ULTRASONIC ANEMOMETERS FOR ATHLETICS COMPETITIONS

Introduction

More recently ultrasonic anemometers supplied by the photofinish timing company have been used for major IAAF competitions in place of the older technology propeller anemometers.

This paper examines issues of accuracy for this type of measurement.

Ultrasonic Theory

The speed of sound (A) in metres per second depends on the type of medium and the temperature of the medium.

$$A = \sqrt{(\gamma RT)}$$

γ = ratio of specific heats (1.4 for air at STP)
R= gas constant (287.1 $m^2/s^2/K^0$
T = absolute temperature (273.15 + ^{0}C)

An approximation of this formula is:

$$A = 331.4 + 0.6Tc$$

Where Tc is the Celsius temperature of air

At 15^{0}C at sea level the speed of sound in dry air is 340.3 m/s.

The speed of sound is almost independent of pressure and only slightly dependent on humidity.

The ultrasonic anemometer measures the time for sound to travel from one transducer to another transducer at a known distance apart. The speed of propagation of sound in still air has the velocity of the wind in the same direction superimposed upon it. A wind velocity in the sound direction supports the sound propagation. A wind in the opposite direction would reduce the sound speed.

$$L/t_1 = A - V \quad (1)$$
$$L/t_2 = A + V \quad (2)$$

Where

V = wind velocity
A = speed of sound
L = distance between the transducers
t = time of the sound pulse travel

Subtracting (1) from (2)

$$V = 0.5L(1/t_2 - 1/t_1)$$

Thus it can be seen that to eliminate the effect of air temperature and other air properties, the time for the sound travel is measured in both directions. The reciprocals of the measured propagation times are subtracted and multiplied by a fixed transducer distance to obtain the wind velocity.

This measurement sequence is repeated at intervals and the average wind speed over predetermined intervals can be determined.

Systematic Errors

Heinemann, Langner et al (1) examined the systematic errors due to inaccurate transducer mounting, transducer shadowing and distortion caused by the mounting struts for three-dimensional ultrasonic anemometers over a range of horizontal wind velocities generally greater than those in which we are interested.

A variation of the measured wind speed up to 5% was noted over the 360^0 wind direction range. In addition the mean wind speed averaged over all directions was about 3% lower than the reference velocity in the wind tunnel.

The study by Helle (2) of the Gill Instruments one component ultrasonic anemometer, especially designed for athletics, found that there was a 5% undermeasure of the wind velocity when the wind was at an angle of 15 degrees due to turbulence from the supporting rods of the mirror plate.

Thus it is important that ultrasonic wind gauges be calibrated as indicated in a companion paper.

Other Possible Error Sources

There should be no obstacle near the wind gauge that could cause disturbance to the wind flow. This means that a wind gauge operator seated near the gauge or a scoreboard could be an obstacle.

The wind component we are interested in is parallel to the runway or the sprint track as the case may be. If the tube of the wind gauge is not parallel to the runway then there will be a velocity underestimation error depending on the cosine of the angle deviation as shown in the table below.

Deviation Angle	Percentage Error
1^0	0.02

2^0	0.06
3^0	0.14
4^0	0.24
5^0	0.38

Thus it will be seen that the error is small compared with other possible errors.

Results obtained would be affected by rain. Some ultrasonic gauges have a cover and others do not. The effectiveness of a rain cover is not known.

Conclusion

Because there are no moving parts as in propeller wind gauges and as the effect of air properties is eliminated, ultrasonic wind gauges are inherently more accurate and reliable. However, as shown above errors are still possible and the continued accurate spacing of the transducers is critical to the accuracy of the instrument.

Ultrasonic wind gauges should be mandatory for all high class international meetings.

Denis Wilson
IAAF Technical Committee
31 December 2002

References

(1) Heinemann D et al, "Measurement and Correction of Ultrasonic Anemometer Errors and Impact on Turbulence Measurements", Carl von Ossietzky Universität, Oldenburg, Germany.
(2) Helle L, "Calibration Results of Wind Gauges", VTT Manufacturing Technology, Finland, 25 January 1997