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Meteorology — Wind measurements —

Part 1:
Wind tunnel test methods for rotating anemometer performance

Météorologie — Mesurages du vent —

Partie 1: Méthodes d'essai en soufflerie pour déterminer les caractéristiques d'un anémomètre tournant

Reference number
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Contents

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 2.

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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 17713-1 was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 5, *Meteorology*.

ISO 17713 consists of the following parts, under the general title *Meteorology — Wind measurements*:

— *Part 1: Wind tunnel test methods for rotating anemometer performance*

The following part is planned:

— *Part 2: Wind tunnel test methods for wind vanes*

Introduction

Cup and propeller anemometers are the most frequently used meteorological instruments for the measurement of mean wind speed in the near surface layer, that portion of the atmosphere which lies within a few tens of meters of the earth's surface. Some types of cup and propeller anemometers are available for measuring wind speeds of a few tenths of a meter per second while other types can measure wind speeds approaching 100 $m \cdot s^{-1}$. These general purpose anemometers are used extensively for meteorology, aviation, air pollution, wind energy and numerous other applications.

This part of ISO 17713 was developed in order to have a worldwide uniform set of test methods to define the characteristics of cup and propeller anemometers. This part of ISO 17713 will allow an end user to compare different manufacturers and different models of cup and propeller anemometers to determine the suitability for a particular application.

Meteorology — Wind measurements —

Part 1:
Wind tunnel test methods for rotating anemometer performance

1 Scope

1.1 This part of ISO 17713 describes wind tunnel test methods for determining performance characteristics of rotating anemometers, specifically cup anemometers and propeller anemometers.

1.2 This part of ISO 17713 describes an acceptance test and unambiguous methods for measuring the starting threshold, distance constant, transfer function and off-axis response of a rotating anemometer in a wind tunnel.

Note that when transferring values determined by these methods to atmospheric flow, there is a difference between anemometer performance in the free atmosphere and in the wind tunnel.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document applies.

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*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply. See also References [1], [2] and [3].

3.1
distance constant
L_U
distance the air flows past a rotating anemometer during the time it takes the cup wheel or propeller to reach (1 − 1/e) or 63 % of the equilibrium speed after a step increase change in air speed

3.2
off-axis response ratio
Q_U
ratio of the indicated wind speed (U_θ) at various angles of attack (θ) to the product of the indicated wind speed (U_i) at zero angle of attack and the cosine of the angle of attack (θ) and thus this ratio (Q_U) compares the actual off-axis response to a true cosine response

3.3
starting threshold

U_0

lowest wind speed at which a rotating anemometer starts and continues to turn and produce a measurable signal when mounted in its normal operating position

NOTE The normal operating position for cup anemometers is with the axis of rotation perpendicular to the direction of air flow and the normal operating position for propeller anemometers is with the axis of rotation aligned parallel with the direction of the air flow.

3.4
transfer function

relationship between predicted wind tunnel air speed and the anemometer rotation rate throughout the specified working range of the anemometer: ($\hat{U} = a + bR + \ldots$)

4 Symbols and abbreviated terms

a	zero offset constant (metres per second)
b	wind passage (apparent pitch) constant or calibration constant (metres per revolution)
D_{P}	wind distance passage (metres) per output pulse for anemometers with pulse output signal
°	symbol for directional degrees
e	base of natural logarithms
L	average of the distance constants (metres) at 5 m·s^{-1} and 10 m·s^{-1}
L_U	distance constant (metres) at wind tunnel air speed U (metres per second)
$M_{\mathrm{R}U}$	wind speed measurement resolution, i.e. the smallest reported speed measurement increment (metres per second) for the anemometer
Q_U	off-axis response ratio at wind tunnel air speed U (metres per second)
r	a shaft revolution
R	rate of rotation (revolutions per second, r·s^{-1})
t	time (seconds)
t_{f}	time (seconds) to reach 74 % of the anemometer equilibrium speed U_{f} (metres per second)
t_{i}	time (seconds) to reach 30 % of the anemometer equilibrium speed U_{f} (metres per second)
T	measurement time interval (seconds)
T_{R}	time resolution of a measurement (seconds)
U	wind tunnel air speed (metres per second, m·s^{-1})
$\hat{U}$	predicted wind speed (metres per second) from the anemometer transfer function
U_{f}	anemometer indicated wind speed (metres per second) at equilibrium
U_{i}	anemometer indicated wind speed (metres per second) in its normal position in the wind tunnel

U_{max} anemometer maximum specified operational speed (metres per second)

U_{min} anemometer minimum specified operational speed (metres per second)

U_t instantaneous indicated wind speed (metres per second) at time t

U_0 starting threshold (metres per second)

U_θ indicated wind speed (metres per second) of the anemometer at off-axis angle of attack θ

θ off-axis angle of attack (degrees)

θ_s stall angle for fixed-axis propeller anemometers (degrees)

τ anemometer response time (seconds) for the equilibrium speed U_f

5 Summary of test method

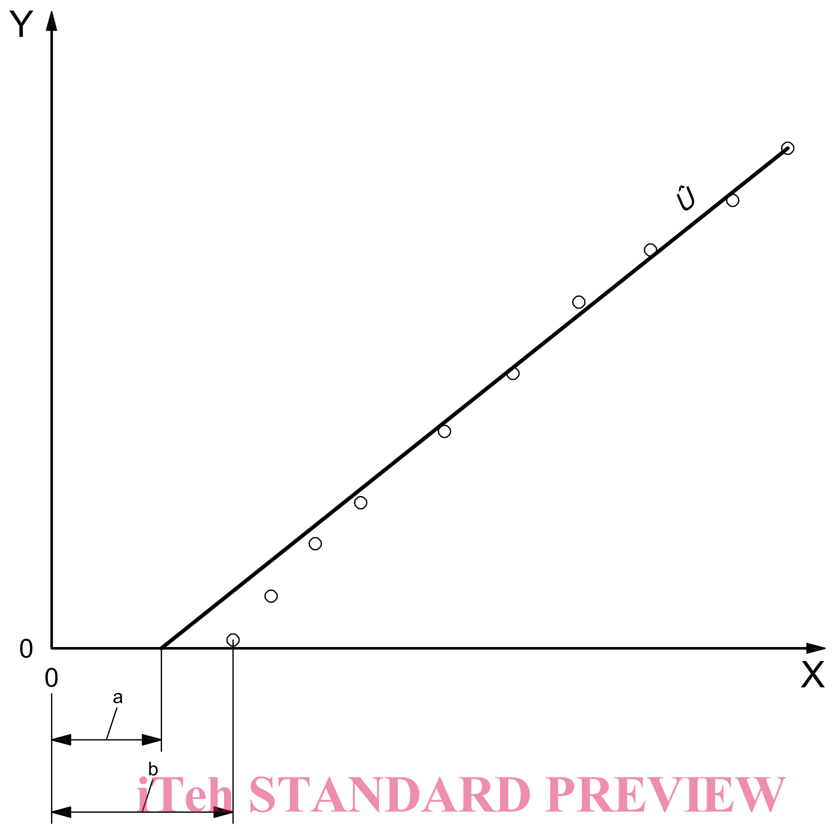
5.1 This test method requires a wind tunnel described in Annex A. Additional information regarding wind tunnel testing is listed in the bibliography [7][10][12][13].

5.2 The starting threshold (U_0) is determined by measuring the lowest speed at which a rotating anemometer starts and continues to turn and produce a measurable signal when mounted in its normal operating position. The anemometer axis is aligned parallel with the direction of air flow for a propeller anemometer. The anemometer axis is aligned perpendicular to the direction of air flow for a cup anemometer.

5.3 The transfer function ($\hat{U} = a + bR + ...$) [1][6] is determined by measuring the rate of rotation, or output signal, of the anemometer at a number of wind speeds throughout the working range (range of intended use). In the range of wind speeds where the anemometer response is non-linear (near threshold), measurements at a minimum of five different speeds are recorded. Measurements at a minimum of five additional speeds are recorded within the working range of the anemometer and wind tunnel but above the non-linear threshold region (see Figure 1). If the application working range extends into a further high speed non-linear range, then measurements at additional speeds shall be included in that range, sufficient to enable a suitable polynomial expression to be determined. A minimum of three sets of measurements are to be taken. The values of a and b are determined by least-squares regression using the individual measurements taken at each data point.

The transfer function can be approximated to a linear relationship for certain application ranges and certain anemometer designs. The function can be non-linear at low tunnel speeds (typically two to five times the U_0) and again at higher speeds. $\hat{U}$ is the predicted wind speed in metres per second; a and b are polynomial constants. Constants beyond b would be zero for the linear relationship. For the linear case, the constant a is commonly called zero offset, in metres per second, b is a constant representing the wind passage in metres per revolution for each revolution of the particular anemometer cup wheel or propeller, and R is the rate of rotation in revolutions per second. It should be noted that zero offset is not the same parameter as the starting threshold. In some very sensitive anemometers, the constant a, zero offset, may not be significantly greater than zero. The constants a and b shall be determined by wind tunnel measurement for each type of anemometer. In the case of anemometers that do not directly output a rate of rotation, for example, with an output directly in wind speed (ASCII, hexadecimal, etc.) or electrical units (volts, milliamperes, etc.), R and b can have different units that correspond to those of the output.

NOTE Although this transfer function model does not completely represent the anemometer response in the non-linear starting portion of the curve, for most applications the additional accuracy provided by more rigorous mathematics is not warranted. These data points in the non-linear starting area can be the basis for a more advanced mathematical model of the transfer function.



Key

X wind tunnel speed, U, in metres per second

Y rotation rate, R, in revolutions per second

a zero offset, a, in metres per second

b starting threshold, U_0, in metres per second

Figure 1 — Typical anemometer calibration curve

5.4 The distance constant (L_U) shall be determined at a number of wind speeds which shall include 5 m·s^{-1} and 10 m·s^{-1}. It is computed from the time required for the anemometer rotor to accelerate (1 – 1/e) or 63 % of a step increase change in rotational speed after release from a restrained, non-rotating condition [4]. The final response, U_f, is the wind speed at equilibrium as indicated by the anemometer (see Figure 2). This response time (τ) is only applicable at the particular test speed. For some applications, additional wind speeds over the operational range can be of interest.

NOTE There is a different distance constant for a decreasing step change of speed. This value will be an indicator of the amount of anemometer over speed (the anemometer reporting a wind speed value higher than the true wind speed) in gusty wind conditions. For specific anemometer applications, this distance constant for decreasing wind speed can be of interest. The determination of the distance constant for decreasing wind speeds is beyond the scope of this part of ISO 17713.

The response of a rotating anemometer to a step change in which the air speed increases instantaneously from $U = 0$ to $U = U_f$ is [5]:

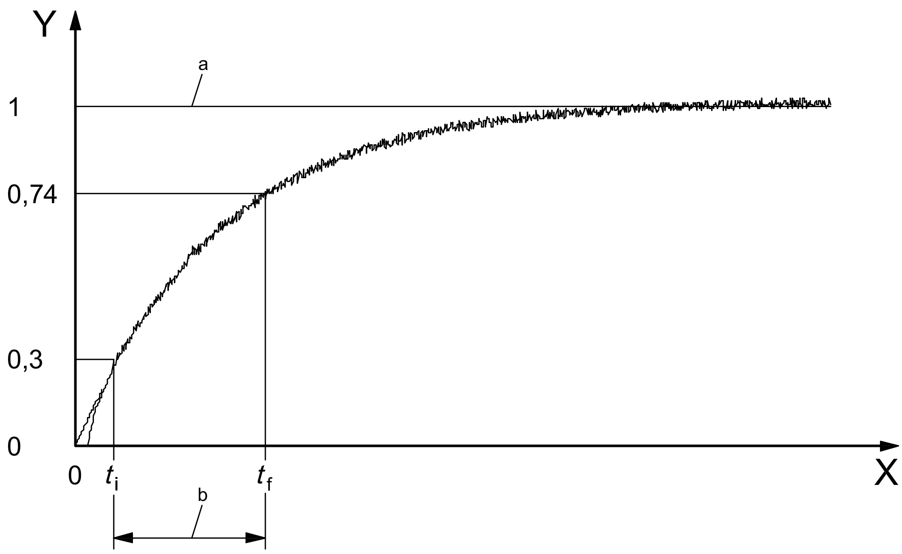
$$U_t = U_f(1 - e^{-(t/\tau)}) \tag{1}$$

The response time is:

$$\tau = t_f - t_i \tag{2}$$

The distance constant is:

$$L_U = U\tau \tag{3}$$



Key

X time, t, in seconds

Y anemometer indicated wind speed, U_i, in metres per second

a final response

b response time, τ

Figure 2 — Typical anemometer response curve — Increasing wind speed step change

In order to avoid the unrealistic effects of the restrained condition, as shown in Figure 2, the time measurement should be made from 0,30 of U_f to 0,74 of U_f. This calculated response time (τ) interval in seconds is to within 1 % of the theoretical (1 – 1/e) response of the instrument and is converted to the distance constant (L_U) by multiplying by the wind tunnel air speed (U) [1].

5.5 The off-axis response ratio (Q_U) can be a function of speed. The off-axis response ratio shall be measured at a number of wind speeds which shall include 5 m·s^{-1} and 10 m·s^{-1}.

5.5.1 For *cup anemometers*, a measurement is made of the output signal when the anemometer is inclined into the wind (representing a down-draft) and away from the wind (representing an updraft), while the wind tunnel is running at a steady speed. The output signal is measured with the anemometer axis at 5° intervals from vertical to ± 30° from vertical. The measured signal is then converted to a ratio for each interval by dividing by the product of cosine of the angle and the signal measured with the anemometer axis in the normal (vertical) position.

5.5.2 For *vane-mounted propeller anemometers*, a measurement is made of the output signal when the anemometer's axis of rotation is inclined downward into the wind (representing a down-draft) and inclined upward into the wind (representing an updraft), while the wind tunnel is running at a steady speed. The output signal is measured as 5° intervals from a horizontal axis of rotation to ± 30° from the horizontal. The measured signal is then converted to a ratio for each interval by dividing by the product of the cosine of the angle and the signal measured with the anemometer axis in the normal (horizontal) position. This test may be conducted either with the vane in place or with the vane removed. In either case, the axis of rotation shall be fixed in the down-tunnel direction.