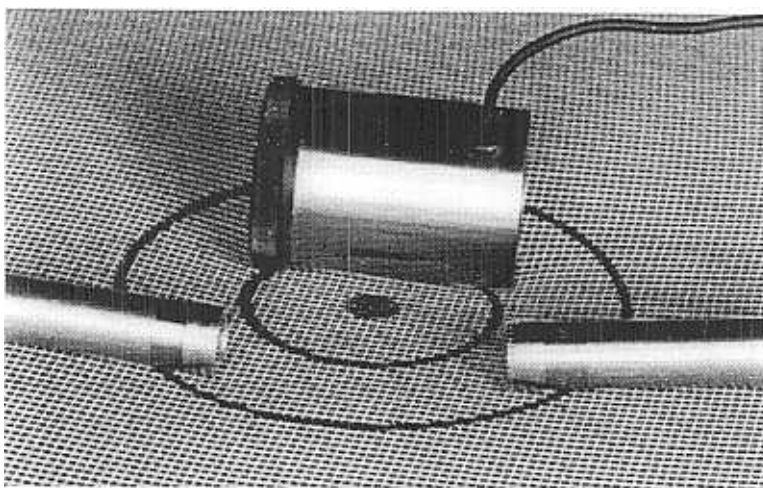


Figure 1 The prototype active coupler used in the facility for the calibration of working standard microphones

Recent research in microphone calibration has focused on improving the methods used to calibrate working standard microphones and microphone systems. This has resulted in the development of a calibration method based on a simultaneous comparison technique¹. During such measurements, the microphone under test and a reference microphone are exposed to the same sound field simultaneously. It is then possible to determine the sensitivity of the microphone under test by measuring the ratio of output voltages from these two microphones and knowing the sensitivity of the reference microphone. A broad band test signal is used when the two devices have a similar frequency response, resulting in a very efficient calibration procedure. A sinusoidal test signal must be used when there is significant difference in the frequency response between the two microphones. This is typically in the frequency range approaching the resonance frequency of the microphones. However since the microphones are exposed to the sound pressure simultaneously, the method still offers considerable benefits in time saving over previous sequential methods. This technique now forms the basis of a service for the pressure calibration of working standard microphones at NPL. The main advantage offered by this type of calibration is the reduction in time required to perform the calibration. Through use of computer automation it is less labour intensive than previous methods, although the operator is still required to be present during the whole procedure. It also results in an acceptable level of uncertainty for users of the service.

While these benefits have been introduced for the calibration of working standard microphones and systems, they have not been immediately transferable to the calibration of ear simulators. However, the potential advantages in doing so warranted further research that was necessary to examine the feasibility of this method. The measurement service for the calibration of audiometric equipment is running at full capacity and ear simulators account for approximately 60% of all the devices submitted to the service, so a significant reduction in the time required to calibrate these devices would do much to improve customer service in this area. There is also potential for a reduction in the calibration uncertainty.

2. POTENTIAL FOR IMPROVING THE CALIBRATION METHOD

Although ear simulators are used in a range of applications, the NPL measurement service is used predominantly by the audiometric community. The types of earphone in use have resulted in the need for two standardised types of ear simulator: the IEC 303 reference coupler, specified for use with the Telephonics TDH-39 earphone exclusively and the IEC 318 artificial ear for all other types of supra-aural earphone. Both devices are designed to form a closed cavity when fitted with an earphone. A microphone is housed in the cavity and used to measure the sound pressure that results when the earphone is driven. In the reference coupler, a simple cylindrical cavity is used to couple the earphone to an IEC type LS1P microphone. The artificial ear is more sophisticated and aims to present the earphone with an acoustic load that better represents the human ear. This device has an IEC type WS2P microphone mounted at the bottom of the cavity.

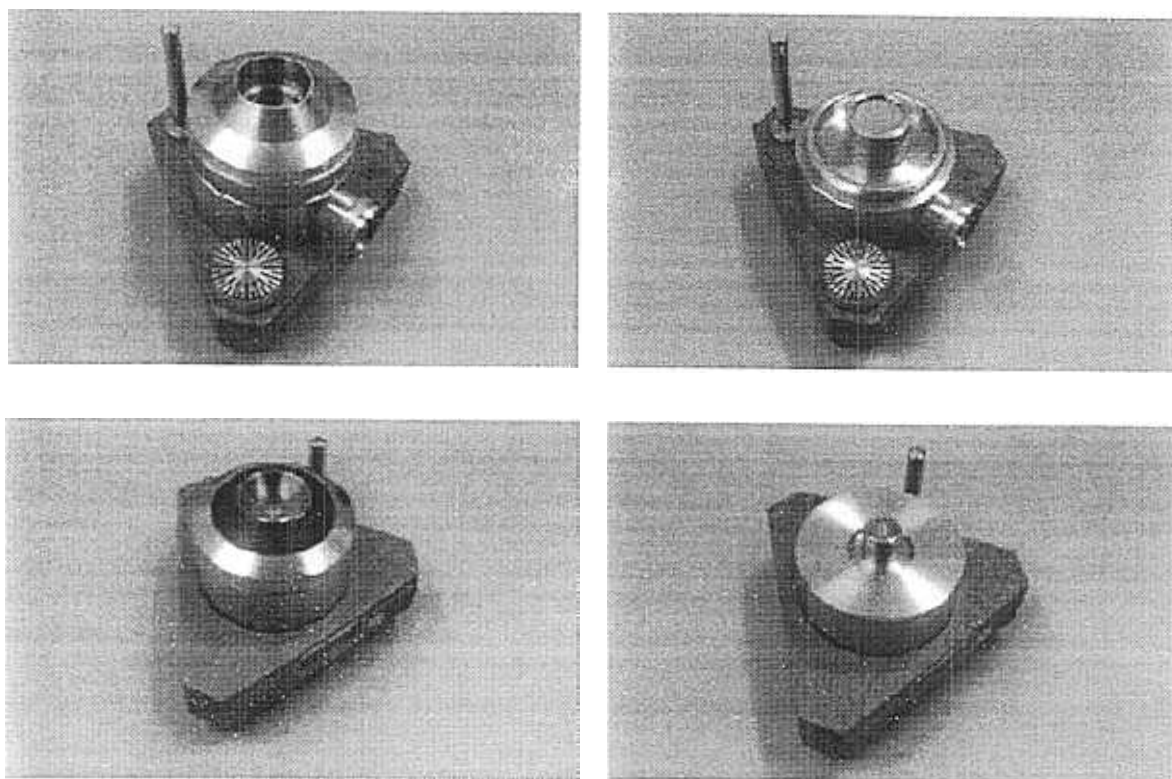


Figure 2. The reference coupler (*top*) and artificial ear (*bottom*) in normal configuration and with coupler removed for calibration.

For the purpose of calibrating these devices, the cavity is removed, giving clear access to the microphone. This is the extent to which the microphone system can be isolated from the complete device. The connector for the microphone, containing the ground shield that has a critical influence on the sensitivity, is built into the base of the instrument. The microphone preamplifier is also integrated into the structure of the instrument. So with the cavity

removed, it is then necessary to calibrate the remaining microphone system with respect to the reference microphone.

2.1. SIMULTANEOUS CALIBRATION OF LS2/WS2 MICROPHONES

The facility for the calibration of working standard microphones (IEC type WS2 microphones only) uses a so-called active coupler. This enables two microphones to be placed face-to-face in a small cavity that also contains an active element for generating a sound field. The idea for the coupler was conceived from the design of a commercial sound calibrator (Brüel and Kjær type 4226). When used as part of this instrument, the coupler contains both a piezo-ceramic sound source and a radial PDVF element. It also houses a feed-back microphone that is used to stabilise the sound pressure produced in the device. In discussions with the manufacturer it was agreed that the coupler from this sound calibrator could be modified to produce the prototype active coupler. This was achieved by replacing the feedback microphone and the piezoceramic source with a socket, therefore enabling two microphones to be placed in the coupler. Just three examples of this prototype device were produced for the purpose of developing the calibration method. NPL received one of them. Figure 1 shows this prototype device. Its origins as part of a type 4226 sound calibrator are evident from its size and form.

The prototype active coupler played an important role in the research necessary to develop the method. However in routine use, it proved to be very unreliable. The PVDF film needed to be driven with a high voltage to generate a suitable sound pressure, but was very susceptible to damage from being over driven. Now that a suitable test has been developed and even standardised, the manufacturer has refined the design and added a generally available version to its product range. This means that the prototype versions are no longer supported and can no longer be serviced or repaired. Clearly any applications making use of the active coupler need to be based on the production version.

While the prototype active coupler was produced in co-operation with those who intended to use it for their research, the production version was very much a product of the manufacturer. NPL therefore had little input to its design, other than pointing out the limitations of the prototype.

2.2. SEQUENTIAL CALIBRATION OF LS1 MICROPHONES

Having its origins in the design of a sound calibrator, the active coupler is constrained to use with LS2/WS2 microphones only. When looking at potential solutions for improved methods of calibrating ear simulators it is also necessary to consider systems based on LS1/WS1 microphones. Figure 3 shows a coupler developed at PTB for the calibration of LS1 microphones in the IEC 303 reference coupler.

This coupler houses an auxiliary microphone used as a sound source. The reference and test microphones are placed in the coupler in turn and exposed to the sound pressure. An important issue in sequential calibration is that the sound pressure does not change between each part of the measurement sequence. Any change to this sound pressure caused by replacing one microphone with the other must therefore be insignificant or compensated for. In this method, the sound pressure is detected by the probe tube microphone and this is used to control the sound pressure in the coupler. This method has been found to produce results consistent with alternate calibration methods within an appropriate level of uncertainty.

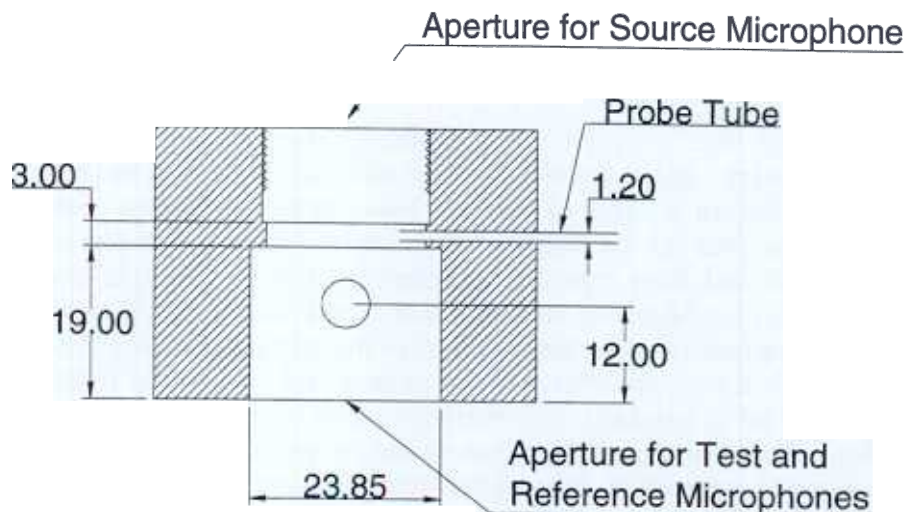


Figure 3. Coupler for the calibration of LS1 microphone (dimensions are in mm)

3. FEASIBILITY OF POTENTIAL CALIBRATION METHODS

In looking for improved methods of calibrating IEC 303 reference couplers and IEC 318 artificial ears, the methods described above were taken as starting points. As well as the acoustical considerations, other factors also needed to be considered if the calibration procedure was to be practical.

The first issue was how the output of the microphone system would be read. In most cases the audiometric systems make use of a sound level meter. At present during a calibration, the output reading is displayed and read visually from the instrument. This practice could continue with a simultaneous comparison approach, but the advantage of automation becomes lost. This would also restrict the test signal to stepped sinusoids and the speed advantage offered by a broad-band test signal would be lost. However many sound level meters have a voltage output. If this was available and could be measured by a frequency analyser, it would restore these benefits. It would then remain to determine the relationship between the output used in practice (for example the display) and the voltage output used in the calibration. The calibration method would also have to deal with equipment where no such voltage output was available.

Another issue was that, while different couplers are needed to perform measurements on the two types of ear simulator, the remaining instrumentation should be common. The whole apparatus can then be considered as a single facility requiring only as much effort to maintain as the one currently in use.

A point was reached where no further progress could be made until the production version of the active coupler was available. Unfortunately, when this was released, it soon became apparent that although the new coupler was a similar size externally, the microphone sockets were set deeper inside the housing than they had been previously. The prototype active coupler has the sockets spaced asymmetrically, so that on one side, the microphone mounting location was very close to the outer face of the housing. The new model positioned both microphones centrally. Given that the microphone in the artificial ear is mounted on the base of the device, it was impossible to fit it with the coupler. It therefore transpired that the production version of the active coupler was incompatible with the design of the artificial ear and development of a calibration method based on this device could be taken no further.

Although the dimensions of the prototype device make it suitable for use in this application, the previous experience with its reliability does not warrant this course of action. It is also known that the manufacturer of the device will not provide a repair of the device in the future. Regarding it as a research tool that has now served its purpose. The specialised nature of the device also prohibits in-house maintenance.

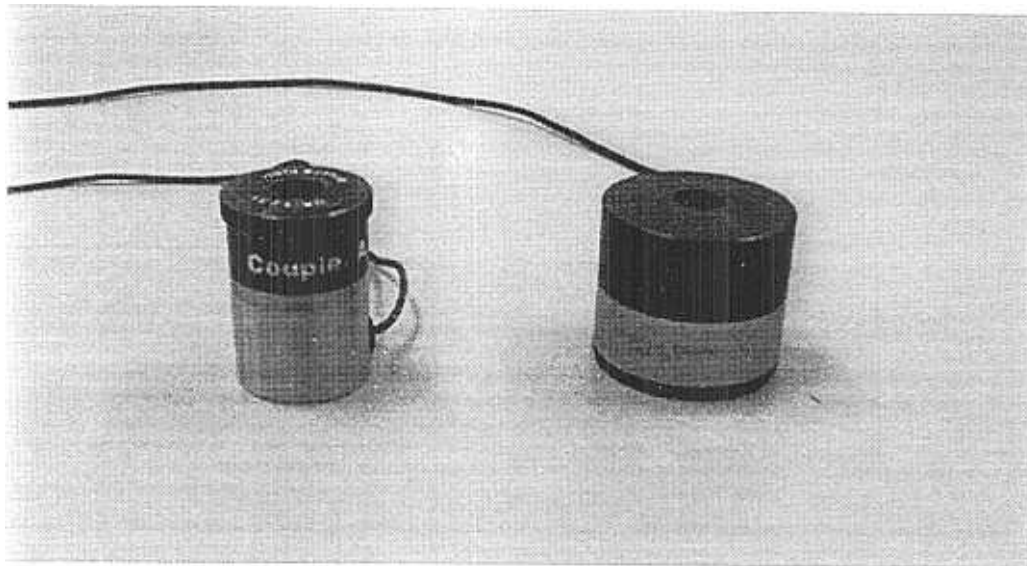


Figure 4. The prototype and production versions of the active coupler.

4. CONCLUSIONS AND RECOMMENDATIONS

In view of the findings discussed above, and the need to have new methods for *both* reference coupler and artificial ear if improvements are to be viable, it was decided to suspend the research in this area. While no further progress can be made at present, this does not mark the end of such endeavours. If the design of any future production versions of the active coupler can be influenced, there will be scope to continue this work from the point now reached.

The outcome of the feasibility study is therefore that the project remains technically viable, but presently lacks the necessary hardware to implement it practically. It is recommended that further developments of comparison calibration methods be monitored, particularly in the area of microphone calibration and standardisation through IEC. Discussions should also take place with the manufacturer of the active coupler to influence the dimensional design of any second generation version of the device.

5. ACKNOWLEDGEMENTS

The author acknowledges the financial support of the National Measurement System Policy Unit of the UK Department of Trade and Industry.

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TO THE EDITOR:
I have the honor to acknowledge the receipt of your letter of the 10th inst. regarding the matter of the purchase of a certain quantity of certain material. I am sorry that I am unable to supply the material at the present time, but I am sure that you will understand the situation. I am sure that you will be able to find a suitable substitute for the material which you require. I am sure that you will be able to find a suitable substitute for the material which you require. I am sure that you will be able to find a suitable substitute for the material which you require.

Very truly yours,
[Signature]

Enclosed for you are the following documents:

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