Airflow resistivity measurement by using two different alternating airflow apparatus

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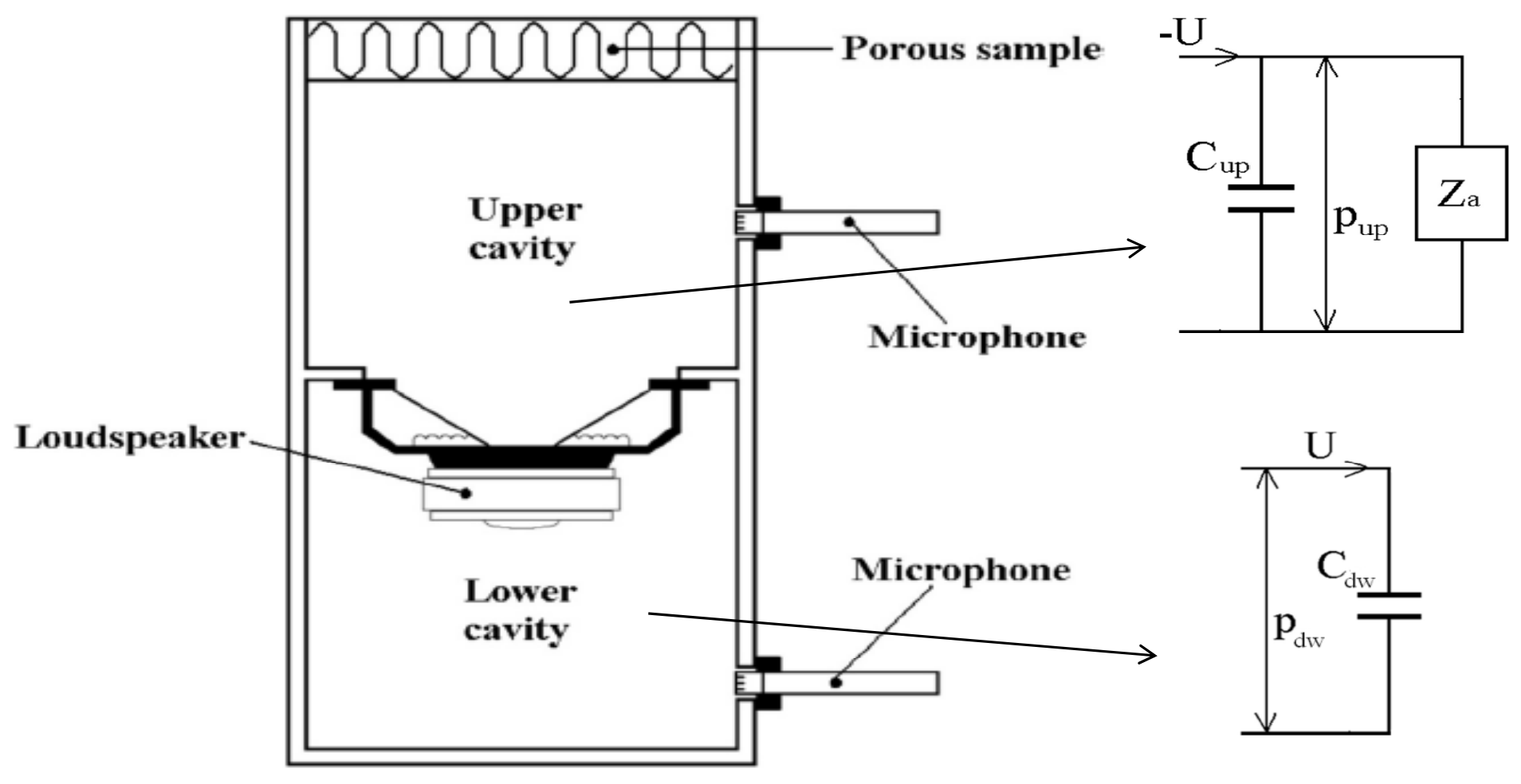
Abstract

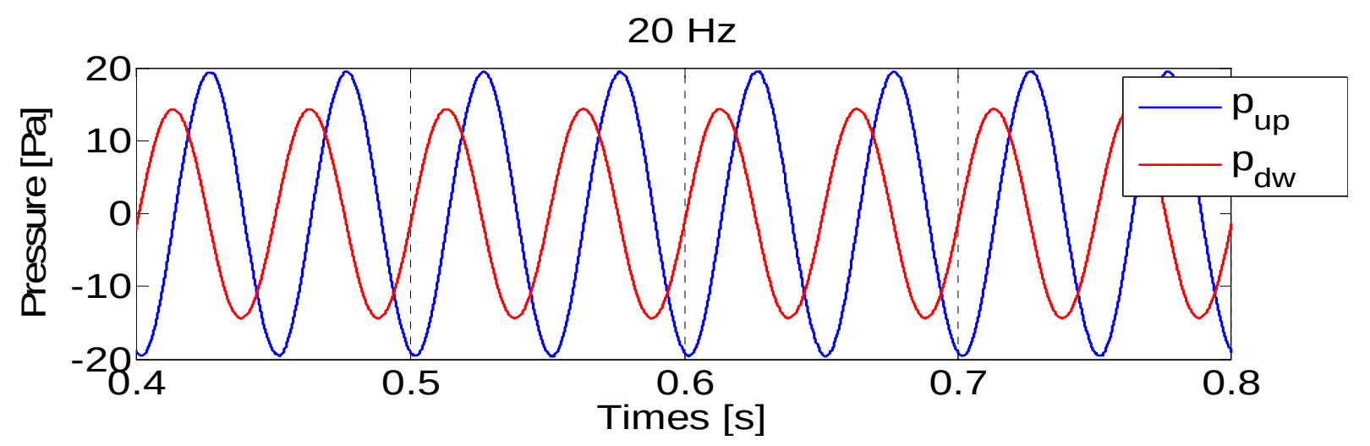
Airflow resistivity is one of the main parameters governing the acoustic behavior of porous materials. The assessment of the above-mentioned parameter is, therefore, of major concern for describing the acoustic behavior of a given porous material especially by using analytic or semi-empirical models.
The international standard ISO 9053 specifies two different methods to measure the airflow resistivity, namely a steady-state airflow method and an alternating air-flow method.
This paper reports comparative measurements performed on glass fiber, rock fiber, polyester fiber and polyethylene fiber materials by using two different apparatus for airflow measurement. Both measurement apparatus are based on an alternating airflow method and differ each other, essentially, for the air handling system consisting of an oscillating piston for the first apparatus and a loudspeaker in the other one.

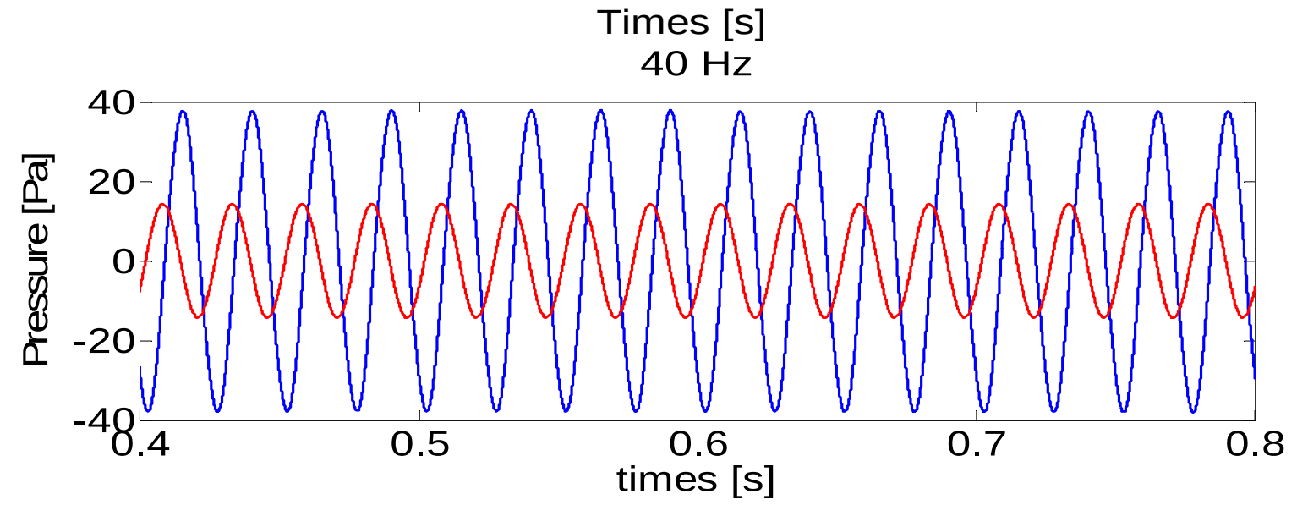
LAD apparatus

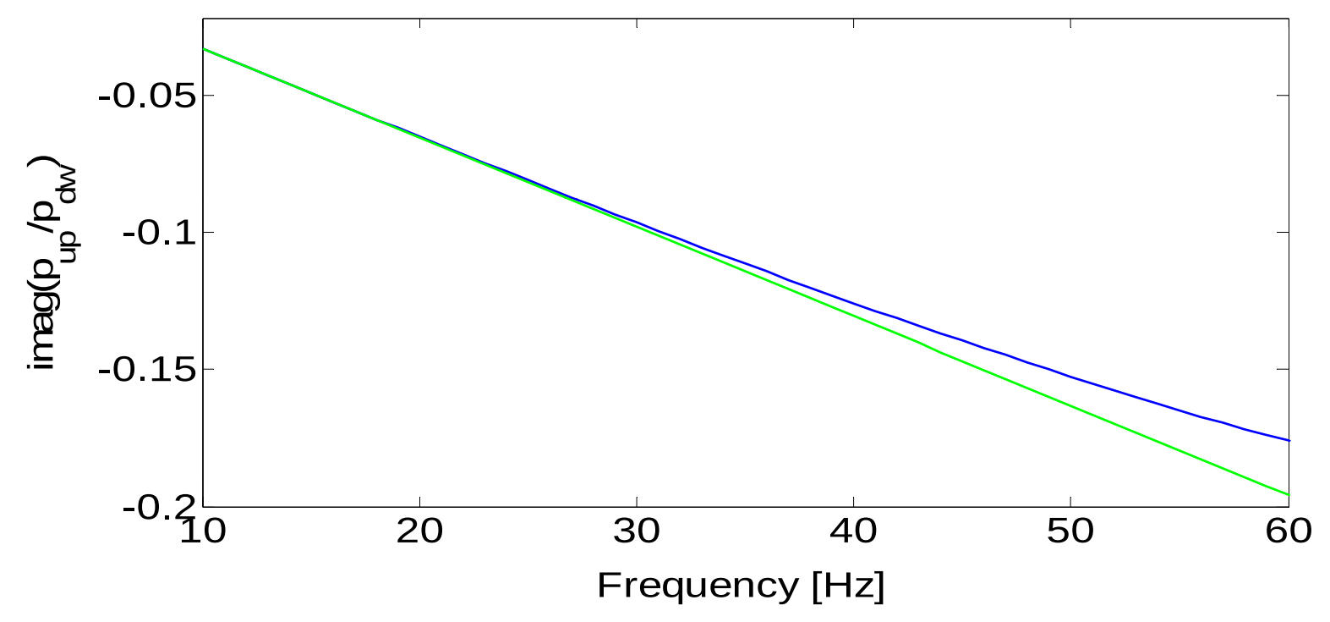
The method is based on the pressure measurement in two cavity separated by a loudspeaker as shown in the sideways figure. In the low frequency range the system can be approximated by a simple circuit with the acoustic impedance Z_a, depending on the porous layer and the radiation impedance Z_{rad} representing the load seen by the sound wave leaving the porous material, reduced to a simple resistance and the cavity reduced to a simple compliance.

With the above-mentioned assumption there is a constant phase shift between the pressure measured respectively in the upper cavity (p_{up}), where is located the material under test, and the lower cavity (p_{dw}). Furthermore the imaginary part of the ratio between pressures p_{up} and p_{dw} decreases linearly due to the 180°-phase shift of volume velocity exciting the air inside two cavities.







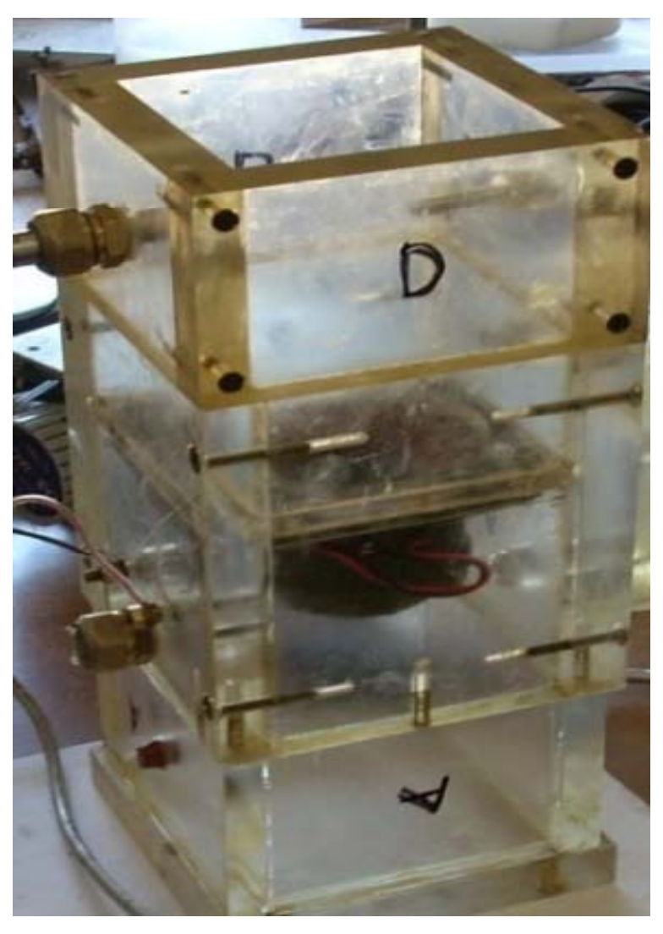


It is possible to show that the airflow resistivity can be related to the imaginary part of the ratio between pressures measured in the upper cavity and the lower one by a simple formula:

$$\sigma = -\frac{imag\left(\frac{p_{up}}{p_{dw}}\right) S\gamma P_0}{\omega V_{dw} d}$$

where S is the acoustic surface of the porous material, γ is the specific heat ratio, P_0 is the atmospheric pressure, d is the thickness of the porous sample under test and V_{dw} is the volume of the lower cavity. So the accuracy of the measurement depends on an exact assessment of the lower cavity volume and of the air temperature.

The apparatus developed at the beginning was made of plexiglas with a rectangular cross section; instead the measurement apparatus utilized for this work is made of aluminum with a circular cross section. The latter allows the combination with a conventional impedance tube.



INRIM apparatus

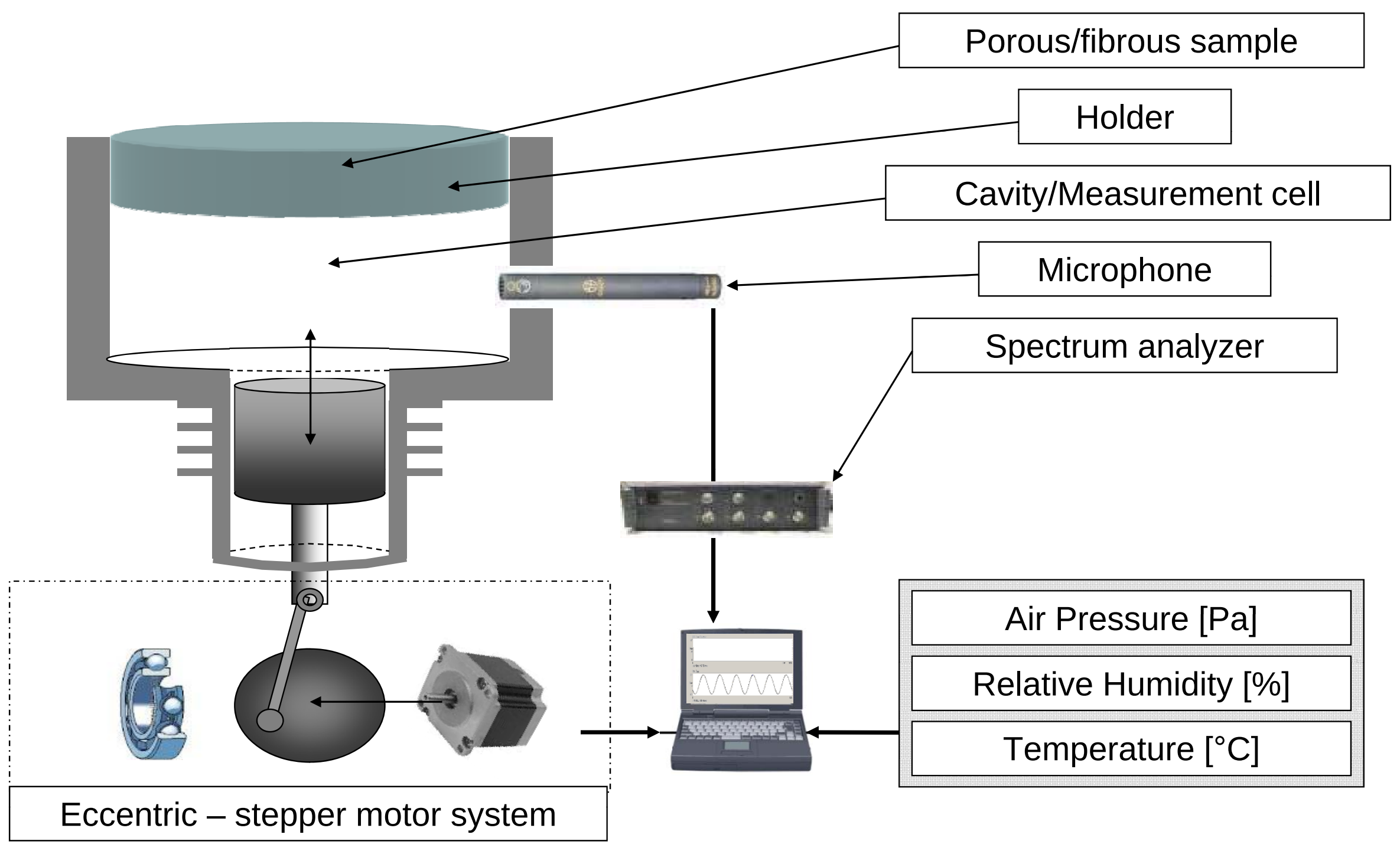
The system, designed and realized at INRIM, generates an alternating airflow in an enclosed volume and the sinusoidal pressure component (at 2 Hz) is measured with a calibrated capacitive microphone allocated in the enclosed volume. In order to perform measurement is necessary to first determine the sensitivity of the instrument. This corresponds to the actual calibration of the system. The airflow resistivity is determined from:

$$\sigma = \frac{p_{r.m.s.}}{q_{v,r.m.s.}} \cdot \frac{A}{d}$$

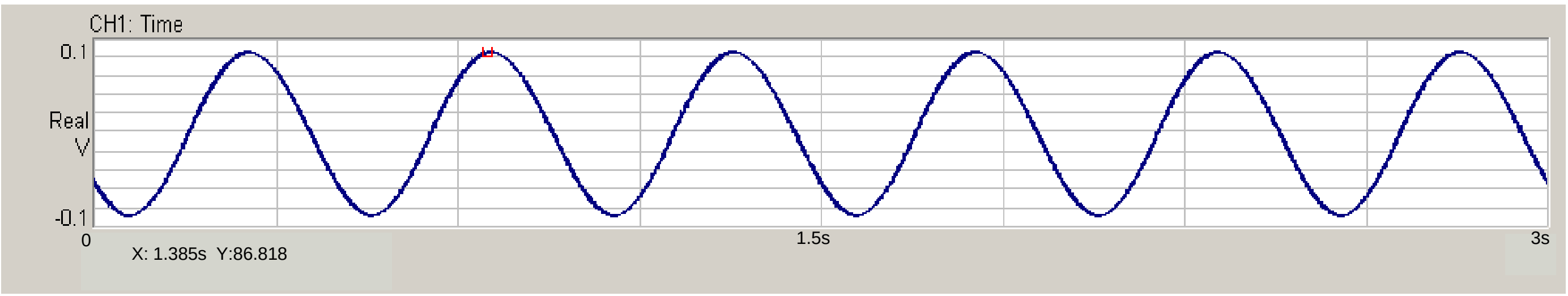
$$p_{r.m.s} = 1{,}4 \cdot \frac{p_0}{\sqrt{2}} \frac{V_{pk}}{V}$$

$$q_{v,r.m.s} = \frac{\pi}{\sqrt{2}} fhA_p$$

where *A is the* effective surface area of the sample, *L* is the thickness of the sample, $q_{v,r.m.s.}$ is the rms volumetric airflow, $p_{r.m.s.}$ is rms pressure, *f* is the frequency oscillation of the piston, *h* stroke of the piston (peak to peak), *Ap* is the piston surface area, p_0 is the atmospheric pressure, V_{pk} is the air volume moved by the piston, *V* is the volume of the cavity.



The sinusoidal pressure component during a porous/fibrous sample characterization



Results

	thickness [mm]	Airflow resistivity [Ns/m^4]		
		INRIM	**LAD**	**%**
fiberglass A	**2.05**	**2.88E+04**	**2.30E+04**	**20**
fiberglass B	**14.6**	**5.65E+04**	**4.29E+04**	**24**
polyethylene A	**10.65**	**3.05E+04**	**2.31E+04**	**24**
polyethylene B	**20.1**	**8.80E+03**	**7.09E+03**	**19**
rock wool	**39.7**	**1.22E+04**	**9.42E+03**	**23**
polyester fiber A	**50**	**3.70E+03**	**3.58E+03**	**3**
polyester fiber B	**50**	**5.80E+03**	**5.60E+03**	**3**
polyester fiber C	**30**	**2.30E+03**	**2.20E+03**	**4**
polyester fiber D	**6.3**	**5.99E+04**	**4.66E+04**	**22**

To compare the above-mentioned different apparatus for airflow resistivity measurements, classics acoustic materials were used. In particular, three types of fiber materials (glass fiber, rock fiber and polyester fiber) and polyethylene fiber of various density and thickness were investigated.
The results show that, except for materials with low resistivity, the difference between the two methods becomes bigger as the resistivity increases.
The difference can be due to several reasons. The most likely is a possible lack of air in one of the apparatus, in particular in LAD apparatus where the upper cavity was obtained by cutting a tube along its axis.
Another reason for the differences among measurement results could be related to the hypothesis of adiabatic process for air behavior. In the low frequency range, the thermal penetration depth is comparable with the geometrical dimension of the tube and then the thermal resistance can not be ignored. One of the consequence is that for LAD apparatus the two cavities are not simple compliances and for INRIM apparatus a calibration of the system should be repeated as the frequency or the temperature changes.