Characterization of a New Calibration Wind-Tunnel within Low Air Velocity Range

Isabelle CARE
(CETIAT, Domaine Scientifique de la Doua, 25, avenue des Arts, 69603 VILLEURBANNE Cedex, France)

Abstract Air velocity is a quantity often used in specifications of industrial processes or buildings. In these applications, the velocity is generally below 1 m.s^{-1}, the air temperature can be different from ambient one and the air can flow in any direction whatever. Furthermore, to reach minimum uncertainty measurements, a minimum calibration uncertainty of the used anemometer is needed as well as a calibration as close as possible to measurements conditions. To answer these needs, CETIAT has built a new anemometers' calibration test rig. Its evaluation is presented in terms of stability, homogeneity on humidity, temperature and velocity fields as well as calibration uncertainty.

Keywords: anemometer, low air velocity, wind-tunnel, calibration, uncertainty

1. Introduction

International and European standards such as EN ISO Standard 7730 1995 [1], ASHRAE Standard 55 1992 [2] are used to qualify air quality and comfort through parameters in which air velocity is involved.

A European study [3] has shown that, in the domain of low velocity range (0.05 m.s^{-1} to 2 m.s^{-1}), the maximum calibration uncertainty of anemometers should be ± 0.02 m.s^{-1} to be able to qualify comfort with a good accuracy.

Moreover, anemometers are calibrated in horizontal flow at ambient conditions and generally used at different conditions of temperature, humidity and flow direction. The influence of these conditions could be non-negligible, especially for the thermal anemometers but is difficult to estimate because of the lack of means to do it.

All these reasons have led CETIAT to build a new anemometers' calibration wind tunnel within low velocity range which could met these specifications of temperature and flow direction.

2. Concept of the wind-tunnel

The general concept of the new wind-tunnel is shown on the Figure 1 below:

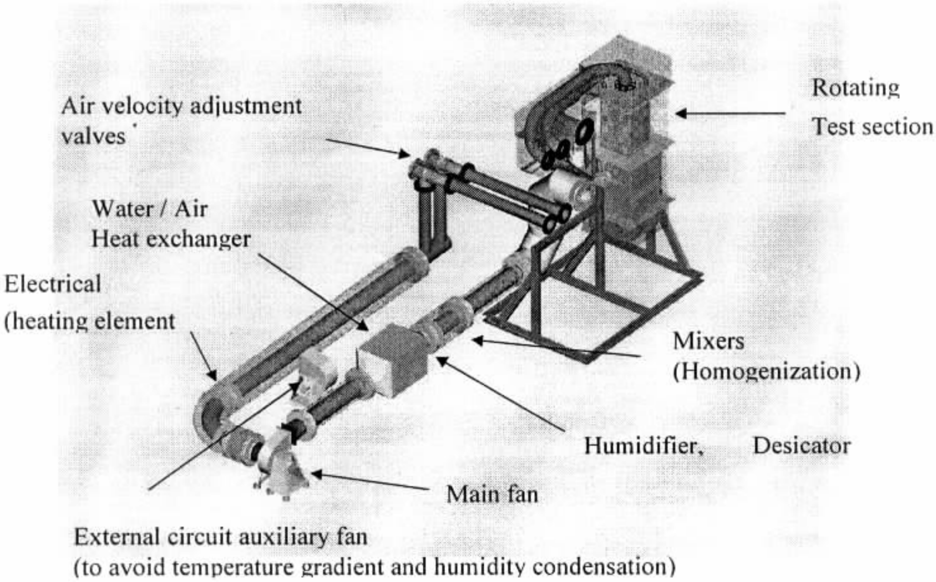

Figure 1 – Scheme of the wind-tunnel

The wind tunnel is made up of a main circuit on which are settled a fan (to generate the flow), the heat exchangers and the systems to dry and humidify the air. The calibration zone is located on the secondary circuit, defined as a diversion of the main one. Adjustment valves let the flow rate going through the secondary circuit and allow the adjustment of the air velocity in the calibration area. The reference air velocity is measured with a Laser Doppler Anemometer.

3. Technical performances

3.1. Humidity and temperature

A characterization of the thermal performances of the new wind tunnel has been performed. The present performances, in terms of humidity and temperature ranges, are presented on the figure 2 below on which the target and reached performances are drawn.

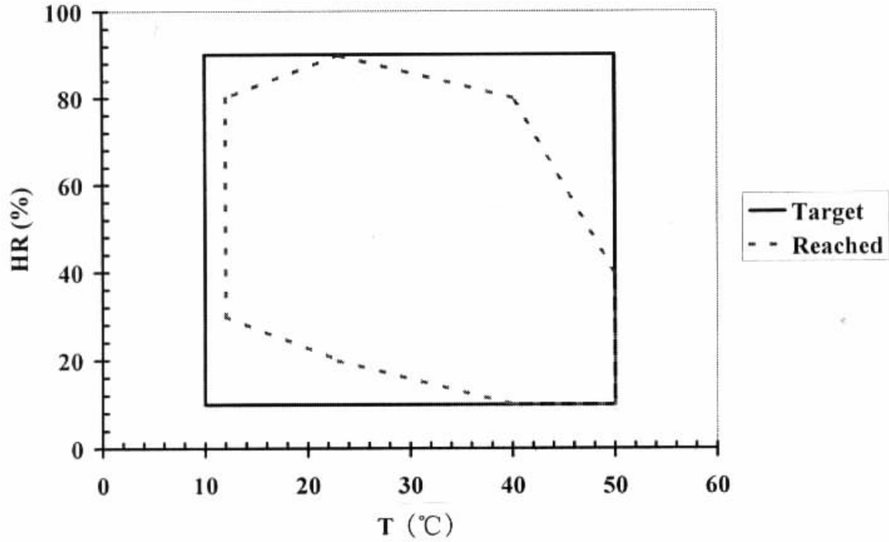

Figure 2 – Humidity and temperature ranges

In the present conditions, some temperature and humidity field have been established to characterized homogeneity of these parameters inside the calibration zone. Some of these characterizations are shown below (Figure 3 for the temperature field and Figure 4 for the humidity field).

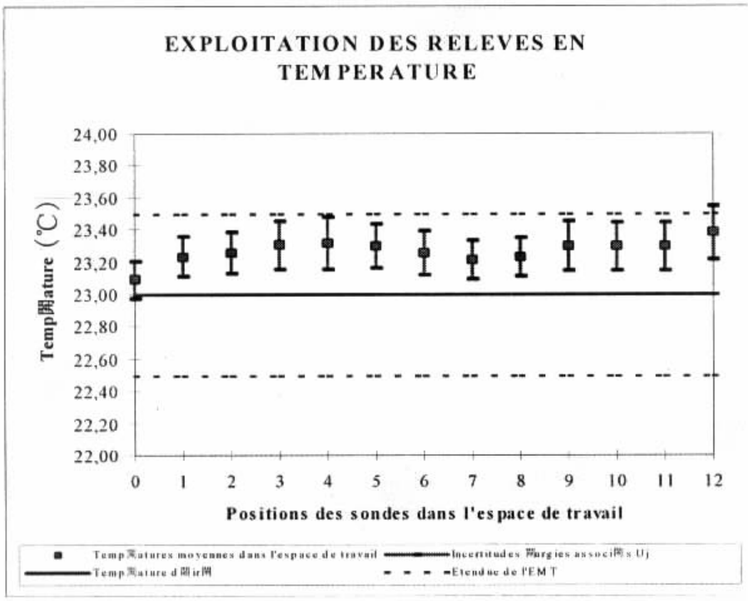

Figure 3 – Temperature field in the calibration zone around 23°C

There is a deviation between the temperature set point and the actual mean temperature. However, the reading of all temperature probes is inside the specification, which is 23°C ± 0.5°C. Moreover, the homogeneity inside the calibration zone, in this example, is better than ± 0.2°C.

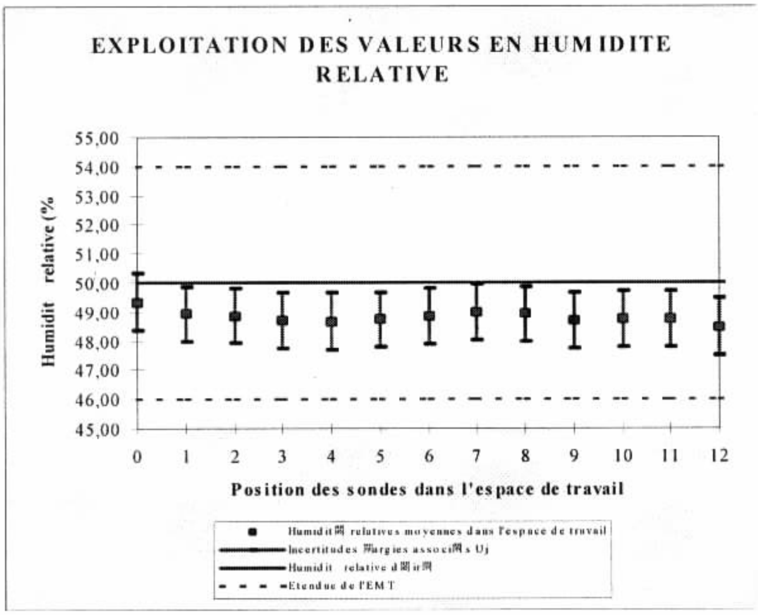

Figure 4 – Relative humidity field in the calibration zone (temperature and relative humidity set points : 23°C and 50°%)

There is a deviation between the relative humidity set point and the actual mean relative humidity. However, the reading of all relative humidity sensors is inside the specification, which is 50% ± 4%. Moreover, the homogeneity inside the calibration zone, in this example, is better than ± 0.5%.

Generally speaking, tests have been performed at different relative humidity and temperature set points. Within the reached humidity and temperature ranges (Figure 2), the temperature and relative humidity fields in the calibration zone are all inside the acceptable deviation defined in the technical specifications.

3.2.Time of thermal stabilization

The aim was that the stabilization times were below 2 hours. Some changes in temperature and relative humidity set points have been performed. These figures show the time necessary for the stabilization of the parameter at the new set point. The stabilization times are satisfactory as well for temperature as for relative humidity.

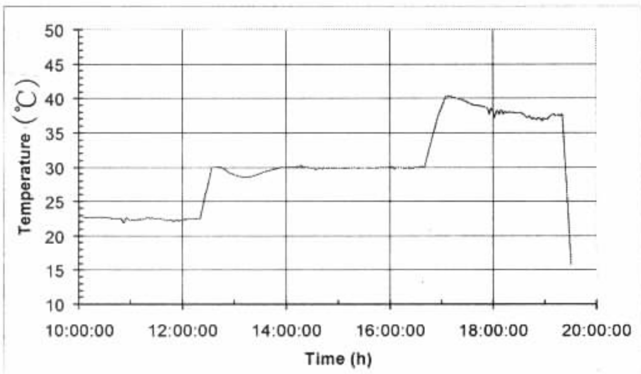

Figure 5 – Visualization of the stabilization time in temperature

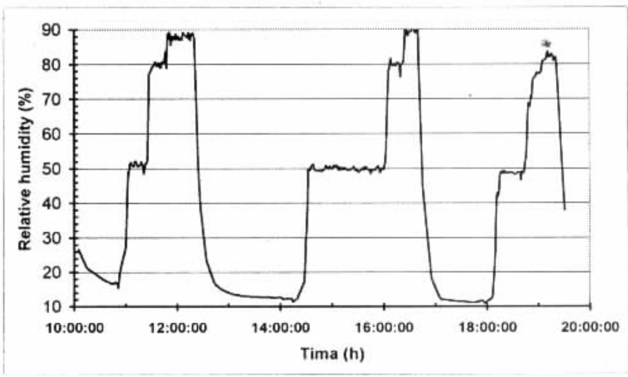

Figure 6 – Visualization of the stabilization time in relative humidity between 23°C and 40°C for different relative humidity set points

3.3. Velocity characterization

The velocity in the calibration zone is reached by adjustment of valves located between the primary and the secondary circuits. The velocity can vary between 0.05 $m.s^{-1}$ and 2 $m.s^{-1}$. Visualizations by PIV (Particle Imaging Velocimetry) have been realized. Some of these are shown on the figures below:

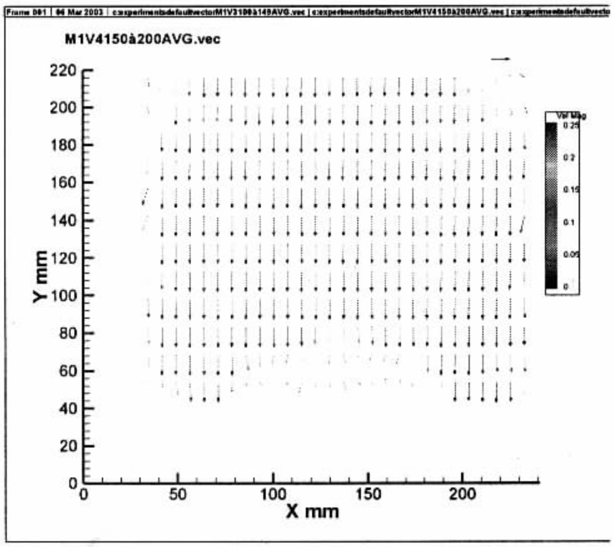

Figure 7 – Visualization of the velocity field in a plane in the calibration zone for a targeted velocity of about 0.25 $m.s^{-1}$

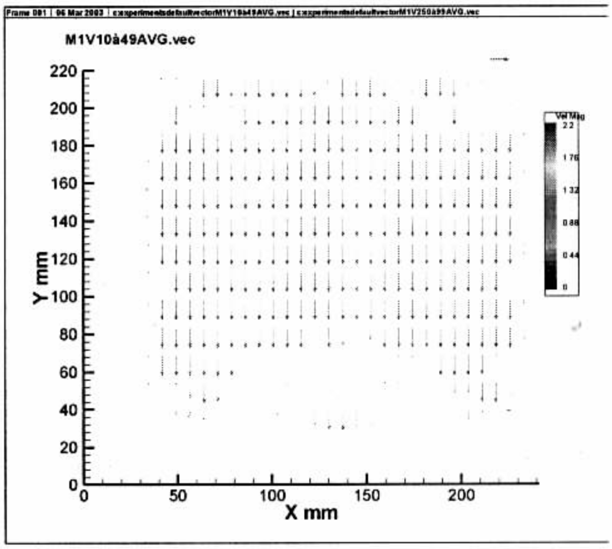

Figure 8 – Visualization of the velocity field in a plane in the calibration zone for a targeted velocity of about 2 $m.s^{-1}$

The velocity fields are quite satisfactory within the calibration zone (velocity vectors are parallel and of same magnitude).

Some more accurate measurements have also been performed by LDA 5Laser Doppler Anemometry) in the calibration zone between 0.05 $m.s^{-1}$ and 2 $m.s^{-1}$ at 10°C, 23°C and 50°C. These velocity profiles have established in horizontal flow which is the worst case for the natural convection.

The homogeneity of the flow is confirmed at all temperatures.

Then, in the configuration of the calibration of an anemometer, we have estimated the deviation between the velocity measured by the reference anemometer and the one at the point where the anemometer under calibration should be located. This deviation has been estimated within the whole velocity range and at different temperature. The results are shown at 23°C on Figure 9 below.

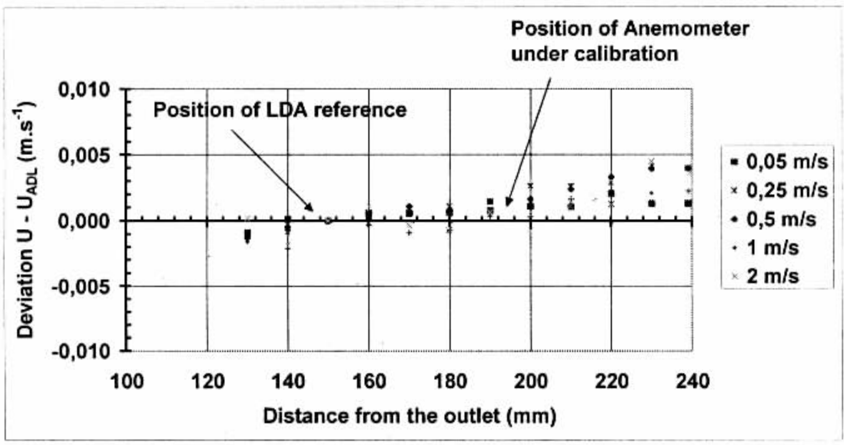

Figure 9 – Velocity profile at 23°C and horizontal flow

The difference between the two velocities is slightly higher in case at 10°C or 50°C but the behavior is the same. It exists a small drift between the two positions. This one is taken into account in the estimation of the global uncertainty of the new test rig.

4. Calibration uncertainty

Taken into account the characterization of the wind tunnel and the reference anemometer (LDA), the different uncertainty components are evaluated within the whole velocity and temperature ranges. The global estimated uncertainty is drawn on figure 10 below.

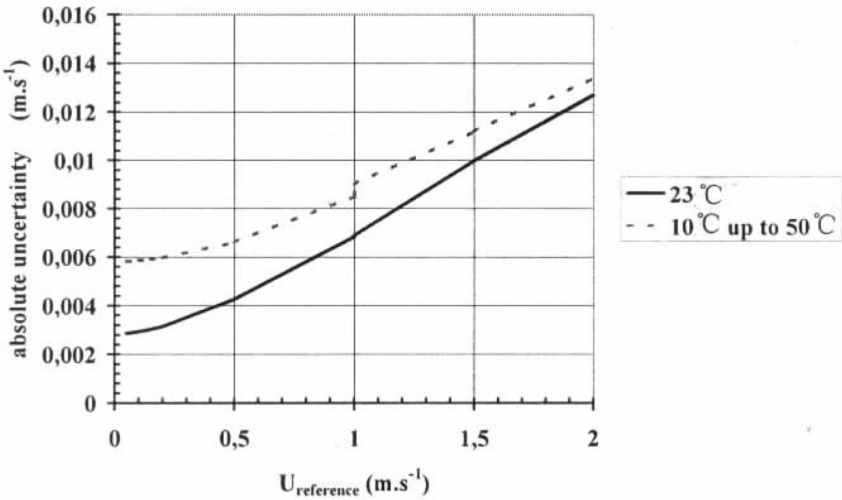

Figure 10 – Evaluated absolute uncertainty of the new anemometers' calibration test rig

The objective was to reach a global uncertainty less that ± 0.02 m.s^{-1} to let the characterization of comfort quality with enough accuracy. This specification is reached on the whole velocity range.

5. Conclusion

A new anemometers' calibration wind tunnel has been built. The objective was to answer the industrial need and let the calibration of instruments in different conditions (temperature, humidity, flow direction) in the low velocity range. The objective was also to improve the reference in the velocity field.

The different tests of characterization, which has been performed, show that most of the technical specifications have been reached as well as the specification about uncertainty of the new test rig.

Acknowledgment

Author wish to thank BNM (Bureau National de Metrologie), Rhône Alpes county, ATTITA organization as Airflow, E+E, SWEMA and TESTO anemometers' manufacturers for their financial support.

CETIAT wish also to thank André CLOT and Yves LECOFFRE (Ylec Consultants) without whom this new test rig would not exist.

Reference

[1] EN ISO Standard 7730, 1995. Specifications for thermal comfort conditions.

[2] ASHRAE Standard 55, 1992. Thermal environmental conditions for human occupancy

[3] Melikov A.K. *et al.* Calibration and requirements for accuracy of thermal anemometers for indoor velocity measurements. *EC project MAT1-CT93-0039*, 1997