IEC 61094-2

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

AMENDMENT 1
AMENDEMENT 1

Electroacoustics – Measurement microphones –
Part 2: Primary method for pressure calibration of laboratory standard microphones by the reciprocity technique

Électroacoustique – Microphones de mesure –
Partie 2: Méthode primaire pour l'étalonnage en pression des microphones étalons de laboratoire par la méthode de la réciprocité

IEC 61094-2:2009-02/AMD1:2022-02(en-fr)

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ELECTROACOUSTICS –
MEASUREMENT MICROPHONES –

Part 2: Primary method for pressure calibration of laboratory standard microphones by the reciprocity technique

AMENDMENT 1

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Amendment 1 to IEC 61094-2:2009 has been prepared by IEC technical committee 29: Electroacoustics.

The text of this Amendment is based on the following documents:

Draft	Report on voting
29/1108/FDIS	29/1112/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Amendment is English.

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- amended.

5.5 Heat-conduction correction

Add, after the second existing paragraph, the following new paragraph:

At medium frequencies, transmission line theory, Equation (4), is applied to account for plane wave propagation in the coupler, but the influence of heat conduction at the ends of the coupler cannot be modelled accurately as impedances at the end surfaces. However, it can be demonstrated that, at frequencies where the pressure variations in the length direction of the coupler are moderate, the usable frequency range of the correction factor Δ_H can be extended by application of Δ_H to the cross-sectional area of the coupler, S_0, for the calculation of the acoustic impedance of the plane waves in the coupler, $Z_{a,0} = \rho c / S_0$ and setting α equal to zero and β equal to ω / c in Equation (4).

Add, after the last existing paragraph, the following notes:

NOTE 1 At the lowest frequencies, application of the correction factor Δ_H to the cross-sectional area of the coupler in Equation (4) is effectively the same as application of the factor to the volume in Equation (3).

NOTE 2 The two methods described in this standard for accounting for heat conduction and viscosity are not entirely consistent at any frequency. However, a transition frequency range can be identified for plane wave couplers used for reciprocity calibration. Estimates for the frequency range of validity are given in Annex A.

6 Factors influencing the pressure sensitivity of microphones

Add, after the existing 6.5, the following new subclause:

6.6 Influence of leakage

At low frequencies, care should be taken to avoid leakage in the coupler as it affects the acoustic transfer impedance. Alternatively, a capillary tube can be used as a controlled leakage. In that case, its effects on the acoustic transfer impedance shall be calculated.

7.3.3.1 Front cavity

Replace "NOTE 1" *with* "NOTE".

Delete the existing Note 2.

7.3.3.2 Acoustic impedance

Replace the existing second and third paragraphs with the following new paragraph:

At low frequencies, heat conduction in the cavity behind the diaphragm and the pressure-equalizing tube of the microphone contribute significantly to the acoustic impedance of the microphone. The acoustic impedance $\underline{Z}_{a}$ of each microphone forms an important part of the acoustic transfer impedance $\underline{Z}_{a,12}$ of the system. At high frequencies, errors in the determination of $\underline{Z}_{a}$ influence the accuracy of the calibration in a complicated way.

Replace "NOTE" *with* "NOTE 1".

Add, after the existing note, the following new note:

NOTE 2 For type LS1 microphones, heat conduction and pressure equalization result in an increase of the diaphragm compliance that reaches 20 % to 25 % below the lower limiting frequency. For LS2 microphones, the increase is 6 % to 9 %.

Table 1 – Uncertainty components

Add, in column "Relevant subclause no.", *line* "Unintentional coupler/microphone leakage", *the references* "6.6; 7.3.2.1".

Delete, in column "Relevant subclause no.", *line* "Polarizing voltage", *the reference* "6.5.3".

Replace, in column "Relevant subclause no.", *line* "Static pressure corrections", *the reference* "6.5" *with* "6.5.1".

Replace, in column "Relevant subclause no.", *line* "Temperature corrections", *the reference* "6.5" *with* "6.5.2".

A.1 General

Add, before the last existing paragraph, the following new paragraph:

For plane wave couplers, it can be demonstrated that the low frequency solution correction, when applied to the cross-sectional area of the coupler, is valid at frequencies where pressure variations due to wave-motion are moderate, see [A.5][2].

A.2 Low frequency solution

Replace the existing text with the following new text:

At low frequencies, where the sound pressure can be assumed to be the same at all points in the coupler, the effect of heat conduction can be considered as an apparent increase in the coupler volume expressed by a complex correction factor $\underline{\Delta}_{H}$ to the geometrical coupler volume [A.4], V, in Equation (3) or to the cross-sectional area, S_0, in Equation (4) with $\underline{\gamma} = 0 + j\omega c$.

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[2] Figures in square brackets refer to Clause A.4.

The correction factor is given by:

$$\Delta_{\mathrm{H}} = \kappa - (\kappa - 1)\underline{E}_p \tag{A.1}$$

where $\underline{E}_p$ is a complex quantity derived from the fundamental solution of the Fourier equation for heat conduction and which depends on the coupler geometry. For finite cylindrical couplers, the quantity $\underline{E}_p$ is given by

$$\underline{E}_p = \sum_{m=0}^{+\infty} \sum_{n=1}^{+\infty} \left[\frac{8/\pi^2}{\left(m+\frac{1}{2}\right)^2 \lambda_n{}^2} \underline{F}_{m,n} \right] \tag{A.2}$$

with

$$\underline{F}_{m,n} = \left(1 + \frac{\lambda_n^2 R^2 + \left(m + 1/2\right)^2 \pi^2}{\left(1 + 2R\right)^2} \underline{X}_{\mathrm{P}}^2 \right)^{-1}, \tag{A.3}$$

and where

$R = I_0 / (2a)$ is the length to diameter ratio of the coupler;

a is the radius of the coupler in metres (m);

λ_n are the roots of $J_0(\lambda_n) = 0$, see [A.6], for example; $J_0()$ is the cylindrical Bessel function of the first kind, zero order;

$\underline{X}_{\mathrm{P}}$ $= A(1-j)/\left(V\sqrt{2}\right)\sqrt{\alpha_t / \omega}$;

A is the total area surface of the cavity (m^2);

α_t is the thermal diffusivity of the enclosed gas in square metres per second (m^2·s^{-1}).

Tabulated values of Δ_{H} for typical dimensions of couplers are given in Table A.1 as function of frequency and at reference environmental conditions. The data can be used for validation of calculation software. The tabulated data given are considered accurate to 0,000 01. The quantity $\underline{E}_{\mathrm{P}}$ converges more quickly at low frequencies and for small dimensions of couplers. For example, the modulus of Δ_{H} is within 0,001 dB from the values in Table A.1 when calculated for (m,n) = (100,100) at 1 995,3 Hz for the largest coupler and for (m,n) = (2,2) at 1,995 3 Hz for the smallest coupler mentioned in Table A.1.

When the quantity Δ_{H}, as calculated from Equation (A.1), is applied to Equation (3), the calculated transfer admittance is assumed to be valid within 0,003 dB for the modulus and 0,01° for the phase at frequencies where $\lambda > 10^2 \cdot \sqrt[3]{V}$. When Δ_{H} is applied to S_0 in Equation (4) with $\underline{\gamma} = 0 + \mathrm{j}\omega c$, the calculated transfer admittance is assumed to be valid within 0,003 dB and 0,01° at frequencies where $\lambda > 25 l_0$. This corresponds to frequencies approximately in the range 1 000 Hz to 3 450 Hz for plane-wave couplers in the range of dimensions given in Table C.1.

Table A.1 – Values for $\underline{\Delta}_{\mathrm{H}}$

Frequency	a **= 9,3 mm** l_0 **= 18,9 mm**		a **= 9,3 mm** l_0 **= 11,4 mm**		a **= 4,65 mm** l_0 **= 10,4 mm**		a **= 4,65 mm** l_0 **= 5,7 mm**	
(Hz)	**Re($\underline{\Delta}_{\mathrm{H}}$)**	**Im($\underline{\Delta}_{\mathrm{H}}$)**	**Re($\underline{\Delta}_{\mathrm{H}}$)**	**Im($\underline{\Delta}_{\mathrm{H}}$)**	**Re($\underline{\Delta}_{\mathrm{H}}$)**	**Im($\underline{\Delta}_{\mathrm{H}}$)**	**Re($\underline{\Delta}_{\mathrm{H}}$)**	**Im($\underline{\Delta}_{\mathrm{H}}$)**
1,995 3	1,117 15	–0,091 65	1,141 80	–0,105 09	1,223 30	–0,134 20	1,278 08	–0,136 63
3,981 1	1,083 28	–0,070 22	1,101 15	–0,082 16	1,159 58	–0,113 26	1,198 79	–0,128 79
7,943 3	1,059 08	–0,052 43	1,071 82	–0,062 13	1,113 96	–0,089 93	1,142 13	–0,105 26
15,849	1,041 87	–0,038 50	1,050 92	–0,046 00	1,080 99	–0,068 69	1,101 39	–0,082 31
31,623	1,029 65	–0,027 95	1,036 08	–0,033 59	1,057 44	–0,051 19	1,071 99	–0,062 26
63,096	1,021 00	–0,020 14	1,025 55	–0,024 30	1,040 70	–0,037 54	1,051 04	–0,046 10
125,89	1,014 87	–0,014 44	1,018 09	–0,017 46	1,028 83	–0,027 23	1,036 16	–0,033 66
251,19	1,010 53	–0,010 31	1,012 81	–0,012 49	1,020 41	–0,019 61	1,025 61	–0,024 35
501,19	1,007 45	–0,007 34	1,009 07	–0,008 91	1,014 45	–0,014 05	1,018 14	–0,017 50
1 000,0	1,005 28	–0,005 22	1,006 42	–0,006 34	1,010 23	–0,010 03	1,012 84	–0,012 52
1 995,3	1,003 74	–0,003 71	1,004 55	–0,004 51	1,007 24	–0,007 14	1,009 09	–0,008 93

NOTE 1 The values given in this table are valid at reference environmental conditions only.

NOTE 2 The zero-frequency value of $\underline{\Delta}_{\mathrm{H}}$ is κ.

A.3 Broad-band solution

Remove the penultimate existing paragraph.

Replace the existing last paragraph with the following new paragraph:

When calculated with Equation (4) using Equations (A.4) to (A.6), the transfer admittance is estimated to be valid within 0,003 dB and 0,02° at frequencies where $\lambda < 16 l_0 a$ (the factor 16 is an empirical factor, expressed in m^{-1}). This corresponds to frequencies approximately in the range 175 Hz to 1 150 Hz for plane-wave couplers in the range of dimensions given in Table C.1.

A.4 Reference documents

Replace the existing reference [A.4] with the following new reference:

[A.4] VINCENT, P.; RODRIGUES, D.; LARSONNIER, F.; GUIANVARC'H, C. and DURAND, S. Acoustic transfer admittance of cylindrical cavities in infrasonic frequency range, Metrologia, 2018, Vol. 56, No. 1

Add the following references:

[A.5] OLSEN, E.S., Microphone acoustic impedance in reciprocity calibration of laboratory standard microphones, Proceedings of Forum Acusticum 2020, Paper 1023, 2020

[A.6] WATSON, G.N. A treatise on the theory of Bessel functions. Cambridge University Press. Second edition, 1944

Annex E – Methods for determining microphone parameters

E.4 Acoustic impedance of the microphone

Replace the existing first paragraph with the following new paragraphs and note:

The acoustic impedance can be expressed directly as a complex impedance or as a complex equivalent volume, see IEC 61094-1. At medium frequencies, a lumped parameter representation is possible, whereas the impedance deviates from that of the lumped parameter representation at low and high frequencies. This is particularly important for LS1 microphones at low frequencies where the contribution to the acoustic transfer impedance is significant compared to the uncertainty of measurement.

NOTE The deviation at low frequencies depends on the construction of the back cavity, the pressure equalization system of the microphone and its lower limiting frequency. For LS microphones available at the time of publication of this standard, the deviation will lead to an error in the resulting sensitivity that reaches 0,01 dB around 10 Hz for LS1 microphones and around 2 Hz for LS2 microphones.

At low and medium frequencies, the acoustic admittance of an LS microphone is to a good approximation proportional to the sensitivity of the microphone [E.1]. Hence, the acoustic admittance can be determined with an iterative procedure when a calibration is performed. First, the lumped parameter representation is established, and the sensitivity results are calculated based on this representation. From this sensitivity, the ratio of the acoustic admittance to the sensitivity is determined for a single frequency in the mid-frequency range, e.g. at the local minimum of the sensitivity. The acoustic impedance of the microphone is then calculated from the sensitivity by multiplication with the ratio. The iteration may be repeated based on the new acoustic admittance. Methods for the determination of the lumped parameter representation of a microphone are described in the following.

Add, after Clause E.4, the following new clause:

E.5 Reference documents

[E.1] SANDERMANN OLSEN, E. and FREDERIKSEN, E. Microphone acoustic impedance in reciprocity calibration of laboratory standard microphones, Inter-noise, 2013, Innsbruck, Austria

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

ÉLECTROACOUSTIQUE –
MICROPHONES DE MESURE –

Partie 2: Méthode primaire pour l'étalonnage en pression des microphones étalons de laboratoire par la méthode de la réciprocité

AMENDEMENT 1

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