ACOUSTICAL STANDARDS CALIBRATION AT THE PHYSICS DIVISION OF THE NATIONAL RESEARCH COUNCIL OF CANADA

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Abstract

This paper describes some recent research and development in acoustical standards calibration at NRC. Topics included are: instrumentation and apparatus for precise reciprocity and comparison methods of calibration of condenser microphones. Also, a three-port two microphone cavity technique for the overall calibration of sound level meters is discussed together with various methods of verification of acoustical calibrators.

Résumé:

On décrit les plus récents travaux en recherche et développement sur l'étalonnage primaire acoustique au CNRC. On discute notamment de l'instrumentation et de l'appareillage pour l'étalonnage des microphones à condensateur par les méthodes de comparison et de réciprocité précise. On présente aussi une technique en cavité à trois orifices utilisant deux microphones pour l'étalonnage total des sonomètres ainsi que diverses méthodes de vérification des calibrateurs acoustiques.

Introduction

Most technology-based countries have national standards laboratories. In accordance with the mandate given NRC by Canada's Weights and Measures Act, the Division of Physics has responsibility for reference standards including national acoustical standards. This paper describes some recent research and development in acoustical standards calibration at NRC.

1.0 Reciprocity Pressure Calibration of Condenser Microphones

Various new and classical methods of microphone calibration have been described (1-8) and there are national and international standards (9, 10) to govern the absolute method of reciprocity calibration, which for the last 10 to 20 years, has achieved an accuracy of between 0.025 and 0.05 dB.

At NRC an arrangement has been developed (11) for precision reciprocity calibration of condenser microphones, and it is anticipated that in the very near future it will be possible to attain an accuracy of better than 0.005 dB.

The reciprocity method is essentially the measurement of the product of the sensitivities of each pair of a set of three microphones in terms of related electrical and mechanical quantities, from which the absolute sensitivity of each microphone can be calculated. It is outside the scope of this paper to describe the theoretical aspects of the reciprocity method. The combined result of two important developments which enable one to achieve an order of magnitude improvement on accuracy is explained as follows: The first development is,

a) The development of a precision A.C. null-detecting system which has a resolution of better than 0.001 dB. In the reciprocity calibration arrangement shown in Fig. 1, two microphones are mounted in a common cavity. Microphone (A) is driven by a signal (e) from an oscillator. After attenuation, signal (e_2) from the receiving microphone (B), is compared with signal (e_1), which is derived from the driving current (I) of microphone (A). The attenuator is a seven-decade ratio-transformer with an accuracy of 0.5 ppm. The A.C. null detector is a lock-in amplifier with full scale resolution of 100 nV.

The second development is,

b) The precise measurement of the equivalent volume of the calibration cavity by means of an unique acoustical method. The equivalent volume is expressed in terms of the readings of the ratio-transformer and a precisely known small change in volume, which is implemented with optical-flat spacers. The relation between the equivalent volume V and the readings of the ratio-transformer is (see fig. 2).

$$V = V_0 + \sum V_m = \Delta V_0 \left[\beta_0/(\beta_2 - \beta_1)\right]$$

where $\sum V_m$ and V_0 are the total equivalent volumes of the microphones and the cavity respectively, and ΔV_0 is the small change in volume.

Since the equivalent volume of the cavity is measured acoustically under controlled environmental conditions using frequencies similar to the reciprocity calibration, correction factors such as capillary correction, heat-conduction correction and wave-pattern correction are unnecessary. The precision of these corrections is only of the order of 0.1%, and they are essential for conventional calibration arrangements. It is estimated that the uncertainty of our reciprocity calibration is less than 0.005 dB.

Fig. 3 shows the sectional view of the cavity arrangements

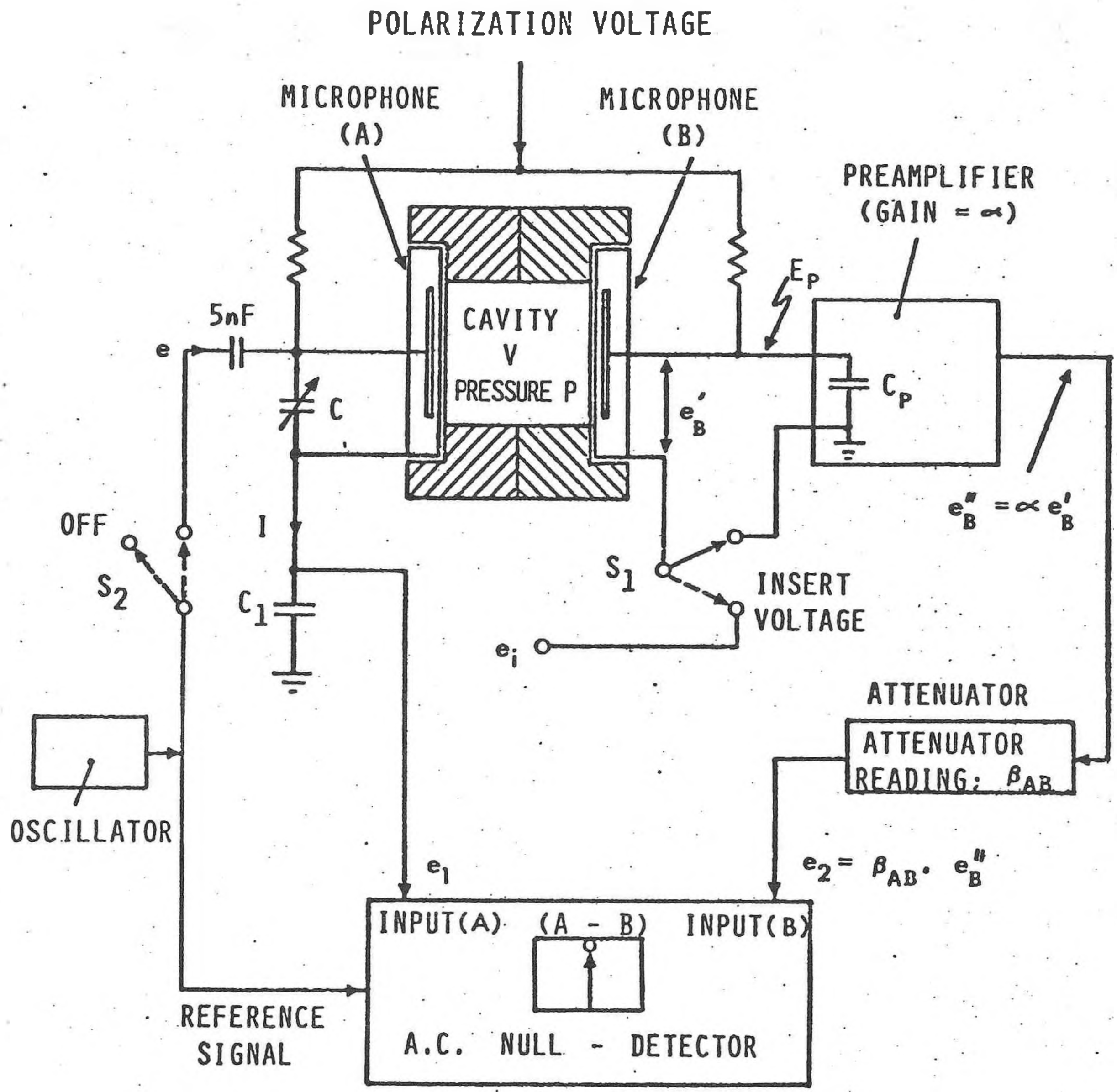


FIG. 1 GENERAL ARRANGEMENT OF AN A.C. NULL-DETECTING SYSTEM FOR RECIPROCITY CALIBRATION

2.0 Comparison Method of Microphone Calibration

The absolute method of reciprocity pressure calibration of microphones is relatively time consuming. For some microphone applications, the comparison calibration method developed at NRC is very attractive economically. The calibration procedure is as follows: -

(1) A standard microphone with a known pressure sensitivity, is closely coupled to a stable sound source (e.g. pistonphone calibrator). The signal from the microphone is monitored with a precision measuring amplifier (12) which was developed at NRC. The sensitivity of the reference microphone is entered into the multiturn potentiometer dial, which is calibrated in the format of microphone sensitivity (mV/Pa), of the measuring amplifier. A level reading is taken via an external digital voltmeter which has a resolution of better than 0.01 dB.

(2) The reference microphone is replaced with the test microphone. The calibrated sensitivity dial is adjusted until the same reading is obtained with the monitoring voltmeter. The dial reading gives the sensitivity of the test microphone in mV/Pa.

(3) As an added precaution, the abovce procedure is repeated with the reference microphone.

Some salient features of the above method are:

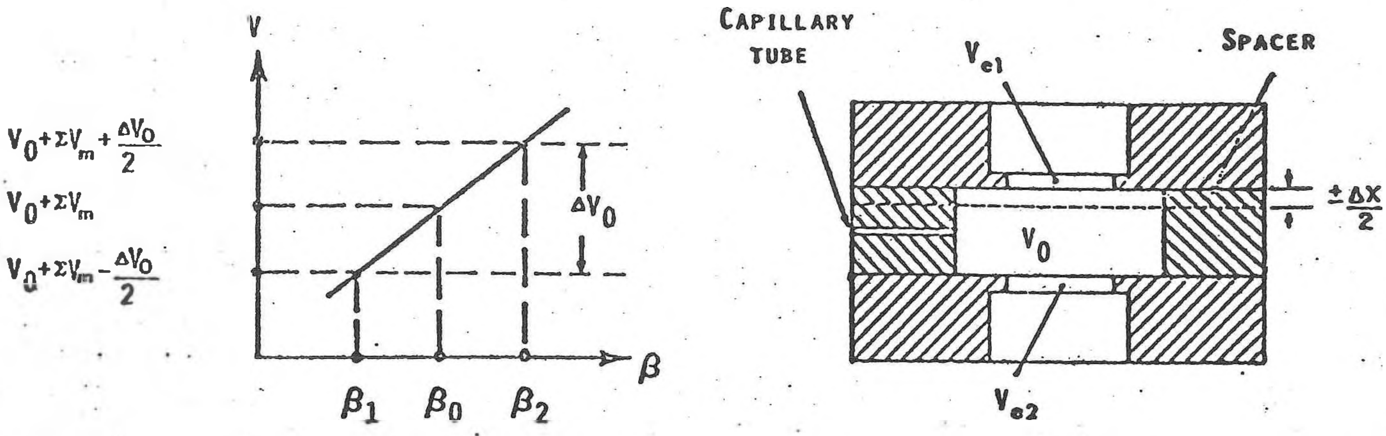
(a) The accuracies of the monitoring voltmeter and RMS detector of the measuring amplifier need not be stringent, since only good repeatability is needed.

(b) The multiturn potentiometer, which consists of an integral three-digit readout and a graduated dial has an accuracy of 0.02 dB.

(c) The total time required for the above comparison method is of the order of minutes.

The repeatability of the dial readings is better than 0.01 dB, and it is estimated that the error of the calibrated sensitivity of the test microphone is less than 0.05 dB plus the sensitivity uncertainty of the reference microphone.

There are several limitations which must be recognised: Since the two microphones are not presented to the sound field simultaneously, high accuracy can only be achieved if both microphones are of the same model so that the effective cavity volume remains essentially constant. The stability of the sound source and the mechanical positional repeatability of the microphones are some obvious requirements. However, the above limitations can be eliminated by the use of a three-port two microphone cavity which is described later.



$$V = V_0 + \sum V_m = \Delta V_0 \left[\beta_0/(\beta_2-\beta_1)\right]$$

FIG. 2. Equivalent volume of cavity

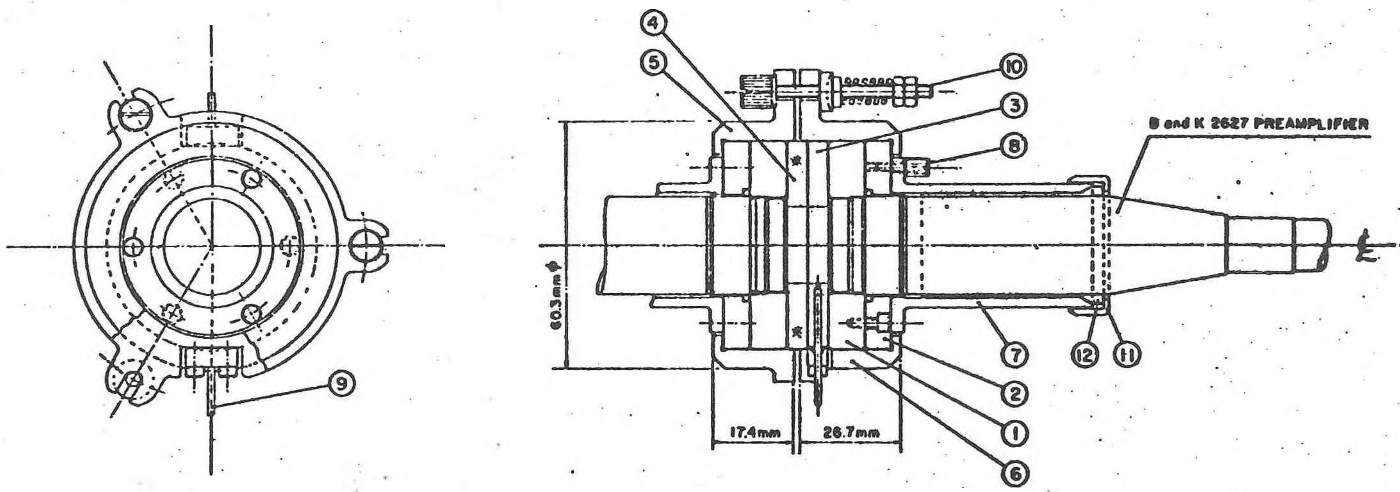


FIG. 3 CAVITY FOR PRIMARY STANDARDS

3.0 Calibration of Acoustical Calibrators

Acoustical calibrators are useful as a convenient means of checking the performance of acoustical measuring systems, and they are not intended to replace standard laboratory calibration procedures.

The arrangement for calibrator assessment is shown in Fig. 4. It consists of a standard microphone with a known pressure sensitivity, a pre-amplifier with a gain α, and the provision for insert voltage measurement.

The usual calibration procedure is to obtain a reading from the detector-indicator with the switch S at position 1. With the acoustical signal turned off, and the switch at the second position, the same reading is obtained by adjusting the insert voltage. Since the microphone pressure sensitivity is known, the measured magnitude of the insert voltage enables the calculation of the sound pressure level of the calibrator. In theory, the sole requirement of the detector-indicator is good repeatability. However, is practice, the RMS accuracy of the detector is important since the insert-voltage is usually a relatively pure sinewave, whereas the signal from acoustical calibrators may have 1 to 3% distortion.

A second approach is to measure the signal directly at the output of the pre-amplifier (switch S at position 1). The gain of the pre-amplifier can be measured accurately (to the order of ppm) by means of the A.C. nulling arrangement, and the assessment of the signal is performed with a precision RMS differential voltmeter (Fluke 931B) which has an accuracy better than 0.005 dB. The estimated error of the calibrated sound pressure level is less than 0.01 dB plus the sensitivity uncertainty of the reference microphone.

It is important to point out that the above methods only provide a calibrated sound pressure level for the particular model of microphone used as the reference. A correction is required for microphones with different equivalent volumes. Other corrections such as those due to barometric pressure and temperature variations are normally supplied by the manufacturer of the acoustical calibrator.

4.0 Theory of a Three-Port, Two-Microphone Cavity

The effects of the microphone equivalent volume and the stability of the sound source on the conventional comparison method of microphone calibration can be eliminated with the aid of a three-port, two-microphone cavity (13). The two microphones simultaneously monitor the sound field that is produced by a suitable driver unit (fig. 5).

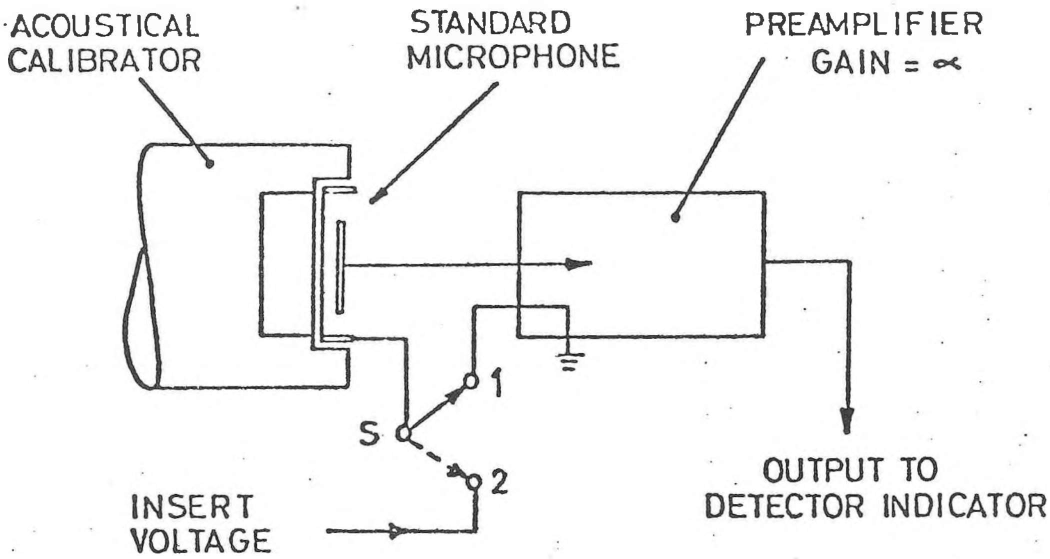


FIG. 4. SCHEMATIC ARRANGEMENT FOR ACOUSTICAL CALIBRATOR ASSESSMENT

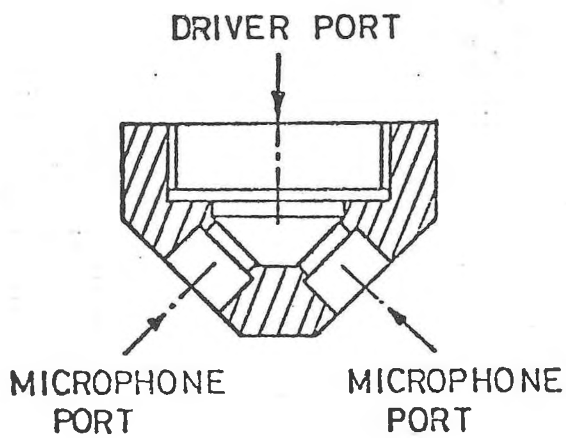


FIG. 5. A THREE-PORT TWO MICROPHONE CAVITY

The comparison procedure is as follows:

(1) The test microphone with the test measuring system, and the reference microphone with the corresponding reference measuring system simultaneously monitor the sound field of the cavity shown. Level readings are obtained for signals of various frequencies.

(2) With the microphones and their corresponding measuring systems: exchange microphone ports new level readings are taken.

(3) The test microphone and the reference microphone exchange measuring systems so that the test microphone is with the reference measuring system and the reference microphone with the test system; steps (1) and (2) are repeated.

It can be shown that based on the above level readings, the pressure response of the test microphone and the response of the test measuring system can be deduced.

Initial tests have shown that with two Type 1 measuring systems the error of the difference between the A-weighted responses is within 0.6 dB when compared with those obtained with direct electrical measurements, over the frequency range from 12.6 Hz to 16 kHz.; and the error of the difference between the frequency responses of two 1/2 inch condenser microphones (B & K model 4133 and model 4144) was found to be within approximately 1 dB when compared with those obtained with the electrostatic actuator method, over the frequency range from 1 kHz to 10 kHz. Below 1 kHz, the error was within 0.15 dB.

It must be pointed out that the above errors included the errors of the detector-indicators of the measuring systems; and the measurements were performed with the protecting grids on the microphones in place.

5.0 Conclusion

This paper describes some recent research and development in acoustical standards calibration in our laboratory. If any readers would like to have more information in the metrological procedures of the calibration methods described, we would be glad to discuss them in more detail.

Note: This paper was presented at the 101st Meeting of the Acoustical Society of America in Ottawa, 18-22 May 1981.

References

(1) K.J. Taylor, "Microphone Calibration using Laser-Doppler Measurement of Particle Velocity." Tenth International Congress on Acoustics, Sydney (July 1980).

(2) D.L.H. Gibbings, "Reciprocity Calibration at the National Measurement Laboratory Division of Applied Physics, CSIRO." Paper L-10.3 Tenth International Congress on Acoustics, Sydney (July 1980).

(3) A.J. Rennie, "A Laser-Pistonphone for Absolute Calibration of Laboratory Standard Microphones in the Frequency Range 0.1 to 100 Hz." NPL Acoustics Report Ac. 82, National Physical Laboratory, England (1977).

(4) Per V. Bruel, "The Accuracy of Condenser Microphone Calibration Methods, Part I." Tech. Rev., Bruel and Kjaer, Denmark, No. 4 (1964).

(5) Per V. Bruel, "The Accuracy of Condenser Microphone Calibration Methods, Part II." Tech. Rev., Bruel and Kjaer, Denmark, No. 1 (1965).

(6) M.E. Delany and E.N. Bazley, "Pressure Calibration of Microphones: A Note Concerning the Implementation of IEC 327:1971." J. Sound Vib., 68(4) (1980).

(7) M.E. Delany and E.N. Bazley, "Uncertainties in Realising the Standard of Sound Pressure by the Closed-Coupler Reciprocity Technique." NPL Acoustics Report Ac. 99 1st and 2nd Edition (Dec. 1980, Jan. 1982).

(8) T. Salava, "Measurements of the Acoustic Impedance of Standard Laboratory Microphones." Acoustics Laboratory Report No. 18. Technical University of Denmark (1976).

(9) American National Standards Institute, "Methods for the Calibration of Microphones." ANSI, S1.10-1966 (1968).

(10) International Electrotechnical Commission, "Precision Method for Pressure Calibration of One-Inch Standard Condenser Microphones by the Reciprocity Technique." Publication 327 (1971).

(11) G.S.K. Wong and T.F.W. Embleton, "Arrangement for Precision Reciprocity Calibration of Condenser Microphones." J. Acoust. Soc. Am. 66(5), (Nov. 1979).

(12) G.S.K. Wong, "Precision AC-Voltage-Level Measuring System for Acoustics." J. Acoust. Soc. Am. 65(3), (March 1979).

(13) G.S.K. Wong and T.F.W. Embleton, "Three-port two microphone cavity for acoustical calibrations." J. Acoust. Soc. Am. 71(5), (May 1982).