INTERCOMPARISON OF HALF INCH MICROPHONE CALIBRATION

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PREFACE:

Integration within Europe is creating an increasing need for mutual recognition of test results and therefore comparable standards. Several international organisations are dealing with such questions. Probably the best known of these organisations is the so-called BCR program (Bureau Comunautaire de Reference) an EEC body which is looking at measurements in industrie mainly. Another organisation acting worldwide in this field is the OIML (Organisation Internationale de Métrologie Légale) which is responsible for the legal aspects in Metrology. EUROMET, an organisation of Standards Laboratories of the States of the European Free Trade Association and the States of the European Communities, takes care of the development and improvement of measurement techniques in Standards Laboratories. This work was carried out for EUROMET (project number A89/017), a report containing the results will be published in Metrologia.

INTRODUCTION

The standard of sound pressure is realized through the calibration of standard condenser microphones by the reciprocity method [1]. In the case of one-inch standard microphones, this technique is well established and covered by international standards. However, one-inch microphones are becoming obsolete in preference to microphones of smaller sizes which allow measurements at higher frequencies. This fact is taken into account in the latest revision of the IEC standard [2] which now includes half-inch standard microphones. Some national acoustics laboratories in Europe, which (with one exception) did not have the possibility to participate in an earlier intercomparison sponsored by the European Community Bureau of Reference (BCR) [5], showed an interest in taking part in an international intercomparison of half-inch microphone calibrations. Thanks to the participation of NPL, which provided its calibration facilities and expertise, a link to the results of earlier world-wide intercomparisons was established.

PARTICIPANTS

The British National Physical Laboratory (NPL), the Dutch van Swinden Laboratory (VSL), the Telecom Laboratory of Finland (P&T Tele), the Swedish Statens Provningsanstalt (SP), and the Swiss Federal Office of Metrology (OFMET) agreed in September 1989 upon an intercomparison of the pressure calibration of half inch Standard Microphones. All participating laboratories are National Standard Laboratories and therefore responsible for accurate standards in their countries.

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MEASUREMENTS

The participants agreed to calibrate three of their half-inch pressure type standard microphones (Brüel & Kjaer model 4180) in the frequency range from 125 Hz to 25 kHz in octave steps up to 1 kHz and third octave steps thereafter. The microphone sensitivities were determined by the reciprocity technique using air-filled couplers. Two participants (OFMET, SP) made all the measurements using a commercially available calibration system (Brüel&Kjaer model 4143). The acoustic impedance of the microphones which is needed to calculate the equivalent volume, was taken in these two cases from the specifications of the manufacturer. The other two laboratories (P&T Tele, VSL) were equipped with a partly self-made measurement system. In the Finnish laboratory, an optimising technique was utilized to determine the loss-factors and resonance frequencies as well as the front-cavity volumes of the microphones by varying cavity-volumes [3].

All stated results were corrected to a static pressure of 1013.25 hPa, a temperature in the coupler of 23° C and 50% relative humidity. The pressure coefficients of standard microphones, type B&K 4180, were measured at VSL [4]. It was found that the results were, within the measurement uncertainties given by VSL, the same for different microphones. The VSL values for the pressure coefficient were therefore also used by the other participants.

During June 1990, each laboratory sent two microphones of the triad to NPL, the remaining one was kept as a reference. The measurements at NPL were carried out by the author of this report. First the microphone parameters which influence the acoustic transfer impedance (depth and volume of the front cavity and acoustic impedance of the microphone) were determined as described in [2]. In order to complete the triads necessary for the reciprocity calibration and to link the results to earlier intercomparisons [5,6], a B&K 4180 microphone from NPL was added to each pair. Six reciprocity calibrations were performed with each triad of microphones, three measurements with a NPL coupler giving a diaphragm separation of 6.7mm [5] and another three measurements with the commercially available B&K coupler type UA 0990, leading to a diaphragm separation of 5.7mm. The NPL value for an individual microphone is defined as the mean value of these six measurements. The random uncertainty of the measurements was found to be in the order of 0.01 dB (one standard deviation estimate). The differences between the results obtained with the NPL coupler and the B&K coupler were ≤ 0.02 dB at 125 Hz, ≤ 0.01 dB in the main range between 1 and 10 kHz and 0.06 dB at 16 kHz. These values are small compared to the overall uncertainties given by NPL.

RESULTS AND DISCUSSION

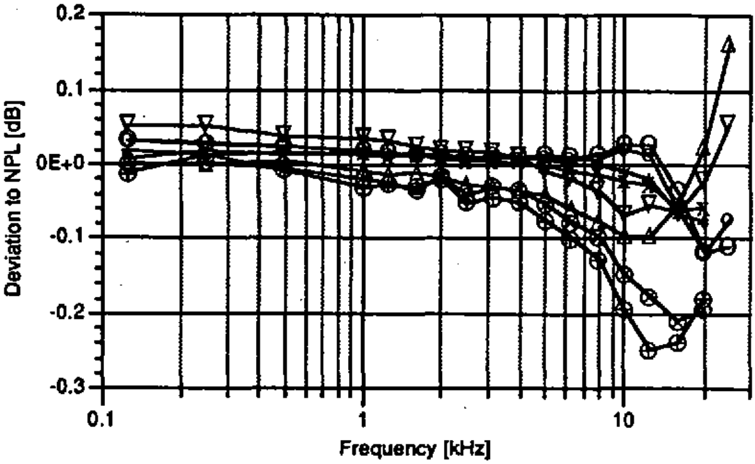
The differences *D* (Lab,NPL) between the microphone sensitivities determined at the participating laboratories and the results obtained at NPL are shown in Figure 1.
As mentioned earlier, each participant has sent two microphones calibrated in the same manner to NPL. The difference D_1(Lab,NPL)-D_2(Lab,NPL), where D_1 and D_2 are the deviations from the NPL values for the microphone one and two respectively, gives an indication on how well the microphone parameters could be determined. Figure 2 shows that these values are indeed much smaller than the values D_1 and D_2 plotted in Figure 1. This allows us to calculate the mean value

$$\overline{D}(\mathrm{Lab,NPL}) = \frac{1}{2}\,\{D_1(\mathrm{Lab,NPL}) + D_2(\mathrm{Lab,NPL})\}$$

as given in Figure 3. The uncertainty limits calculated by NPL are also indicated.

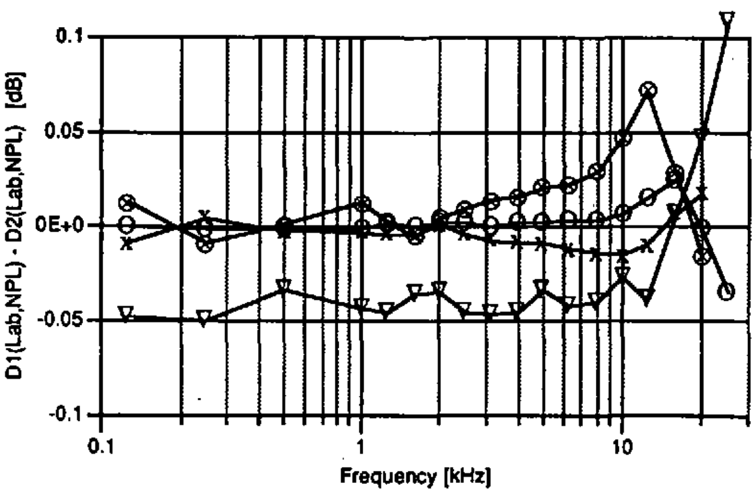
INTERCOMPARISON OF HALF INCH MICROPHONE CALIBRATION

Figure 1



Differences D(Lab,NPL) between the microphone calibrations determined at the participating laboratories and NPL. Legend: OFMET 1,2= o/O, VSL 1,2= ⊗/⊕, SP 1,2= Δ/∇, P&T Tele 1,2= x/•

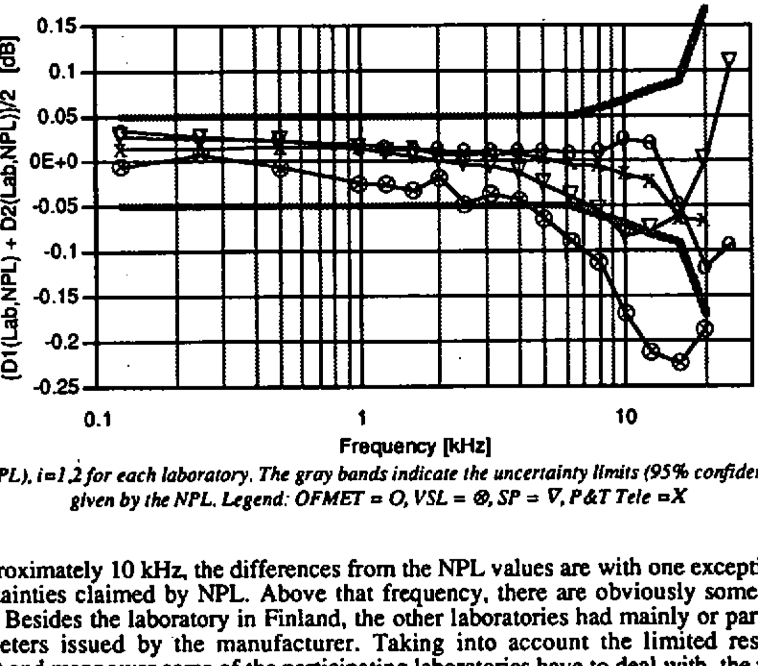
Figure 2



Difference of the deviations to NPL between the two micophones of each participant. Legend: OFMET = O, VSL = ⊗, SP = ∇, P&T Tele =x

A complete investigation of the measuring uncertainties involved in the reciprocity calibration of half-inch microphones is contained in the Ph.D. work of D. Jarvis [7]. There are more than 20 parameters listed which influence the accuracy of the finally determined sensitivity product of a microphone. Some parameters are independent of frequency (polarization voltage for example), others show a sharp raise at higher frequencies (e.g. front volume). D. Jarvis found the overall uncertainty for the NPL set-up to be approximately 0.03 dB up to 4 kHz and .11 dB at 12.5 kHz (95% confidence level).

Figure 3



D_i(Lab,NPL), i=1,2 for each laboratory. The gray bands indicate the uncertainty limits (95% confidence level) given by the NPL. Legend: OFMET = O, VSL = ⊗, SP = ∇, P&T Tele =X

Up to approximately 10 kHz, the differences from the NPL values are with one exception within the uncertainties claimed by NPL. Above that frequency, there are obviously some unsolved problems. Besides the laboratory in Finland, the other laboratories had mainly or partly to rely on parameters issued by the manufacturer. Taking into account the limited resources in equipment and manpower some of the participating laboratories have to deal with, the results are good. Further analysis of the results will help to solve the still existing problems and allow all laboratories to state their uncertainties accordingly.

PRACTICAL ACCURACY CONSIDERATIONS

The user of an ordinary Sound Level Meter does not see much benefit in work dealing with hundredths of a dB. He knows that for ordinary field measurements its even doubtful to talk about tenths of dB's. So what is to be gained by such work?

When we consider that a sound calibrator, used by a technician to calibrate his sound measuring equipment, is probably fourth or fifth in line descending from the national standard, things look rather different. Some Standards Laboratories maintain three different standards, the main standards, the secondary standards and the so called working standards. There could already be a difference in accuracy between the absolute calibrated Standard Microphone and the working standard, depending the method used to calibrate the working standard. The value of the working standard is usually distributed by comparison measurements among accredited laboratories and from there to the calibrators of each individual user. Each additional comparison measurement adds uncertainties to the values distributed. The quality of the calibration equipment used and the quality of the intermediate standards degrade with the descendance from the Standards Laboratory as well. To calibrate a class 0 calibrator (±0.15 dB) in an accredited laboratory with an appropriate accuracy, the high accuracy in the Standards Laboratory is absolutely necessary.

It is therefore necessary to maintain the national standards and all related measurements as accurate as possible. Intercomparisons show Standards Laboratories how their standards compare with other Standards Laboratories.

ACKNOWLEDGEMENT

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