AS/NZS 3580.14:2014

EXTRACT RE SITING (SPEED/DIRECTION)

Australian/New Zealand Standard™

Methods for sampling and analysis of ambient air

Part 14: Meteorological monitoring for ambient air quality monitoring applications

SECTION 2 WIND SPEED AND DIRECTION

2.1 SCOPE OF SECTION

This Section sets out methods for the measurement of horizontal wind speed and direction using automated electronic sensors and data logging devices.

2.2 APPLICATION

This Section applies to the determination of wind speed and direction for the purpose of air quality applications at wind speeds ranging from the lowest measurable with this type of equipment, i.e. less than 0.5 m/s up to gale force and above, in various terrain categories and environmental conditions at heights typically from 10 m to 100 m above ground level. This Section has been developed for use in air quality monitoring applications, however, it may be applied in other fields of study.

2.3 PRINCIPLE

Wind velocity is a three-dimensional vector quantity with small-scale random fluctuations in space and time superimposed upon a larger-scale organized flow. However, for the purpose of air quality monitoring applications, surface wind is considered as a two-dimensional vector quantity specified by two numbers representing direction and speed.

The output of these sensors is typically connected to data logging systems to both convert the signal into engineering units and to record the data. These sensors are mounted at a standard height to ensure uniformity for this type of measurement.

2.4 APPARATUS

2.4.1 General

Surface wind is usually measured by mechanical or ultrasonic devices. The instruments and techniques specifically discussed here are only a few of those more commonly used and do not comprise a complete list. Sensors shall meet or exceed the instrument performance specifications listed in Tables 2 and 3.

2.4.2 Cup anemometer and vane systems

The cup anemometer has cups that relate the rate of rotation to the wind speed. The cup anemometer's dynamic performance characteristics (starting threshold and distance constant) are density-dependent, but its transfer function (rate of rotation versus wind speed) is independent of density. The cup is not very efficient and creates turbulence as the air flows through and around it. The cup anemometer is omni-directional in a horizontal flow situation but exhibits a complicated reaction to vertical flow situations. It may indicate speed slightly greater than the total speed when the flow is not horizontal.

The wind vane is perhaps the simplest of instruments. A fin is fixed to a vertical shaft so that when force is applied to the area by the wind, it will turn the shaft, seeking a minimum force position. The relationship of the shape, size, and distance from the fin's axis of rotation to the bearing assembly and transducer torque determines the starting threshold. These attributes of the fin area, along with its counterweight, determine the dynamic performance characteristics of overshoot (damping ratio) and delay distance (distance constant) of the direction vane.

Vane design is of little importance if average wind direction is the only requirement. If turbulence parameters are of interest, the design of the vane becomes important.

The vane transducer is usually a potentiometer. It is common that the range of the sensor is 355° rather than the physically true 360°. The reason is related to the problem of a continuous range (a circle) with a discontinuous output (zero to a defined reference voltage). Knowing how the transducer works is important if the performance of the wind vane will be challenged for quality assurance purposes.

2.4.3 Propeller anemometer and vane systems

The propeller anemometer is a more efficient shape. The helicoid propeller is so efficient that its transfer function can be specified from theory. It creates little turbulence because the air flows mostly through it. The propeller measures wind speed when it is oriented into the wind by a vane. Its errors from imperfect alignment with the mean vector are small and are nearly proportional to the cosine of the angle of misalignment.

2.4.4 Ultrasonic anemometers

Ultrasonic anemometer systems are based on the principle that wind changes the transit time of a sound pulse across a fixed distance. Ultrasonic systems can be designed in two dimensions for horizontal wind speed and direction as a replacement for the cup and vane or propeller units, or in three dimensions for both horizontal and vertical wind measurements. For those applications where the contribution of small eddies is important, ultrasonic systems are an excellent choice.

2.5 INSTRUMENT

A continuous direct-reading instrument that meets or exceeds the specifications given in Tables 2 and 3 for wind speed and wind direction sensors respectively is required. The manufacturer's published performance specifications shall be deemed as acceptable evidence of conformance to the given requirements if accompanied by a statement of uncertainty.

TABLE 2

INSTRUMENT PERFORMANCE SPECIFICATIONS FOR WIND SPEED SYSTEMS

Parameter	Minimum requirements
Range	0.5 to 30 m/s
Total accuracy	3% or ±0.2 m/s*
Resolution	≤0.25 m/s
Starting threshold	≤0.4 m/s
Distance constant	≤3 m
Maximum averaging interval	10 min
Data sampling frequency	5 s

* Whichever is the greater.

TABLE 3

INSTRUMENT PERFORMANCE SPECIFICATIONS FOR WIND DIRECTION SYSTEMS

Parameter	Minimum requirements
Range	
Mechanical	0 to 360°
Output	0 to 355°
Total accuracy*	±3°
Resolution	1°
Starting threshold	≤0.5 m/s at 10°
Damping ratio	0.25 to 0.6
Maximum averaging interval	10 min
Minimum number of data samples	>60 for scalar/vector means >360 for sigma theta

* Excludes measurement deadband range.

2.6 PROCEDURE

2.6.1 Siting

In the siting, installation and assessment of the number of anemometers required, consideration should be given to mounting, exposure and protection in adverse conditions. Additional information about siting of meteorological sensors in urban areas can be obtained from the WMO, Instruments and Observing Methods, Report No. 81.

Location of the instrument is critical for wind measurement. In a sheltered location or on a small building or hill of low relief, the measured wind may easily differ by −50% to +100% in speed and 90° or more in direction from the wind representative of a wider area. To identify suitable locations for anemometers in difficult sites, it is advisable to make a detailed wind survey under various conditions of wind speed, wind direction and atmospheric stability or to obtain the advice of a meteorologist.

In many applications wind measurements are made in order to estimate dispersion over a horizontal scale of about 100 m to 10 km. On this scale the representative wind is the wind measured at a height of 10 m over a flat open area substantially free of obstructions, where the anemometer is distant from any obstruction by at least 10 times the height of the obstruction (see Figure 1). It is generally considered that the appropriate measurement height for air quality applications is 10 m. Special projects may dictate measurement at greater heights.

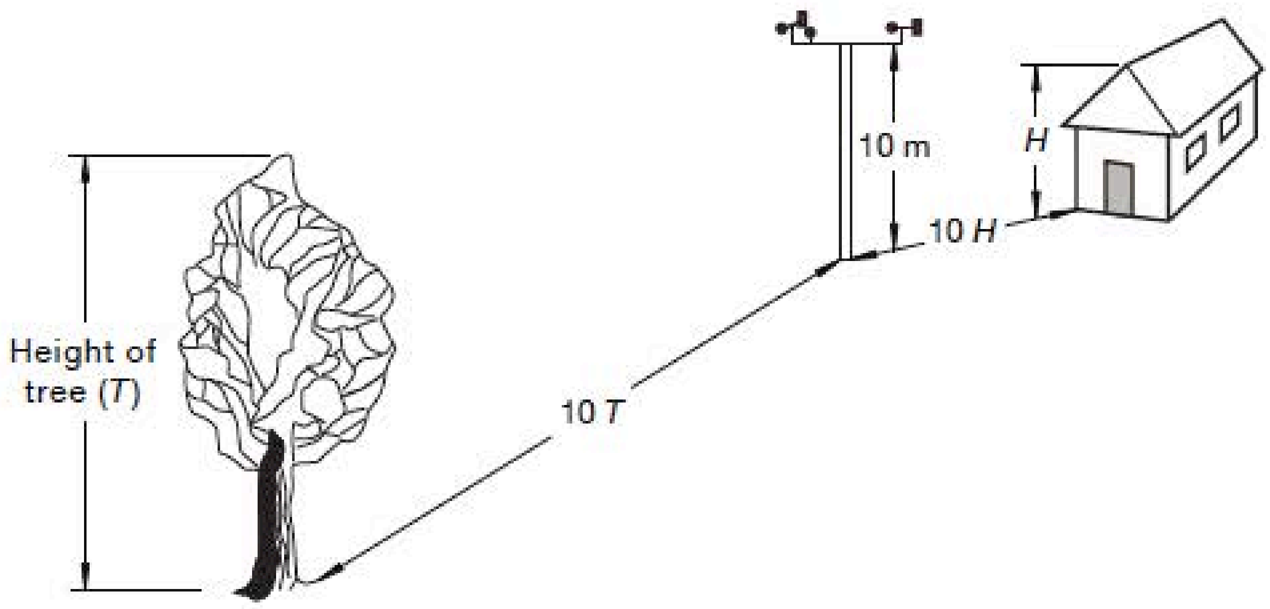

FIGURE 1 EXAMPLE OF SITING WIND INSTRUMENTS

2.6.2 Vertical variation of the wind—Atmospheric stability

Consideration of wind variation with height may influence the choice of height for an anemometer or indicate the need for more than one anemometer set at various heights. In an atmosphere which is unstable, or neutral, or stable to a small degree, the average wind speed in undisturbed flow increases with height in an approximately logarithmic manner, i.e. the ratio of wind speeds at two levels, above at least twice the height of surface roughness elements, is proportional to the logarithm of the ratio of their heights. There is also a slight anti-clockwise turn of the wind with height in the southern hemisphere.

When the flow is disturbed, e.g. when it has recently passed over a change in the roughness of the ground surface, the wind speed still increases with height, but in a more complex manner. In a stable atmosphere there may be strong variation of both wind speed and wind direction with height, therefore wind observations made at one height cannot be used without further information as an indication of the wind at another height.

2.7 OBSTRUCTIONS

2.7.1 General

The effect of obstructions does not lend itself to simple description. Wind flow over buildings will result in an exposure downwind that will be unrepresentative. A site on a roof, solid fence or wall will be unrepresentative unless the anemometer is on a mast high enough to clear the area of increased wind speed or decreased flow in the lee eddy or wake where the flow is turbulent. Porous structures such as rows of trees or mesh fences have similar but lesser effects. As a general rule, obstructions should not project above the horizon by more than 6° at the sensor height.

2.7.2 Multiple obstructions

In a built up area, or in an area with many trees, the atmospheric motion responsible for dispersion on scales of 100 m to 10 km is represented by the wind in the undisturbed flow clear of the obstructions. Structures with gaps or rows (spaces between buildings, or streets) cause funnelling of the airflow with local crowding of streamlines and changes of direction. None the less, suitable locations may be found in open level spaces where the 10 times height rule (Clause 2.6.1) is satisfied. Failing this, the anemometer may be placed among the obstructions, typically 5 m to 10 m above their general level but, if on a building, well above the disturbed flow. It should be located away from obstructions which are higher than the anemometer, at distances not less than 10 times the difference of the heights of the anemometer and the obstructions.

2.7.3 Measurements among obstructions

In some special cases, such as estimation of dispersion on small scales, measurements of wind may be required within the disturbed flow among buildings or trees. In such locations the wind will be very variable and no representative location may exist. It will then be necessary to make measurements at more than one location to obtain estimates of ventilation rates or other quantities.

2.7.4 Hills, valleys and uneven terrain

Wind in hilly terrain varies strongly in the vertical and horizontal directions, and with time of day. The effect of hills may be observed on flat country many kilometres away from the hills, and at such a site it is unwise to infer the wind at 50 m or above from measurements made at 10 m in stable air. Wind on exposed ridges of any size may be two or three times as strong as the representative wind because of the streamline crowding effect. Valleys usually have lighter winds but may experience very strong flows in a markedly different direction from the representative wind if a funnel effect is present. No general guidance to anemometer exposure can be given for hilly or dissected terrain. Choice of a site shall be determined with regard to a precise statement of objectives, as to what feature of the flow is to be described, and on what scale. Measurements at more than one location may be needed.

2.8 INSTALLATION

2.8.1 Mounting

Wind measuring equipment should be mounted solidly. Horizontal and vertical alignment should each be checked with a good quality spirit level at two points 90° apart. Wind direction sensors should be oriented so that wind directions are measured clockwise from true north. If wind vanes or anemometers are mounted on a tower or mast, they should be located in such a way that the tower does not significantly alter air flow at the point where sensors are located. The preferred procedure is to mount the wind vane and anemometer on top of the tower. If they are to be mounted part-way up on a large tower, they should be mounted away from that tower on a bracket or boom by at least twice the maximum width of the tower at that level.

Anemometers and wind vanes should be mounted on the side of the tower best exposed to the wind that is most significant for the purpose the data are to serve. If there is no significant direction, they should be mounted on the side from which the wind blows most frequently. A wind instrument should be securely mounted on a mast that will not twist, rotate, or sway. Leads connecting the sensors and display or recording instruments should be shielded from extraneous signals and protected from physical damage.

2.8.2 Protection in adverse conditions

Sensors and other instruments exposed to the ambient atmosphere should be capable of operation without significant degradation in the environment to which they are exposed over the measurement program period. As a guide, the following conditions may be expected and where appropriate, equipment, design and construction should allow operation in these conditions:

(a) Temperature: −20°C to +55°C.

(b) Relative humidity: 0 to 100%.

(c) Heavy, driving rain.

(d) Solar radiation heat load.

(e) Corrosive conditions (e.g. marine, industrial).

(f) Abrasive dusty conditions.

2.12 MEASUREMENT UNCERTAINTY

The measurement uncertainty of this method will vary for each specific application. Factors affecting the overall uncertainty include but are not limited to—

(a) degradation or contamination of the mechanical components of the sensors;

(b) misalignment of the wind direction sensor or failure to adjust for true north; and

(c) representative exposure of the anemometer as it is rare to find a location where the wind speed is representative of a large area.

NOTE: Methods exist to obtain estimates of exposure errors. World Meteorological Organization (WMO), Instruments and Observing Methods Report No. 81, '*Initial Guidance to Obtain Representative Meteorological Observations at Urban Sites*' provides guidance for these.

As a guide uncertainties for wind speed of the greater of ±0.6 m/s or 5% U_{95} of reading and ±5° U_{95} for wind direction can be easily achieved using modern equipment. In all cases, the measurement uncertainty shall be determined based on individual laboratory practices.

NOTE: A suitable method for calculating measurement uncertainty can be found in ISO/IEC Guide 98-3.