INTERNATIONAL

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Standard Practice for Characterizing Surface Wind Using a Wind Vane and Rotating Anemometer[1]

This standard is issued under the fixed designation D5741; 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 practice covers a method for characterizing surface wind speed, wind direction, peak one-minute speeds, peak three-second and peak one-minute speeds, and standard deviations of fluctuation about the means of speed and direction.

1.2 This practice may be used with other kinds of sensors if the response characteristics of the sensors, including their signal conditioners, are equivalent or faster and the measurement uncertainty of the system is equivalent or better than those specified below.

1.3 The characterization prescribed in this practice will provide information on wind acceptable for a wide variety of applications.

NOTE 1—This practice builds on a consensus reached by the attendees at a workshop sponsored by the Office of the Federal Coordinator for Meteorological Services and Supporting Research in Rockville, MD on Oct. 29–30, 1992.

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

1.5 *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.*

1.6 *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
D5096 Test Method for Determining the Performance of a Cup Anemometer or Propeller Anemometer
D5366 Test Method for Determining the Dynamic Performance of a Wind Vane

[1] This practice 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. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *aerodynamic roughness length (z_0,* m *)*—a characteristic length representing the height above the surface where extrapolation of wind speed measurements, below the limit of profile validity, would predict the wind speed would become zero (**1**).[3] It can be estimated for direction sectors from a landscape description.

3.1.2 *damped natural wavelength (λ_d,* m*)*—a characteristic of a wind vane empirically related to the delay distance and the damping ratio. See Test Method D5366 for test methods to determine the delay distance and equations to estimate the damped natural wavelength.

3.1.3 *damping ratio (η,* dimensionless*)*—the ratio of the actual damping, related to the inertial-driven overshoot of wind vanes to direction changes, to the critical damping, the fastest response where no overshoot occurs. See Test Method D5366 for test methods and equations to determine the damping ratio of a wind vane.

3.1.4 *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. See Test Method D5096.

3.1.5 *maximum operating speed* (u_m, m/s)—*as related to anemometer*, the highest speed as which the sensor will survive the force of the wind and perform within the accuracy specification.

3.1.6 *maximum operating speed* (u_m, m/s)—*as related to wind vane*, the highest speed at which the sensor will survive the force of the wind and perform within the accuracy specification.

3.1.7 *standard deviation of wind direction (σ_θ,* degrees*)*—the unbiased estimate of the standard deviation of wind direction samples about the mean horizontal wind direction. The circular scale of wind direction with a discontinuity at north may bias the calculation when the direction oscillates about north. Estimates of the standard deviation such as suggested by (**2**, **3**) are acceptable.

3.1.8 *standard deviation of wind speed (σ_u,* m/s*)*—the estimate of the standard deviation of wind speed samples about the mean wind speed.

3.1.9 *starting threshold* (u_0, m/s)—*as related to anemometer*, the lowest speed at which the sensor begins to turn and continues to turn and produces a measurable signal when mounted in its normal position (see Test Method D5096).

3.1.10 *starting threshold* (u_0, m/s)—*as related to system*, the indicated wind speed when the anemometer is at rest.

3.1.11 *starting threshold* (u_0, m/s)—*as related to wind vane*, the lowest speed at which the vane can be observed or measured moving from a 10° offset position in a wind tunnel (see Test Method D5366).

3.1.12 *wind direction (θ,* degrees*)*—the direction, referenced to true north, from which air flows past the sensor location if the sensor or other obstructions were absent. The wind direction distribution is characterized over each 10-min period with a scalar (non-speed weighted) mean, standard deviation, and the direction of the peak 1-min average speed. The circular direction range, with its discontinuity at north, requires special attention in the averaging process. A unit vector method is an acceptable solution to this problem.

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

3.1.12.1 *Discussion*—

Wind vane direction systems provide outputs when the wind speed is below the starting threshold for the vane. For this practice, report the calculated values (see 4.3 or 4.4) when more than 25 % of the possible samples are above the wind vane threshold and the standard deviation of the acceptable samples, σ_θ, is 30° or less, otherwise report light and variable code, 000.

3.1.13 *wind speed (*u, m/s*)*—the speed with which air flows past the sensor location if the sensor or other obstructions were absent. The wind speed distribution is characterized over each 10-min period with a scalar mean, standard deviation, peak 3-s average, and peak 1-min average.

3.1 *Discussion*—For definitions of additional terms used in this practice, terms that are not defined herein, refer to Terminology D1356.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aerodynamic roughness length (z_0,* m *)*—a characteristic length representing the height above the surface where extrapolation of wind speed measurements, below the limit of profile validity, would predict the wind speed would become zero (**1**).[3] It can be estimated for direction sectors from a landscape description.

3.2.2 *damped natural wavelength (λ_d,* m*)*—a characteristic of a wind vane empirically related to the delay distance and the damping ratio. See Test Method D5366 for test methods to determine the delay distance and equations to estimate the damped natural wavelength.

3.2.3 *damping ratio (η,* dimensionless*)*—the ratio of the actual damping, related to the inertial-driven overshoot of wind vanes to direction changes, to the critical damping, the fastest response where no overshoot occurs. See Test Method D5366 for test methods and equations to determine the damping ratio of a wind vane.

3.2.4 *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. See Test Method D5096.

3.2.5 *maximum operating speed* (u_m, m/s)—*as related to anemometer*, the highest speed as which the sensor will survive the force of the wind and perform within the accuracy specification.

3.2.6 *maximum operating speed* (u_m, m/s)—*as related to wind vane*, the highest speed at which the sensor will survive the force of the wind and perform within the accuracy specification.

3.2.7 *standard deviation of wind direction* (σ_θ, degrees*)*—the unbiased estimate of the standard deviation of wind direction samples about the mean horizontal wind direction. The circular scale of wind direction with a discontinuity at north may bias the calculation when the direction oscillates about north. Estimates of the standard deviation such as suggested by **(2, 3)** are acceptable.

3.2.8 *standard deviation of wind speed* (σ_u, m/s*)*—the estimate of the standard deviation of wind speed samples about the mean wind speed.

3.2.9 *starting threshold* (u_0, m/s)—*as related to anemometer*, the lowest speed at which the sensor begins to turn and continues to turn and produces a measurable signal when mounted in its normal position (see Test Method D5096).

3.2.10 *starting threshold* (u_0, m/s)—*as related to system*, the indicated wind speed when the anemometer is at rest.

3.2.11 *starting threshold* (u_0, m/s)—*as related to wind vane*, the lowest speed at which the vane can be observed or measured moving from a 10° offset position in a wind tunnel (see Test Method D5366).

3.2.12 *wind direction (θ,* degrees*)*—the direction, referenced to true north, from which air flows past the sensor location if the sensor or other obstructions were absent. The wind direction distribution is characterized over each 10-min period with a scalar (non-speed weighted) mean, standard deviation, and the direction of the peak 1-min average speed. The circular direction range, with its discontinuity at north, requires special attention in the averaging process. A unit vector method is an acceptable solution to this problem.

3.2.12.1 *Discussion—*

Wind vane direction systems provide outputs when the wind speed is below the starting threshold for the vane. For this practice, report the calculated values (see 4.3 or 4.4) when more than 25 % of the possible samples are above the wind vane threshold and the standard deviation of the acceptable samples, σ_θ, is 30° or less, otherwise report light and variable code, 000.

3.2.13 *wind speed (*u, m/s*)*—the speed with which air flows past the sensor location if the sensor or other obstructions were absent. The wind speed distribution is characterized over each 10-min period with a scalar mean, standard deviation, peak 3-s average, and peak 1-min average.

4. Summary of Practice

4.1 *Siting of the Wind Sensors:*

4.1.1 The wind sensor location will be identified by an unambiguous label which will include either the longitude and latitude with a resolution of 1 s of arc (about 30 m or less) or a station number which will lead to that information in the station description file. When redundant sensors or microscale network stations (for example, airport runway sensors) are available, they will have individual labels which unambiguously identify the data they produce.

4.1.2 The anemometer and wind vane shall be located at a 10-m height above level or gently sloping terrain with an open fetch of at least 150 m in all directions, with the largest fetch possible in the prevailing wind direction. Compromise is frequently recognized and acceptable for some sites. Obstacles in the vicinity should be at least ten times their own height distant from the wind sensors.

4.1.3 The wind sensors shall preferably be located on top of a solitary mast. If side mounting is necessary, the boom length should be at least three times the mast width. In the undesirable case that locally no open terrain is available and the measurement is to be made above some building, then the wind sensor height above the roof top should be at least 1.5 times the lesser of the maximum building height and the maximum horizontal dimension of the major roof surface. In this case, the station description file shall indicate the height above ground level (AGL) of the highest part of the building, the height of the wind sensors above ground, AGL, and the height of the wind sensors above roof level. Site characteristics shall be documented in sectors no greater than 45 degrees nor smaller than 30 degrees in width around the wind sensors. The near terrain may be characterized with photographs, taken at wind sensor height if possible, aimed radially outward at labeled central angles, with respect to true north. Average roughness of the nearest 3 km of each sector shall be characterized according to the roughness class as tabulated above (**4**). The z_0 numbers in Table 1 are typical and not precise statements.

4.1.4 Important terrain features at distances larger than 3 km (hills, cities, lakes, and so forth, within 20 km) shall be identified by sector and distance. Additional information, such as aerial photographs, maps, and so forth, pertinent to the site, is recommended to be added to the basic site documentation.

NOTE 2—Cameras using 35-mm film in the landscape orientation will have the following theoretical focal length to field angle relationships:

50 mm yields 40°
40 mm yields 48°
28 mm yields 66°

Prints or transparencies may not utilize the total theoretical width of the image. It is desirable to label known angles in the photograph. For example, a 45° sector photograph could have a central label of 360 with marker flags located at 337.5° and 022.5° true.

4.2 *Characteristics of the Wind Systems*—There are two categories of sensor design within this practice. *Sensitive* describes sensors commonly applied for all but extreme wind conditions. *Ruggedized* describes sensors intended to function during extreme wind conditions. The application of this practice requires the starting threshold (u_0) of both the wind vane and the anemometer to meet the same operating range category.

4.2.1 *Operating Range:*

Category	Starting Threshold, u_0	Maximum Speed, u_m
Sensitive	0.5 m/s	50 m/s
Ruggedized	1.0 m/s	90 m/s

4.2.2 *Dynamic Response Characteristics*—Dynamic response characteristics of the measurement system may include both the sensor response and a measurement circuit contribution. The specified values are for the entire measurement system, including sensors and signal conditioners (**5**). It is expected that the characteristics of the sensors, which can be independently determined by the referenced Test Methods D5096 and D5366, will not be measurably altered by the circuitry.

TABLE 1 Characterizations Extracted from Wieringa, J. (4)

No.	z_0, m	Landscape Description
1:	0.0002 Sea	Open sea or lake (irrespective of the wave size), tidal flat, snow-covered flat plain, featureless desert, tarmac and concrete, with a free fetch of several kilometres.
2:	0.005 Smooth	Featureless land surface without any noticeable obstacles and with negligible vegetation; for example, beaches, pack ice without large ridges, morass, and snow-covered or fallow open country.
3:	0.03 Open	Level country with low vegetation (for example, grass) and isolated obstacles with separations of at least 50 obstacle heights; for example, grazing land without windbreaks, heather, moor and tundra, runway area of airports.
4:	0.10 Roughly open	Cultivated area with regular cover of low crops, or moderately open country with occasional obstacles (for example, low hedges, single rows of trees, isolated farms) at relative horizontal distances of at least 20 obstacle heights.
5:	0.25 Rough	Recently developed young landscape with high crops or crops of varying heights, and scattered obstacles (for example, dense shelter-belts, vineyards) at relative distances of about 15 obstacle heights.
6:	0.5 Very rough	Old cultivated landscape with many rather large obstacle groups (large farms, clumps of forest) separated by open spaces of about 10 obstacle heights. Also low-large vegetation with small interspaces, such as bushland, orchards, young densely planted forest.
7:	1.0 Closed	Landscape totally and quite regularly covered with similar-size large obstacles, with open spaces comparable to the obstacle heights; for example, mature regular forests, homogeneous cities, or villages.
8:	>2 Chaotic	Centers of large towns with mixture of low-rise and high-rise buildings. Also irregular large forests with many clearings.