Designation: D 5096 – 96

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

This standard is issued under the fixed designation D 5096; 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*, *Distance Constant*, *Transfer Function*, and *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 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 *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 practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 1356 Terminology Relating to Sampling and Analysis of Atmospheres[2]

D 3631 Test Methods for Measuring Surface Atmospheric Pressure[2]

D 4430 Practice for Determining the Operational Comparability of Meteorological Instruments[2]

D 4480 Test Method for Measuring Surface Winds by Means of Wind Vanes and Rotating Anemometers[2]

3. Terminology

3.1 For definitions of terms used in this standard, refer to Terminology D 1356.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *starting threshold* (U_o, m/s)—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 normal position for cup anemometers is 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 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)—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)**:

$$U_t = U_f\left[1 - e^{(-t/\Gamma)}\right] \quad (1)$$

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
Γ = is the time constant of the instrument.

$$\text{Distance Constant is: } L = U_f\Gamma \quad (2)$$

3.2.3 *transfer function* ($\hat{U}_f = a + bR$, m/s)—the linear relationship between wind speed and the rate of rotation of the anemometer throughout the specified working range. $U_{f|AX}$ 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)**.

3.2.4 *off-axis response* ($U/(U_f \cos \theta)$)—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 ratio compares the actual

[1] This test method is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.11 on Meteorology.

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[2] *Annual Book of ASTM Standards*, Vol 11.03.

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

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
Γ(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 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.

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 avoid the unrealistic effects of the restrained condition, as 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 (Γ) and is converted to the 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 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 angles but must include 10° intervals with additional measurements at 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

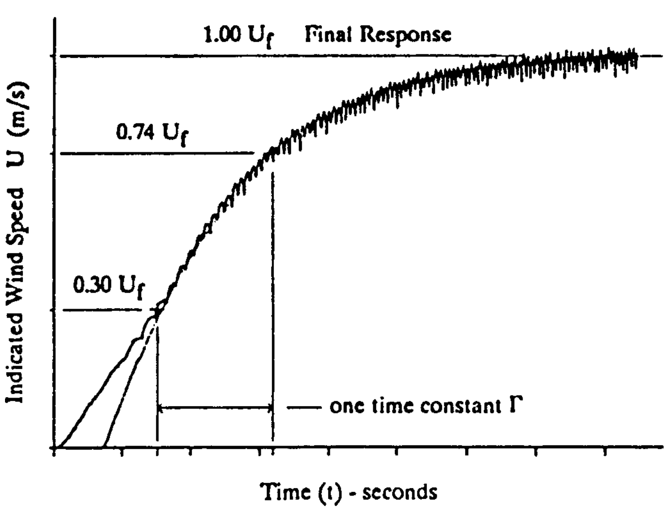

FIG. 1 Typical Anemometer Response Curve

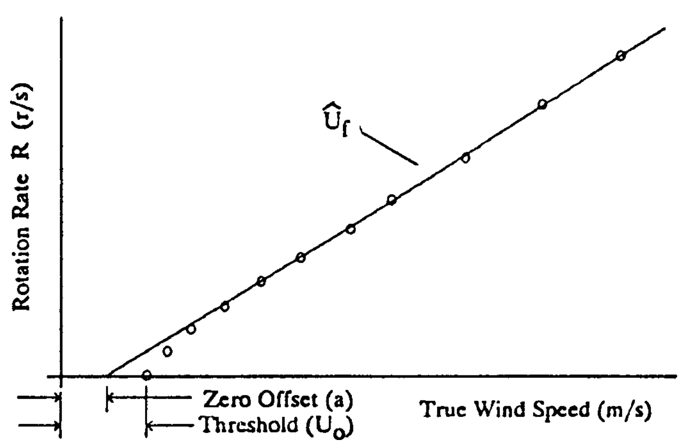

FIG. 2 Typical Anemometer Calibration Curve