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SONIC ANEMOMETERS NOW MEET NRC REQUIREMENTS

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1. INTRODUCTION

Sonic anemometers operate on the principal that the speed of the wind affects the time it takes for sound to travel from one point to a second point. If the sound is traveling in the direction of the wind, then the transit time is decreased. If the sound is traveling in a direction opposite the wind, then the transit time is increased. This principal is well known, and is the basis of all sonic anemometers.

Climatronics has developed a sonic anemometer (Sonimometer®) that can replace cup and vane or propeller and vane wind sensors in terms of cost and accuracy and at the same time be more rugged. The design (Figure 1) consists of two tapered cylinders separated from each other by approximately 10 cm. The transducers are mounted in the upper cylinder pointing down. Sound is transmitted toward the lower cylinder and reflected back towards the upper cylinder. The transmission time is affected only by the horizontal component of the wind.

The Sonimometer® performance is described and compared to standards for anemometers used at nuclear facilities, in general air quality dispersion studies, and in aviation weather systems. The applicability of this sensor for aviation systems and several examples are shown.

2. DESCRIPTION

Climatronics' Sonimometer® is based on the same classic principles as most sonic anemometers. The time required for a sound wave to travel from point A to point B is affected by the speed of the wind in a predictable and repeatable way. The novel feature of this anemometer is that the sound is directed down and reflected from a second surface before being detected at the receiver. This arrangement has the advantage that the transducers are out of the weather and out of the direct path of the wind resulting in a very rugged and compact design.

Figure 1 shows the layout of the anemometer. Only one of two orthogonal axes is shown since the operation of the second axis is identical to the first. Sound is transmitted from transducer X_1 down to the base and then reflected back to the transducer X_2. The transit time is a function of the speed of sound and the speed of the wind component parallel to the top and bottom plates and to the plane passing through X_1 and X_2. A detailed description of the design of the Sonimometer® is in Robertson and Katz (1996).

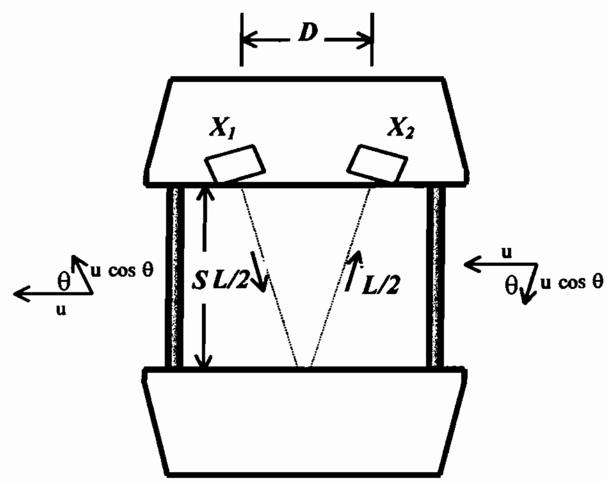

FIGURE 1

The most important result of the unique design of Climatronics' Sonimometer® is that the wind measurement is independent of the vertical spacing between the upper and lower portions of

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the anemometer. This means that the sensor accurately reports the wind even if there is a build up of contamination on the lower plate. Examples of the contamination which this sensor can tolerate include sand, salt, dirt, aircraft exhaust, rain, snow and ice.

3. SURVEY OF SPECIFICATIONS

Table 1 lists the performance specifications of the Sonimometer® compared to several guidelines describing wind sensors used at nuclear facilities, for air quality dispersion modeling, and in aviation weather systems around the world. The table shows first that there is a wide range in the specifications listed in these guidelines. Even those from the same agency, for example both the National Weather Service and the Federal Aviation Administration, have different measuring ranges and accuracies for both wind speed and direction.

The next section compares the Sonimometer® with specifications written by US and international organizations involved in dispersion modeling and aviation meteorology. A brief discussion of the Sonimometer's® different performance descriptors will follow.

3.1 COMPARISON OF SPECIFICATIONS WITH SONIMOMETER®

Climatronics' Sonimometer® meets most of the specifications as shown on Table 1, including those of the US Nuclear Regulatory Commission (NRC), the US Environmental Protection Agency (EPA), the International Civil Aviation Organization (ICAO) and the World Meteorological Organization (WMO). We will now compare the different portions of each specification.

Our first point of comparison is the wind speed measuring range of the sonic anemometer to those of the other sensors specified.. The Sonimometer®, which measures wind speeds up to 65 m-sec^{-1}, meets the requirements of most users. From a practical standpoint, most users need wind sensors that accurately report wind speeds to 50 m-sec^{-1}. Most nuclear facilities and airfields will usually be closed for safety reasons before winds reach these values. Other users, such as those gathering climatological data from these same sensors, probably need a higher maximum wind speed reporting range. This would then be the reason for their specifications indicating a requirement for the higher maximum wind speed.

The accuracy of the wind speed measurement also varies from one set of specifications to another. The accuracy is usually expressed as both a percentage of the measurement and an absolute value. The absolute value is the greater of the two at lower wind speeds, is typically stated as 0.2 to 1.0 m-sec^{-1} (0.5 to 2.0 kt). The Sonimometer® achieves this accuracy through our standard production process with supplemental individual selection.

At higher speeds, the Sonimometer® will be within ±5% of the true value , which is sufficient for all users except those wishing to meet the specifications of the NWS' F420 system. It is interesting to note that this cup anemometer uses a very large and heavy cupset and claim to achieve an accuracy of ±1.5 - 2% of the measurement. At the higher wind speeds, heavy cupsets tend to over-speed, and their data may overstate the actual wind speeds in these conditions. This might be important to the climatological record, but would have little impact on nuclear facility operations.

The resolution of the Sonimometer® is set by the internal signal processing electronics. Electro-mechanical systems' resolution is determined by a combination of the sensor design and signal processing/display systems. Resolving wind speeds to 0.1 m-sec^{-1} as achieved by Climatronics' Sonimometer® is much better than required for aviation users.

The wind direction portion of the Sonimometer® is specified to report wind directions from 0°-360°, with an accuracy of ±5°. This is the median accuracy required of all of the wind reporting systems noted on Table 1. The WMO goes so far as to include a range of direction accuracies in their specification, acknowledging that these systems can have quite a spread.

3.2 DISCUSSION OF OTHER SPECIFICATIONS

Table 1 does not include several sensor specifications typically used to describe wind sensor performance, such as threshold, distance constant, linearity and damping ratio. This is because the method used by the Sonimometer® to measure the wind makes these performance characteristics no longer meaningful.

The starting threshold of an anemometer is defined as, " The lowest wind speed at which a rotating anemometer starts and continues to turn and produce a measurable signal when mounted in its normal position." (ASTM, 1985a). There are no moving parts in a sonic anemometer, so another definition for the lowest wind speed detectable by a sonic anemometer is needed. A sonic anemometer can typically detect wind speeds to the limit of its resolution, and this could be a definition of its threshold. However, it is at low wind speeds where all sonic anemometers have difficulty making accurate measurements, since the acceleration of the sonic wave front due to the wind is smallest at low speeds. Therefore, a definition of threshold for a sonic anemometer should include the lowest resolvable wind speed.

The distance constant is defined as the distance the air flows past a rotating anemometer during the time it takes the cup wheel or the propeller to reach (1-1/e) or 63 percent of the equilibrium speed after a step change in wind speed (ASTM, 1985a). As with the starting threshold, it is difficult to use this definition for a sonic anemometer. With no moving parts to accelerate, the response of a sonic anemometer to a step-wise change in wind speed would be almost instantaneous, and the effective distance constant very small.

The definition of the damping ratio of a wind vane uses the measured amplitude of two successive deflections of a wind vane after it is released from a fixed offset position in a wind tunnel. With no moving parts in a sonic anemometer, this specification of a wind vane is not meaningful to a sonic anemometer.

4. DISCUSSION

The procurement of top-quality equipment is the first step in providing accurate meteorological information to the dispersion modeling and emergency response community. Once installed, it is important that the equipment is operated and maintained properly. A sonic anemometer, with no moving parts, and the availability of built-in test (BIT) helps to eliminate many of the maintenance requirements of electro-mechanical systems. It is also important that the system is tolerant to inattention. This can be especially important where manpower limitations are growing in the unregulated, domestic electric utility market. Climatronics' Sonimometer®, with its novel design, will function properly if there is a build up of contamination (such as dirt, aircraft exhaust, rain, snow, and ice) on the lower plate.

The Sonimometer® performance compares well to standards for anemometers used at nuclear facilities and in other dispersion modeling applications. With its compact, rugged design, and the availability of an internal flux-gate compass, it can be utilized in both mobile emergency response and HAZMAT applications and at fixed sites.

5. REFERENCES

ASTM, 1985a. Standard Test Method for Determining the Performance of a Cup Anemometer or Propeller Anemometer (Draft 6 of D22.11). Amer. Soc. for Testing and Materials, Philadelphia, PA.

ASTM, 1985b. Standard Test Method for Determining the Dynamic Performance of a Wind Vane (Draft 8 of D22.11). Amer. Soc. for Testing and Materials, Philadelphia, PA.

Robertson, J.H., and D.I. Katz, 1996. Climatronics' Novel Sonic Anemometer. Ninth Joint Conference on the Applications of Air Pollution Meteorology with the Air and Waste Management Association, Atlanta, GA. American Meteorological Society.

TABLE 1

	Sonimometer®	NRC (ANS 3.11, proposed)	EPA (EPA-450/ 4-87-013)	F420 (NWS)	ASOS (NWS)	LLWAS (FAA)	AWOS (FAA)	ICAO	WMO
WIND SPEED									
Range	0 – 65 m/s	0 – 45 m/s	NS	0 – 170 kt	0 – 125 kt	0 – 100 kt	0 – 85 kt	NS	1 – 50 m/s
Accuracy	±0.2 m/s; ws ≤5 m/s ±5%; ws ≥ 5 m/s	±0.2 m/s; ws ≤5 m/s ±5%;ws≥ 5 m/s	±0.2 m/s; ws ≤5 m/s ±5%;ws≥ 5 m/s	±1.5%	±2 kt or ±10%	±2 kt or ±5%	±2 kt or ±10%	±1 kt or ±10%	± 0.5 m/s or ± 1kt
Resolution	0.1 m/s	0.1 m/s	0.1 m/s	NS	NS	NS	1 kt	NS	NS
WIND DIRECTION									
Range	0° - 360°	0° - 360°	0° - 360°	0° - 360°	0° - 359°	0° - 360°	1° - 360°	0° - 360°	0° - 360°
Accuracy	±5°	±5°	±5°	±5°	±5°	±2.5°	±5°	±10°	±2°to ±5°
Resolution	±0.1°	±1°	±1°	±2°	NS	NS	±1°	NS	±2°to ±5°

NS: Not stated in the agency's specification document.
NRC: Nuclear Regulatory Commission (US)
EPA: Environmental Protection Agency (US)
NWS: National Weather Service (US)
ASOS: Automated Surface Observing System
FAA: Federal Aviation Administration (US)
LLWAS: Low-Level Windshear Alert System
AWOS: Automated Weather Observing System
ICAO: International Civil Aviation Organization
WMO: World Meteorological Organization