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Standard Test Method for Determining the Dynamic Performance of a Wind Vane[1]

This standard is issued under the fixed designation D5366; 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, delay distance, and overshoot ratio of a wind vane from direct measurements in a wind tunnel. This test method is applicable only to wind vanes having measurable overshoot.

1.2 This test method provides for determination of the performance of a system consisting of a wind vane and its associated position-to-output transducer in wind tunnel flow. Use of values determined by this test method to describe performance in atmospheric flow of a wind direction measuring system incorporating the vane must be done with an understanding of the differences between the two systems and the two environments.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this 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, 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

3. Terminology

3.1 Refer to Terminology D1356 for general terms and their definitions.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *delay distance (D), n*—the distance air flows past a wind vane during the time it takes the vane to return to 50 % of the initial displacement.

3.2.2 *overshoot* (θ_n), *n*—the amplitude of a deflection of a wind vane as it oscillates about θ_B after release from an initial displacement.

3.2.3 *overshoot ratio (Ω), n*—the ratio of two successive overshoots, as expressed by the equation:

$$\Omega = \theta_{(n+1)}/\theta_n \quad (1)$$

where θ_n and $\theta_{(n+1)}$ are the n and $n + 1$ overshoots, respectively. In practice, since deflections after the first to the side opposite the release point are normally small, the initial release point (that is, the $n = 0$ deflection) and the first deflection after release ($n = 1$) are used in determining the overshoot ratio.

3.2.4 *starting threshold* (U_o), *n*—the lowest speed at which the vane can be observed or measured moving from a 10° offset in a wind tunnel.

3.3 *Symbols:*

D	(m)	delay distance
U_o	(m/s)	starting threshold
Ω	(none)	overshoot ratio
η	(none)	damping ratio
λ_d	(m)	damped natural wavelength
θ_n	(degrees)	overshoot; maximum angular excursion
θ_o	(degrees)	reference direction
θ_B	(degrees)	vane equilibrium position
$\theta_B - \theta_o$	(degrees)	dynamic vane bias

3.4 *Calculated or Estimated Values:*

3.4.1 *damping ratio (η), n*—calculated from the overshoot ratio (**1, 2**).[3]

$$\eta = \frac{ln(1/\Omega)}{(\pi^2 + [ln(1/\Omega)]^2)^{0.5}} \quad (2)$$

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[1] This test method is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.11 on Meteorology.

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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.

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

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3.4.2 *damped natural wavelength* (λ_d), *n*—at sea level in the U.S. Standard Atmosphere, damped natural wavelength is related to delay distance and damping ratio by the empirical expression (**1**, **2**).

$$\lambda_d = \frac{D(6.0 - 2.4\eta)}{(1 - \eta^2)^{0.5}} \tag{3}$$

4. Summary of Test Method

4.1 *Reference Direction* (θ_o, degrees) is the indicated angular position of the vane when aligned along the centerline of a wind tunnel.

4.2 *Vane Equilibrium Position* (θ_B, degrees) is the final resting position of the vane after motion in response to an initial displacement. Ideally, $\theta_B = \theta_o$.

4.3 *Dynamic Vane Bias* ($\theta_B - \theta_o$, degrees) is the displacement of the vane from the wind tunnel centerline at 5 m/s. This measurement will identify wind vanes with unbalanced aerodynamic response because of damage (for example, bent tail) or poor design.

4.4 *Starting Threshold* (U_o, m/s) is determined by observing or measuring the lowest speed at which the vane, released from a 10° offset position in a wind tunnel, moves toward θ_B. Movement must be distinguishable from vibration.

4.5 *Delay Distance* (*D*, m) may be determined at a number of wind speeds but shall include 5 m/s and 10 m/s. It is computed from the time required for the vane to reach 50 % of the initial displacement from 10° off θ_B. This time in seconds is converted to delay distance by multiplying by the wind tunnel speed in metres per second. Tests shall include an equal number of displacements to each side of θ_B.

4.6 *Overshoot Ratio* (Ω) may be determined at the same time as the delay distance. The maximum angular excursion on the opposite side of θ_B from the initial 10° displacement from θ_B is measured. This value is divided by the initial displacement to obtain Ω.

5. Significance and Use

5.1 This test method provides a standard for comparison of wind vanes of different types. Specifications by regulatory agencies and industrial societies (**3-5**) have stipulated performance values. This test method provides an unambiguous method for measuring starting threshold, delay distance, and overshoot ratio.

6. Apparatus

6.1 *Wind Tunnel* (**6**):

6.1.1 *Size*—The wind tunnel shall be large enough so that the total projected area of supports, sensor apparatus, and the vane in its displaced position is less than 5 % of the cross-sectional area of its test section.

6.1.2 *Speed Range*—The wind tunnel shall have a speed control that will allow the flow rate to be varied from 0 to at least 10 m/s. The speed control shall maintain the flow rate within ±0.2 m/s.

6.1.3 *Turbulence and Swirl*—Across the volume to be occupied by the vane, the flow profile shall vary by no more than 1 % about the mean speed and shall exhibit a turbulence of less than 1 %. (**Warning—**Swirl in the wind tunnel may influence starting threshold measurements. Variations in the measurement of θ_B at low speeds, likely, indicate the existence of swirl.)

6.1.4 *Calibration*—The mean flow rate shall be verified at the mandatory speeds of 5 m/s and 10 m/s by use of transfer standards that have been calibrated by the National Institute of Standards and Technology[4] or by a fundamental physical method.

6.1.4.1 Speeds below 2 m/s for threshold determination shall 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 a known distance.

6.1.5 *Environment*—The temperature and pressure of the environment within the wind tunnel test section shall be reported. Differences of greater than 3 % in the density of air within the test environment may result in poor intercomparability of independent measurements of starting threshold, delay distance, and overshoot ratio since these values are density dependent.

6.2 *Measuring System:*

6.2.1 *Direction*—The resolution of the wind vane position–to–output transducer limits the resolution of the measurements. The accuracy of the position–to–output conversion shall be within ±0.1°. (**Warning—**Avoid potentiometer dead spots or crossover positions while performing these procedures.)

6.2.2 *Time*—Time resolution shall be consistent with the distance accuracy required. For this reason, the time resolution may change as the wind tunnel speed is changed. For example, for a distance constant measurement to 0.1 m, one must have a time resolution of 0.05 s at 2 m/s and 0.01 s at 10 m/s. If time accuracy is based on commercial electrical power frequency, it will be at least an order of magnitude better than the resolution presented above.

6.3 *Signal Conditioning*—Care shall be taken to avoid electronic circuits in signal conditioning and recording devices that adversely affect the apparent vane performance. (**Warning—**Time constants in signal conditioning and recording devices shall be less than 0.01 s.)

6.4 *Recording Techniques*—The measuring or recording system shall represent the 10° displacement on each side of θ_B with a resolution of 0.2°. One simple technique is to use a fast-response recorder (flat to 40 Hz to 60 Hz or better) with enough gain so that a vane can be oriented in the wind tunnel with θ_B represented at mid-scale, and ±10° of vane displacement traversing the full span of the recorder.

6.4.1 The recorder shall have a fast chart speed of 50 mm/s or more. An alternative is to use an FM tape recorder to record the signal. When played back at lower speed, a proportionately slower analog strip chart recorder yielding an equivalent 50 mm/s chart speed is acceptable. Oscilloscopes with memory and hard copy capability may also be used.

[4] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov.

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6.4.2 Digital recording and data reduction systems are satisfactory if the sampling rate is at least 100 per second.

7. Sampling

7.1 *Starting Threshold*—Ten consecutive tests at the same speed meeting the test method requirement, five in each direction from θ_B, are required for a valid starting threshold measurement.

7.2 *Delay Distance and Overshoot Ratio*—The arithmetic mean of ten tests, five in each direction from θ_B, is required for a valid measurement at each speed. The results of measurements at two or more speeds shall be averaged to a single value for delay distance and a single value for overshoot ratio.

8. Procedure

8.1 *Dynamic Vane Bias:*

8.1.1 Set vane at tunnel centerline with no flow in the wind tunnel.

8.1.2 Adjust the wind tunnel to give a flow of 5 m/s.

8.1.3 Measure the equilibrium vane position (θ_B) relative to the tunnel centerline (θ_o). The angular difference, $\theta_B - \theta_o$ is the dynamic vane bias.

8.1.4 A dynamic vane bias greater than 1° indicates poor design or a problem with the vane. Appropriate corrections shall be made before continuing.

8.2 *Starting Threshold:*

8.2.1 Provide a mechanical method for holding and releasing the vane at 10° ± 1° from θ_B. With no flow in the wind tunnel, verify that the vane moves by no more than ±0.5° when the release mechanism is activated.

8.2.2 Adjust the wind tunnel to a speed expected to be lower than the starting threshold. Displace the vane by 10° and then release it by the procedure described in 8.2.1. Observe the motion of the vane, if any, and record the angle, relative to θ_B, where motion ceases. Increase the speed slightly and repeat the test; continue in this manner until a speed is reached where the vane moves at least 1° toward θ_B.

8.2.3 Using the speed determined in 8.2.2, displace the vane by 10° and release it five consecutive times to one side of θ_B, observing and recording the angle where it stops each time. Repeat five times with the displacements to the other side of θ_B.

8.2.4 If all ten repetitions result in the vane moving at least 1° toward θ_B, the wind speed may be used as the starting threshold in accordance with this test method. The average of the absolute angular displacement from θ_B on each side should be calculated. The higher of the two is the accuracy at the threshold speed.

8.3 *Delay Distance:*

8.3.1 Set the wind tunnel speed at 5 m/s. Displace the vane 10° from θ_B and release it by the method in 8.2.1. Take four more samples in the same direction and five samples in the opposite direction.

8.3.2 Repeat the procedure of 8.3.1 with the wind tunnel speed set a 10 m/s.

8.3.3 If desired, repeat the procedure of 8.3.1 at other wind tunnel speeds.

8.3.4 For the ten samples taken at a tunnel speed, measure the time from release to crossing 5° from θ_B (or 50 % of the actual release displacement, a nominal 10°) for each of the samples. Convert each of these times to a distance by multiplying by the tunnel speed. Average the distances to arrive at a delay distance for this speed.

8.3.5 Repeat the procedure of 8.3.4 for ten samples taken at each tunnel speed considered.

8.3.6 Average the delay distances found in 8.3.4 and 8.3.5. The delay distance for each speed shall be within 10 % of this average.

NOTE 1—If the delay distance for any speed considered is outside ±10 % of the average, a delay distance for the vane cannot be specified.

8.4 *Overshoot Ratio:*

8.4.1 For each of the samples recorded for 8.3, read the maximum angular excursion on the opposite side of θ_B from the initial displacement.

8.4.2 Form a ratio by dividing each angular excursion obtained in 8.4.1 by the corresponding angular difference between the release angle and θ_B. Average these ratios to arrive at the overshoot ratio for the vane.

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9. Precision and Bias

9.1 The accuracy in measurement of the wind tunnel speed limits the accuracy of this test method. An accuracy of 0.1 m/s is required. This shall be documented at the wind tunnel facility and be related to measurements at NIST[4] by a report on the transfer standard that carries the same accuracy limit.

9.2 *Precision*—Using this equipment and procedure, an estimate of the precision of the test method follows:

9.2.1 *Starting Threshold*—The precision of this test method is 0.1 m/s or better.

9.2.2 *Delay Distance*—The precision of this test method is 0.1 m or better.

9.2.3 *Overshoot Ratio*—The precision of this test method is 0.02 or better.

9.3 *Bias:*

9.3.1 *Starting Threshold*—The bias of this test method is no greater than 0.15 m/s.

9.3.2 *Delay Distance*—The bias of this test method is no greater than 0.15 m.

9.3.3 *Overshoot Ratio*—The bias of this test method is no greater than 0.05.

10. Keywords

10.1 damping ratio; delay distance; overshoot ratio; starting threshold; wind vane