An Improved Bead Thermistor Anemometer for Use in Plant Canopies

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ABSTRACT

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A small, inexpensive anemometer suitable for use in plant canopies was constructed using bead thermistors in a constant-temperature configuration. It overcomes the directional dependence associated with a single thermistor by using twin beads mounted at right angles. The anemometer was calibrated using a pendulum as a velocity standard and achieved an accuracy of ±0.03 m/sec for wind speeds in the 0–2 m/sec range. Two anemometers operated successfully within grapevine canopies for a complete season.

In most years, bunch rots are responsible for large losses to the New Zealand wine industry (4). The extent of these infections is dependent on the weather conditions near harvest (5) and on the microclimate of the developing grape clusters. In particular, wind speeds within the canopy play an important role in influencing both the temperature and moisture relations of the berries and thus the opportunity for fungal growth.

This paper describes an instrument based on a design by Hole (2) in which a single-bead thermistor was used as the sensing element. Because of its size, this instrument is suitable for use within plant canopies.

Initial measurements, using the original design, showed a marked dependence (up to 30%) on the horizontal wind direction (Fig. 1). The form of this relationship indicated that the angular sensitivity could be overcome by mounting two matched thermistors at right angles to each other. Construction and circuit requirements necessary to achieve this design modification are presented along with field use and data collection information.

MATERIALS AND METHODS

Probe. The sensing thermistors (ITT type P15) were mounted at right angles to each other on 10-cm lengths of rigid tubing (6 mm o.d.), which protruded from a length of PVC tubing (Fig. 2). A third thermistor (ITT type G52C), used for temperature compensation, was mounted at the base of the supports to minimize any disturbance to the airflow around the sensing elements. During assembly, the tubing and thermistors require clamping to enable accurate orientation and to prevent accidental damage.

Electronic circuit. The circuit (Fig. 3) consists of two stages. Stage 1 has two bridge networks that provide voltages dependent on both wind speed and direction from each of the sensing thermistors. Stage 2 adds these voltages using a summing amplifier with a smoothing capacitor C1. Temperature compensation is achieved using the third thermistor (ITT type G52C), which has a similar temperature coefficient to that of the sensing thermistors but is enclosed in a glass bead. For our instrument, the ± 15V were obtained from an AC mains supply; however, battery operation for increased portability is feasible because the current drain is only around 30 mA.

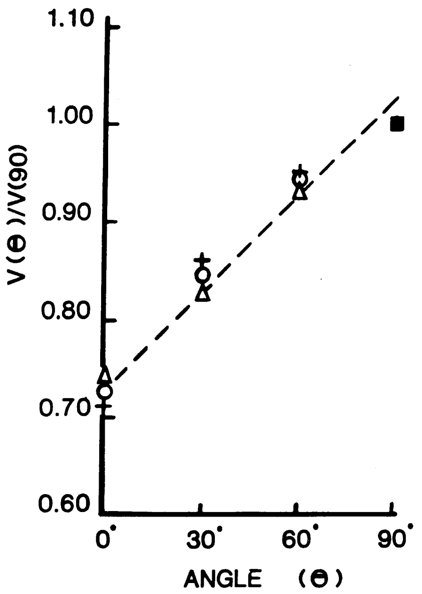

Fig. 1. Output attenuation for a single-bead anemometer as a function of angle at wind speeds of (+) 0.6, (o) 1.1, and (△) 1.33 m/sec. The regression line has the equation: $V(\theta) = V(90)\,(0.73 + 3.3 \times 10^{-3}\theta)$.

RESULTS AND DISCUSSION

Calibration. A prototype anemometer, with a single sensing thermistor without low-pass filtering circuitry, was used to investigate the sensitivity to wind speed and angle. Calibration was achieved using a pendulum as a velocity standard, as suggested by Larmuth (3), with the output of the anemometer connected to a storage oscilloscope. The probe was mounted on the pendulum, which was suspended from the laboratory ceiling by two wires 2 m long and about 1 m apart. The twin support was necessary to prevent rotation of the probe.

For small oscillations within restricted time intervals, the motion of the pendulum is simple harmonic:

$$d = D\sin\left(\frac{2\pi t}{T}\right), \qquad (1)$$

where T = period of oscillation, d = horizontal displacement of the sensing tip from the rest position, and D = maximum displacement. Differentiating equation 1 gives the velocity relationship:

$$U = U_{\max}\cos\left(\frac{2\pi t}{T}\right), \qquad (2)$$

where the maximum velocity $U_{\max}$ is given by

$$U_{\max} = \frac{2\pi D}{T}\ . \qquad (3)$$

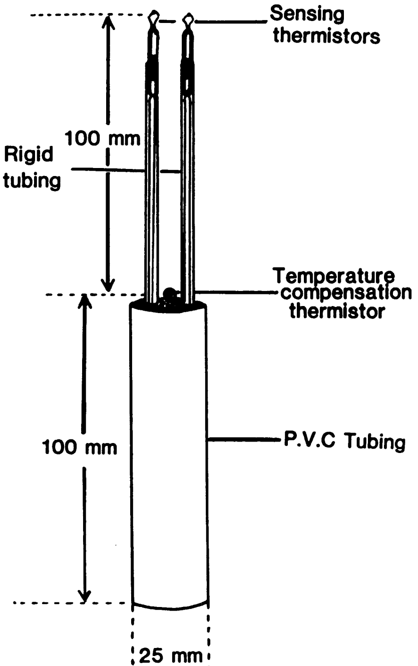

Fig. 2. Probe schematic.

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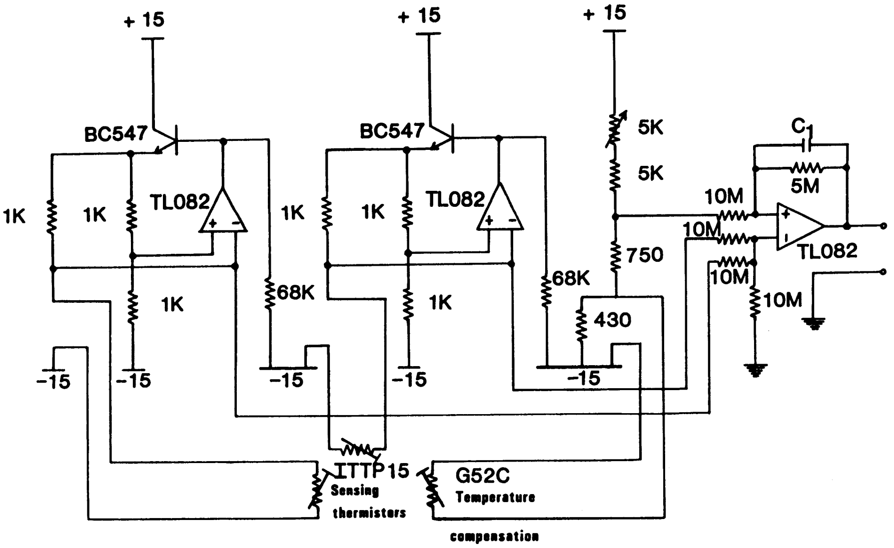

Fig. 3. Circuit diagram.

By timing T for a number of oscillations, equation 3 can be used to obtain $U_{\max}$ for given values of D.

A horizontal scale was placed alongside the anemometer and the pendulum was set swinging. As the horizontal displacement decreased, the oscilloscope was triggered manually at predetermined values of D. The stored trace was then used to measure the peak voltage corresponding to the maximum velocity given by equation 3. Because of the small time constant (10^{-2} sec) of the device relative to the period being measured (3 sec), no amplitude correction as used by Larmuth (3) was required.

For the above calibration, the plane of the thermistor support leads was set at 90° to the airflow. In order to investigate the angular sensitivity, the calibration was repeated with this angle (θ) equal to 0°, 30°, and 60° (Fig. 1). This angular dependence may be approximated by

$$V(\theta) = V(90^\circ)[C\theta + E], \qquad (4)$$

where $V(\theta)$ and $V(90^\circ)$ are the voltage outputs at angles θ and 90° respectively. A second thermistor at right angles to the first will have a similar form to equation 4 but with a negative slope. Thus, summing outputs of two matched thermistors at right angles to one another should eliminate any dependence on wind direction. Matching was achieved on the basis of the output at zero wind speed because all the thermistors had similar slope characteristics but differing voltage offsets.

A probe was constructed using a matched pair of thermistors and calibrated. From the calibration (Fig. 4), it can be seen that there is no significant angular dependence and that the output voltage has a squared dependence on wind speed, as expected from heat-transfer theory (1). The data was fitted to the following relation:

$$U = (AV + B)^2, \qquad (5)$$

where U is the wind speed and V is the voltage output. Even though a quadratic would give a better fit, equation 5 was used for ease of field data handling. Adequate temperature compensation was demonstrated because calibrations at 10, 20, and 30 C were essentially identical.

Field testing. In the field, the anemometer needs some protection from accidental damage and direct rainfall. To achieve this, the anemometer was secured in the canopy within a cage of coarse wire mesh (about 8-cm radius) with a 10-cm-diameter disk of plastic supported above it to protect it from direct rainfall. The leads of the sensing thermistor were given a light coat of silicone sealant to prevent any buildup of corrosion, which could result in a short circuit across the leads. The probe can be capped conveniently with a test tube to prevent physical damage during transport and any chemical contamination during spraying operations.

Field measurements were monitored with a Campbell CR21 micrologger (Campbell Scientific Inc., Logan, UT), which could transform the output voltage of the anemometer (using equation 5) to give a wind speed reading in meters per second. The time constant of the summing amplifier was set approximately to the logger scan interval, by using a value of 47 pf for the capacitor C1, thus providing a time-averaged wind speed. The anemometers as described have been in use over a 6-mo growth season measuring low wind speeds in grapevine canopies. A typical day's data (Fig. 5) shows the difference in wind speeds within two grapevine canopies along with the above-canopy wind speed.

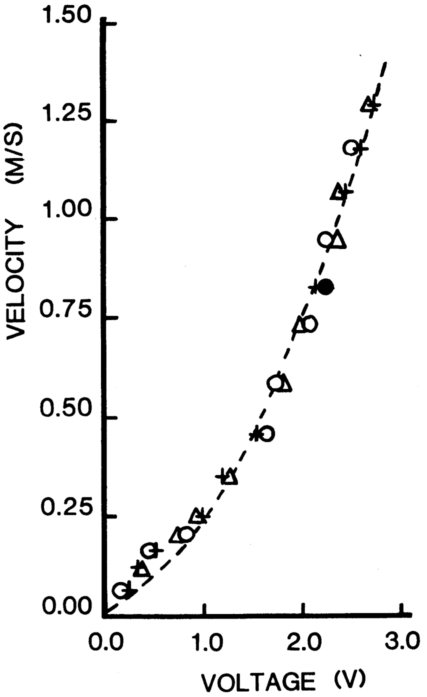

Fig. 4. Calibration for final anemometer. The fitted line has the mathematical form of $U = (AV + B)^2$. Best fit values for A and B obtained using a nonlinear regression analysis are 0.37 and 0.12, respectively, with a residual standard error of 0.03 m/sec. o = 0°, + = 45°, △ = 90°, and ● = 135°.

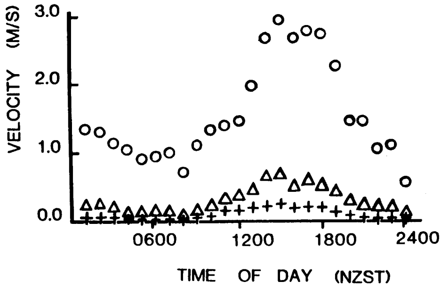

Fig. 5. Typical day's data showing wind speeds within two grape canopies and the above-canopy wind speed: o = above canopy, △ = low-density canopy, and + = high-density canopy.

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