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Meteorology — Sonic anemometers/thermometers — Acceptance test methods for mean wind measurements

Météorolgie — Anémomètres/thermomètres soniques — Méthodes d'essai d'acceptation pour les mesurages de la vitesse moyenne du vent

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 16622 was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 5, *Meteorology*.

Annex C forms a normative part of this International Standard. Annexes A, B and D are for information only.

Introduction

Most human activity influencing the dispersion of anthropogenic pollutants occurs within the surface layer (SL), that portion of the atmosphere which lies within a few tens of metres of the earth's surface. The SL is typified by sharp gradients and time-varying fluxes of heat, moisture and momentum. Three-dimensional flow and turbulence information resolved over short temporal and spatial scales is needed to characterize the SL. This information must be presented not only as time-mean quantities, but also as the turbulent fluctuations of those quantities which contribute to the production, transport, dispersion and dissipation processes operating within the SL. The sonic anemometer/thermometer (shortened to “sonic” in the following) is an instrument well suited to obtain measurements necessary for SL characterization.

A sonic consists of a transducer array containing paired sets of ultrasonic transmitter/receivers, and circuitry designed to measure the transit times of acoustic waves propagating over the path (typically 10 cm – 20 cm) between transducer pairs. A three-dimensional array resolves horizontal and vertical wind components plus the speed of sound from which the sonic (virtual) temperature can be derived. Sonic anemometry has been used for several decades in atmospheric research, but recent advances in instrument design and signal processing, coupled with increased sophistication of atmospheric dispersion models, has led to an increasing demand for their use, including routine wind speed and direction measurements. Because they contain no moving parts, sonics offer low maintenance and operational advantages in adverse weather conditions. These factors have stimulated the commercial manufacture of sonics and the drafting of several national sonic standards which form the basis for the following International Standard of performance measurements and test methods.

The procedures presented in this document define methods for acceptance testing of sonics to be used for mean wind measurements. Minimum requirements for conformance with this International Standard include successful completion of the zero wind chamber test (clause 7), the wind tunnel test (clause 8), and the field test (clause 10). The pressure chamber test (clause 9) is recommended if the sonic is to be used at elevations higher than 2 000 m above mean sea level.

Meteorology — Sonic anemometers/thermometers — Acceptance test methods for mean wind measurements

1 Scope

This International Standard defines test methods of the performance of sonic anemometers/thermometers which employ the inverse time measurement for velocity of sound along differently oriented paths. It is applicable to designs measuring two or three components of the wind vector within an unlimited (360°) azimuthal acceptance angle.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 5725-1, *Accuracy (trueness and precision) of measurement methods and results — Part 1: General principles and definitions*

ISO 5725-2, *Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*

ASTM D5741-96, *Standard Practice for Characterizing Surface Wind Using a Wind Vane and Rotating Anemometer*

WMO CIMO, 1996 World Meteorological Organization (ed.) *Guide to meteorological instruments and methods of observation.* WMO-No.8, 6th edn. 1996, Geneva

3 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply.

3.1
array
mechanical structure to support the sonic transducers in the desired geometric configuration

3.2
array symmetry angle
angular distance about which the array is symmetrical

3.3
mean
mean value over the (selected) averaging interval of the sonic

3.4
sonic
sonic anemometer/thermometer
instrument consisting of a transducer array containing sets of acoustic transmitters and receivers, a system clock, and microprocessor circuitry to measure intervals of time between the transmission and reception of sound pulses

3.5
sound path
path between a pair of transducers

3.6
system delay
difference between the electronically detected total propagation time and the transit time

NOTE The time between the electronic generation of the transmission signal and the electronic detection of the received signal is longer than the transit time due to the propagation times through the transducers and the electronic circuitry.

3.7
transit time
time required by a sound wave front to propagate between a pair of transducers

3.8
turbulence level
turbulence intensity
T_i
ratio of the square root of the turbulent kinetic energy to the mean wind speed

$$T_i = \frac{\sqrt{\overline{u'^2} + \overline{v'^2} + \overline{w'^2}}}{\bar{U}_0} \quad (1)$$

where

$'$ denotes deviations from the mean.

EXAMPLE $u' = u - \bar{u}$, etc., where

u' is the instantaneous wind component

$\bar{u}$ is the mean wind component.

3.9
zero offset
wind speed indicated by the sonic in calm air

4 Symbols and abbreviated terms

T	temperature, in kelvin
T_s	sonic temperature, in kelvin [see equation (B.4)]
T_i	turbulence intensity
U_0	speed of the undisturbed flow in the wind tunnel, speed, or wind speed measured by a reference sensor, in metres per second
U_a	wind speed, sonic output, in metres per second with sonic azimuth a
U_b	wind speed, sonic output, in metres per second with sonic azimuth b
$U_{a,n}$	nth sample of U_a, in metres per second
U_v	vectorial average of U_a, in metres per second
U_s	scalar average of U_a, in metres per second
U_{max}	specified maximum speed measurable with the sonic, in metres per second
U_{min}	minimum test speed, in metres per second
Z	acoustic impedance ($Z = \rho \cdot c$ [kg·m^{-2}·s^{-1}])
a	sonic azimuth, in degrees
b	sonic azimuth, in degrees
c	speed of sound, in metres per second
d	path length, in metres
e	water vapour partial pressure, in hectopascals
h	height above mean sea level, in metres
p	pressure, in hectopascals
p_e	equivalent pressure, in hectopascals (see Table D.1)
t_a	averaging interval, in seconds
t_+	transit time from transducer+ to transducer– , in seconds
t_-	transit time from transducer– to transducer+ , in seconds
u_0, v_0, w_0	along-axis, cross-axis, and vertical velocity components of the undisturbed flow, in metres per second
u_a, v_a, w_a	along-axis, cross-axis, and vertical velocity components, sonic output, in metres per second
$u_{a,n}, v_{a,n}, w_{a,n}$	nth sample of u_a, v_a, w_a, in metres per second

v_d along-path velocity component of the wind, in metres per second

v_n cross-path velocity component of the wind, in metres per second

v_t wind speed at the location of the sound path ($v_\mathrm{t} = \sqrt{v_\mathrm{n}^2 + v_d^2}$)

α wind direction, reference sensor output, in degrees

α_0 azimuth of the undisturbed flow with respect to the sonic orientation — either equal to the wind tunnel axis azimuth relative to the sonic azimuth, or azimuth measured by a reference sensor, in degrees

α_a wind direction, sonic output, in degrees, with sonic azimuth a

α_b wind direction, sonic output, in degrees, with sonic azimuth b

$\alpha_{a,n}$ nth sample of α_a

α_v vectorial average of α_a, in degrees

α_s scalar average of α_a, in degrees

Δ_a modulus of the vector difference between measured and undisturbed wind tunnel velocity at azimuth α, in metres per second

$\Delta_{a,b}$ modulus of the vector difference between the wind vectors measured in the zero wind chamber with the instrument azimuths α_a and α_b, in metres per second

$\Delta_{a,n,m}$ modulus of the vector difference between the nth and the mth sample of the wind vector measured in the zero wind chamber with the instrument azimuth α_a

φ the tilt of the sensor relative to the horizontal wind tunnel airflow, in degrees; positive angles are the fixture axis above the horizontal on the upwind side, and negative angles are the fixture axis below the horizontal

ρ air density, in kilograms per cubic metre

Ω angular velocity azimuth rotation of the sensor, in degrees per second

5 Summary of methods

The instrument's array should be examined for damage and conformance with manufacturer design specifications prior to testing. The accuracy of all measurements and results shall be ascertained and reported in accordance with ISO 5725-1 and ISO 5725-2.

— Zero wind chamber test: the offset of the measured wind speed is determined over the operational temperature range.

— Wind tunnel test: the deviation of the measured from the true velocity (vector) is determined over the operational range of flow speed and direction.

— Pressure chamber test: the operational range of air density is determined. Although the measuring principle does not depend on air density, a minimum density is required to transmit detectable sound.

— Field test: addresses the response to potentially adverse environmental conditions, which are difficult to simulate in the laboratory.

6 Array examination prior to testing

Ensure that the array is properly oriented and aligned, and is free of damage or obstruction.

Measure and record the path lengths between transducer pairs and compare to manufacturer-specified path lengths and tolerances, if available. If the results exceed manufacturer's tolerances, terminate the procedure.

7 Zero wind chamber test

7.1 Purpose

The purpose of the zero wind chamber test is to define the magnitude of the zero offset and/or instrument alignment or calibration problems.

The system delay (3.6) consists of signal propagation times within the transducers and the electronics. The asymmetric part of the system delay (that is, the difference of delays between both signal propagation directions) causes a zero offset of the corresponding wind component. Usually the zero offset is largely eliminated by the on-line signal processing, based on a factory calibration. Nevertheless, the offset can drift with time and it may be temperature dependent. It can be determined by testing the array into a zero wind chamber (see annex A).

7.2 Procedure

7.2.1 Obtain zero wind chamber performance standards from manufacturer.

7.2.2 Place the array in the zero wind chamber and wait for the internal chamber temperature and air movement to stabilize. Make sure that the anemometer is operating but that array heating, if any, is off.

7.2.3 Set the sonic averaging interval to the same that is used for the application. Make sure that the chamber fan, if used, is switched off.

7.2.4 Read and record the temperature, the wind velocity and direction or wind components measured by the sonic $\Rightarrow U_{a,n}\alpha_{a,n}$ or $\Rightarrow u_{a,n}v_{a,n}w_{a,n}$. Index a denotes the azimuth orientation of the instrument in the zero wind chamber, and index n denotes the number of the sample.

7.2.5 Repeat 7.2.4 at least three times at 10-min intervals. If all measured wind speeds are within the instrument's specified zero offset, accept. Report the chamber temperature, because the offset may be temperature dependent. If the zero wind chamber design is approved by the manufacturer, and if one or more samples of the measured wind speeds exceed the instrument's specified zero offset, reject.

7.2.6 If a zero wind chamber design is used, which is not approved by the manufacturer, and if one or more samples of the measured wind speeds exceed the instrument specifications, make sure that the variability is not due to some residual air motion in the test chamber. For this purpose calculate the modulus of the vector differences.

$$\Delta_{a,n,m} = \sqrt{(U_{a,n}\sin\alpha_{a,n} - U_{a,m}\sin\alpha_{a,m})^2 + (U_{a,n}\cos\alpha_{a,n} - U_{a,m}\cos\alpha_{a,m})^2} \quad (2)$$

where $\Delta_{a,n,m}$ is the modulus of the vector difference between the nth and the mth sample of the wind vector with the instrument azimuth α.

If the maximum of $\Delta_{a,n,m}$ is less than 10 % of the instrument's zero offset specification, the offset is stable with time, and air motion can be excluded. Now make sure that the offset is not caused by wall reflections. For this purpose rotate the array around its azimuth axis relative to the chamber by about half the symmetry angle of the array (60° for an array with 120° symmetry) and wait again for the air movement to stabilize. Read and record again the wind velocity and direction $\Rightarrow U_b,\ \alpha_b$.