INTERNATIONAL

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Standard Test Method for Determining the Performance of a Cup Anemometer or Propeller Anemometer[1]

This standard is issued under the fixed designation D5096; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the ~~*Starting Threshold,*~~*starting threshold,*~~*Distance Constant,*~~*distance constant,* ~~*Transfer Function,*~~*transfer function,* and ~~*Off-Axis Response*~~*off-axis response* of a cup anemometer or propeller anemometer from direct measurement in a wind tunnel.

1.2 This test method provides for a measurement of cup anemometer or propeller anemometer performance in the environment of wind tunnel air flow. Transference of values determined by these methods to atmospheric flow must be done with an understanding that there is a difference between the two flow systems.

1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate ~~safety and health~~safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1356 Terminology Relating to Sampling and Analysis of Atmospheres
D3631 Test Methods for Measuring Surface Atmospheric Pressure

3. Terminology

3.1 For definitions of terms used in this standard, refer to Terminology D1356.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *starting threshold (U_o, ~~m/s)—~~m/s), n—*the lowest wind speed at which a rotating anemometer starts and continues to turn and produce a measurable signal when mounted in its normal ~~position. The~~position; the normal position for cup anemometers is

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

with the axis of rotation vertical, and the normal position for propeller anemometers is with the axis of rotation aligned with the direction of ~~flow. Note~~flow; note that if the anemometer axis is not aligned with the direction of flow, the calculated wind speed component parallel to the anemometer axis is used to determine starting threshold.

3.2.2 *distance constant (L, ~~m)—~~m), n—*the 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 change in wind speed (**1**).[3] The response of a rotating anemometer to a step change in which wind speed increases instantaneously from $U = 0$ to $U = U_f$ is (**2**):

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

where:

U_t = is the instantaneous indicated wind speed at time t in m/s,
U_f = is the final indicated wind speed, or wind tunnel speed, in m/s,
t = is the elapsed time in seconds after the step change occurs, and
τ = is the time constant of the instrument.

$$\text{Distance Constant is:} L = U_f \tau \tag{2}$$

3.2.3 *transfer function ($\hat{U}_f = a + bR$, ~~m/s)—~~m/s), n—*the linear relationship between wind speed and the rate of rotation of the anemometer throughout the specified working range. $\hat{U}_f$ is the predicted wind speed in m/s, a is a constant, commonly called zero offset, in m/s, b is a constant representing the wind passage in m/r for each revolution of the ~~particular~~ anemometer cup wheel or propeller, and R is the rate of rotation in r/s. ~~It should be noted that zero offset is not the same as starting threshold. In some very sensitive anemometers the constant a, zero offset, may not be significantly greater than zero. The constants a and b must be determined by wind tunnel measurement for each type of anemometer (3).~~

3.2.3.1 *Discussion—*
Note, the zero offset is not the same as starting threshold. In some very sensitive anemometers the constant a, zero offset, may not be significantly greater than zero. The constants a and b must be determined by wind tunnel measurement for each type of anemometer (**3**).

3.2.4 *off-axis response ($U/(U_f \cos \theta)$~~)—~~), n—*the ratio of the indicated wind speed (U) at various angles of attack (θ) to the indicated wind speed at zero angle of attack (U_f) multiplied by the cosine of the angle of ~~attack. This~~attack; this ratio compares the actual off-axis response to a cosine response.

3.3 *Symbols:*

a (m/s) = zero offset constant
b (m/r) = wind passage (apparent pitch) constant or calibration constant
L (m) = distance constant
r (none) = a shaft revolution
R (r/s) = rate of rotation
τ(s) = time constant
t (s) = time
U_o (m/s) = starting threshold
U (m/s) = indicated wind speed (used in off-axis test)
U_f (m/s) = final indicated wind speed or wind tunnel speed
U_{max} (m/s) = anemometer application range
U_t (m/s) = instantaneous indicated wind speed at time t
$\hat{U}_f$ (m/s) = predicted wind speed
θ (deg) = off-axis angle of attack

4. Summary of Test Method

4.1 This test method requires a wind tunnel as described in Section 6, Apparatus.

4.2 *Starting Threshold* (U_o, m/s) 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 position.

[3] The boldface numbers in parentheses refer to the list of references at the end of this standard.

4.3 *Distance Constant* (*L*, m) may be determined at a number of wind speeds but must include 5 m/s, and 10 m/s. It is computed from the time required for the anemometer rotor to accelerate (1 – 1/*e*) or 63 % of a step change in rotational speed after release from a restrained, non-rotating condition. The final response, U_f, is the wind tunnel speed as indicated by the anemometer. ~~In order to~~ To avoid the unrealistic effects of the restrained ~~condition, as~~ condition shown in Fig. 1, the time measurement should be made from 0.30 of U_f to 0.74 of U_f. This interval in seconds is equal to one time constant (τ) and is converted to the ~~Distance Constant~~distance constant by multiplying by the wind tunnel speed in meters per second (m/s).

4.4 *Transfer Function* ($\hat{U}_f = a + bR$, m/s) is determined by measuring the rate of rotation of the anemometer at ~~a number of~~ several wind speeds throughout the specified working range. In the range of wind speeds where the anemometer response is non-linear (near threshold) a minimum of five data points are recorded. A minimum of five additional data points are recorded within the working range of the anemometer and wind tunnel but above the non-linear threshold region (see Fig. 2). Measurements are recorded for each data point with the wind tunnel speed ascending and descending. The values of *a* and *b* are determined by least-squares linear regression of the individual data points.

4.5 *Off-Axis Response* may be measured at a number of wind speeds but must include 5 m/s, and 10 m/s.

4.5.1 *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 plus and minus 30° from vertical. The measured signal is then converted to a ratio for each interval by dividing by the normal signal measured with the anemometer axis in the normal, or vertical, position.

4.5.2 *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 at 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 normal signal with the anemometer in the normal, or horizontal position. This test may be conducted either with the vane in place or with the vane removed and the axis of rotation fixed in the down-tunnel direction.

4.5.3 *Fixed Axis Propeller Anemometer*—A measurement is made of the output signal when the anemometer is rotated in the air stream throughout the complete 360° angle of attack. The signal is measured at ~~a number of~~ several angles but must include 10° intervals with additional measurements at ~~85, 95, 265,~~85°, 95°, 265°, and 275°. The measured signal for each angle of attack is then converted to a ratio by dividing by the signal measured at 0° angle of attack (axial flow). Additionally, the stall angle of the propeller is measured by orienting the anemometer at 90° and slowly rotating into and away from the air flow until the propeller starts rotating continuously. Stall angle is the total contained angle within which the propeller does not continuously rotate. The procedure is repeated at 270°.

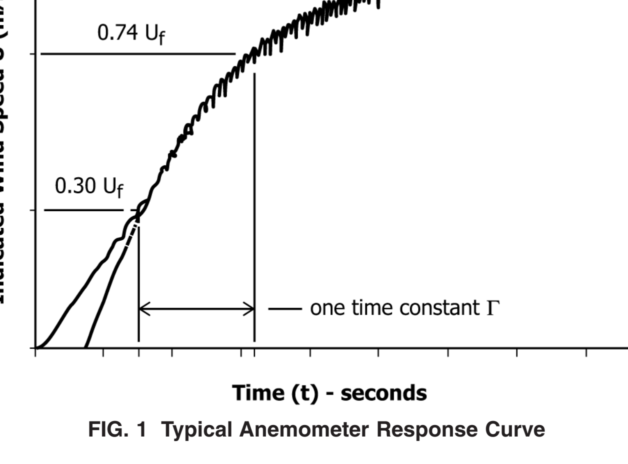

FIG. 1 Typical Anemometer Response Curve

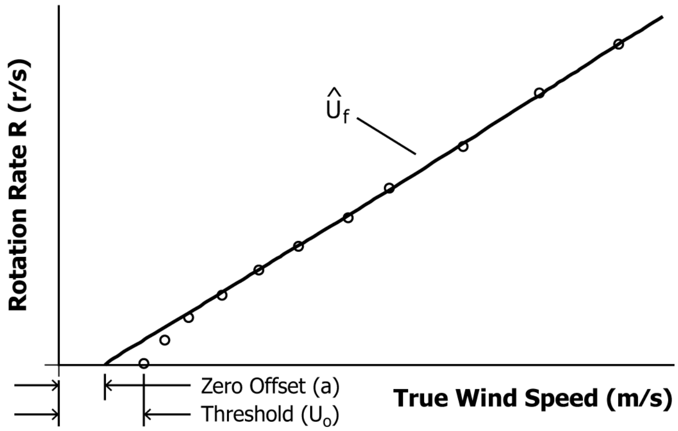

FIG. 2 Typical Anemometer Calibration Curve

5. Significance and Use

5.1 This test method ~~will provide~~ provides a standard for comparison of rotating type anemometers, specifically cup anemometers and propeller anemometers, of different types. Specifications by regulatory agencies (**4-7**) and industrial societies have specified performance values. This standard provides an unambiguous method for measuring ~~*Starting Threshold,*~~*starting threshold,*~~*Distance Constant,*~~*distance constant,*~~*Transfer Function,*~~*transfer function,* and ~~*Off-Axis Response.*~~*off-axis response.*

6. Apparatus

6.1 *Measuring System:*

6.1.1 *Rotation*—The relationship between the rate of rotation of ~~the~~an anemometer shaft and the transducer output must be determined. The resolution of the anemometer transducer limits the measurement. The resolution of the measuring or recording system must represent the indicated wind speed with a resolution of 0.02 m/s.

6.1.2 *Time*—~~The resolution of time~~ Time resolution must be consistent with the distance accuracy required. ~~For this reason~~ Hence, the time resolution may be changed as the wind tunnel speed is changed. If one wants a distance constant measurement to ~~0.1 meter resolution~~ 0.1 m resolution, one must have a time resolution of 0.05 s at 2 m/s and 0.01 s at 10 m/s. If timing accuracy is based on 50 Hz or 60 Hz power frequency, it will ~~be~~require at least an order of magnitude better ~~than the resolution suggested~~ resolution than stated above.

6.1.3 *Angle of Attack*—The resolution of the angle of attack (θ) must be within 0.5°. An ordinary protractor of adequate size with 0.5° markings will permit measurements with sufficient resolution. A fixture should be constructed to permit alignment of the anemometer to the off-axis angles while the wind tunnel is running at a steady speed.

6.2 *Recording Techniques:*

6.2.1 Digital recording systems and appropriate reduction programs will be satisfactory if the sampling rate is at least ~~100~~100 samples ~~samples/s.~~ /s. Exercise care to avoid electronic circuits with time constants which limit the proper recording of anemometer performance. Oscilloscopes with memory and hard copy capability may also be used. Another simple technique is to use a fast-response strip chart recorder (flat to 10 Hz or better) with enough gain so that the signal produced by the anemometer when the wind tunnel is running at 2 m/s is sufficient to provide full scale pen deflection on the recorder. The recorder chart drive must have a fast speed of 50 mm/s or more.

6.3 *Wind Tunnel* (**8**)*:*

6.3.1 *Size—*The wind tunnel must be large enough ~~so~~such that the projection of the cup wheel or propeller, sensor, and support apparatus, is less than 5 % of the cross sectional area of the tunnel test section.

6.3.2 *Speed Range—*The wind tunnel must have a speed control which will allow the flow rate to be varied from ~~θ~~0 % to a minimum of 50 % of the application range of the anemometer under test. The speed control should maintain the flow rate within ±0.2 m/s.

6.3.3 *Calibration—*The mean flow rate must be verified at the mandatory speeds by use of transfer standards which have been calibrated at the National Institute of Standards and Technology (NIST), an internationally recognized standards organization, or by a fundamental physical method. Speeds below 2 m/s for the threshold determination must be verified by a sensitive anemometer or by some fundamental time and distance technique, such as measuring the transition time of smoke puffs, soap bubbles, or heat puffs between two points separated by known distance. A table of wind tunnel blower rpm or some other index relating method of control to flow rate should be established by this technique for speeds of 2 m/s and below.

6.3.4 The wind tunnel must have a relatively constant profile (known to within 1 %) and a turbulence level of less than 1 % throughout the test section.

6.3.5 *Environment* (**9-11**)—~~Environment (9-11).~~ Differences of greater than 3 % in the density of the air within the test environment may result in poor intercomparability of independent measurements of starting threshold (U_o) and distance constant (L) since these values are density dependent. The temperature and pressure of the environment within the wind tunnel test section, and the ambient air pressure (Test Methods D3631) shall be reported for each independent measurement.

7. Sampling

7.1 *Starting Threshold—*The arithmetic mean on ten consecutive tests is required for a valid starting threshold measurement.

7.2 *Distance Constant—*The arithmetic mean of ten tests is required for a valid measurement at each speed. The results of the measurements at two or more speeds are averaged to a single value for distance constant.

7.3 *Transfer Function—*Two measurements of U_f and R are recorded for each data point, one with the wind tunnel speed ascending and one with the wind tunnel speed descending. The values are then tabulated for each data point.

7.4 *Off-Axis Response—*The results of the measurement at two or more speeds are averaged to a single value for each angle of attack. The averaged values are tabulated for each angle of attack.

8. Procedure

8.1 *Starting Threshold* (U_o)*:*

8.1.1 Provide a mechanical method for holding the anemometer in its normal position (see 3.1) and for releasing the anemometer from a restrained, or non-rotating condition, while the wind tunnel is running at the test speed. Test the release mechanism with the wind tunnel off to verify that the release method does not move the anemometer rotor when activated.

8.1.2 Set the wind tunnel to a speed that is lower than the starting threshold. Slowly increase the wind tunnel speed until the cup wheel or propeller continues to rotate and produce a measurable signal.

8.1.3 Repeat the procedure of 8.1.2 ten times and record the results.

NOTE 1—Vibration caused by the wind tunnel or by other sources can cause erroneous measurements of starting threshold. Care must be exercised to eliminate any vibration in the wind tunnel test ~~section~~ during threshold measurements.

8.2 *Distance Constant* (L)*:*