**7.1** FIELD AND OPERATIONAL TESTS OF A SONIC ANEMOMETER FOR THE AUTOMATED SURFACE OBSERVING SYSTEM

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## 1. INTRODUCTION

The National Weather Service (NWS) is replacing the cup and vane anemometers that are currently used in the Automated Surface Observing System (ASOS) with sonic anemometers. The primary problem with the current cup and vane technology is its susceptibility to lock-ups in freezing precipitation conditions. When the cups and/ or vanes are immobilized by freezing precipitation, they will generally remain immobilized until the temperature rises above freezing, which can lead to extended periods when wind data is inaccurate and/ or unavailable. Another problem with the cup speed measurement is that when wet snow attaches to the cups their rotation speed is slowed. The result is a wind speed measurement that is lower than the actual speed. Sonic anemometers overcome problems associated with icing and wet snow by applying heat to their transducers, thus melting ice or wet snow that would otherwise interfere with the speed and direction measurement. While sonic anemometers were originally developed to measure wind speeds that are too low for mechanical anemometers to measure, the technology has evolved to the point where speeds up to 125 Knots can be measured accurately. This paper will discuss the extensive testing in the field and on operational ASOS systems in a wide variety of weather conditions to verify that the sonic anemometers will provide accurate speed and direction measurements for ASOS.

## 2. ANEMOMETERS USED IN TEST

The tests of a sonic anemometer to replace the ASOS cup and vane anemometer was preceded by many years of testing the relationship of the sonic anemometer measurements of speed and direction to more conventional anemometer designs, particularly the cup and vane anemometer that it would replace (Winans,1999 and Childs,2001). For the field tests described in this paper, two different conventional anemometers were used for comparison. These are described in the next two sections.

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### 2.1 Belfort 2000

The Belfort 2000, pictured in figure 1, is the cup and vane anemometer that is used in the NWS's ASOS. It uses a light chopper and pulse counter to obtain speed from the rotating cups and a digitized potentiometer to obtain direction from the vane. The speed and direction are available as a serial data message for ease of interfacing to computer-based data acquisition systems.

**Figure 1**. Belfort 2000 cup and vane anemometer

### 2.2 R.M. Young

The R.M. Young 9305-AQ-SE, pictured in figure 2, uses a propeller and vane arrangement to measure wind speed. The propeller is mounted on the vane in such a way that as the vane rotates, the propeller is pointed into the wind. The anemometer is compact and easy to install. It has also been found to agree well with the Belfort 2000 with a somewhat faster response to changes in wind speed and direction due to its lighter weight. Additionally, it has demonstrated less susceptibility to icing induced failures or degradation in performance due to rime icing or wet snow.


**Figure 2**. R.M. Young propeller vane anemometer

## 2.3 Vaisala 425NWS

The Vaisala 425NWS ultrasonic anemometer, shown in Figure 3, has an array of three equally spaced transducers which project and receive ultrasonic pulses in a horizontal plane. The anemometer measures the transit times of the pulses in both directions on three tranducer pairs for a total of six measurements of transit time. The speed and direction are derived directly from these six transit time measurements. Heat is applied to prevent ice and snow from blocking the transducers. Ten anemometers were provided for field testing at the different test sites.

**Figure 3.** 425NWS sonic anemometer

# 3. TEST LOCATIONS

## 3.1 Johnstown, PA

Johnstown, PA is the NWS's Winter Test Facility. It is located at the Johnstown-Cambria County Airport at an elevation of 700 meters. This site is particularly susceptible to severe winter weather due to its mountaintop location. Thus the primary objective at Johnstown was to expose the sonic anemometers to harsh winter conditions of snow, ice pellets and freezing rain.

At Johnstown, the Belfort 2000 cup and vane anemometer and R.M. Young propeller vane anemometer were used as comparison sensors. The Belfort was mounted on a standard ASOS wind tower to simulate an ASOS configuration. This served as the comparison anemometer for a 425NWS also mounted on an ASOS tower about 30 meters away from the Belfort. The R.M. Young was mounted at a height of about 3 meters. This served as the comparison sensor for a 425NWS at 3 meters about 6 meters away from the R.M. Young.

## 3.2 Sterling, VA

Sterling, VA is the NWS's primary location for testing surface sensors. Anemometers at Sterling were all located at approximately the same height, about 10 meters above ground, on three steel towers that could accommodate multiple anemometers or on standard ASOS towers. Two Belfort 2000 anemometers and two R.M Young anemometers were available as comparison sensors against which two 425NWSs were compared.

## 3.3 Operational ASOS Locations

For testing at operational ASOS locations, the Belfort 2000 and 425NWS were mounted at the same height on the same tower and positioned to avoid interference between the two. Thus data reported by the two anemometers with regard to average wind speed and direction, and peak wind speed and direction could be compared. Figure 4 shows the configuration of the sensors. A list of the ASOS sites that were used for the analysis is given in Table 1.

**Figure 4**. ASOS wind tower with dual installation of Belfort 2000 and 425NWS

Table 1. ASOS test locations

| TEST SITES | |
|---|---|
| **CITY** | **STATE** |
| Ketchikan | AK |
| Sitka | AK |
| Aurora | IL |
| Grand Forks | ND |
| Hancock | MI |
| Oshkosh | WI |
| Terre Haute | IN |
| Topeka | KS |
| Burlington | VT |
| Caribou | ME |

## 4. TEST RESULTS

### 4.1 Results of Field Test at Sterling and Johnstown

Tests results are displayed in figure 5 showing average and peak speed differences in intervals of one knot (lower X-axis) and direction differences in intervals of 3°(upper X-axis) . These comprise all the data from all the anemometers at Johnstown and Sterling, approximately 570 sensor days of operation from fall 2002 through mid-summer 2003. The average for speed and direction were based on 2-minute averages and the peak was based on 3-second running averages of test anemometer vs. comparison anemometer. The overall results were that the difference between the comparison anemometer and test anemometer was within ±2 knots 100% of the time. There is, however, a tendency for the Belfort average speed to be slightly higher than the 425NWS average speed (generally less than 0.5 knots difference). The bias towards slightly higher speed reported by the comparison anemometer results from the well known phenomenon of overrunning which is typical of mechanical anemometers, particularly large cup and vane anemometers (Hyson 1972).

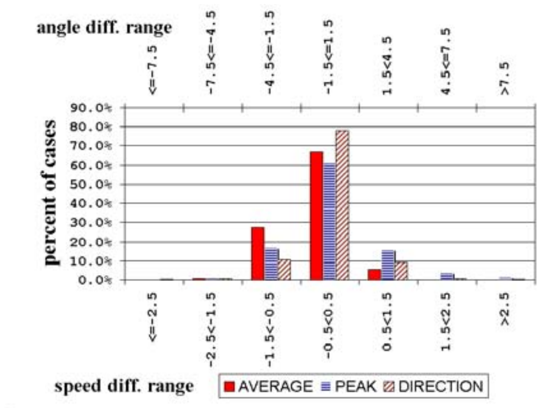


**Figure 5.** Average speed, peak speed, and average direction difference histograms for Sterling and Johnstown ( 425NWS - comparison anemometer).

With respect to peak wind, there is a slight tendency for the 425NWS to report higher peak wind. This is attributed to the faster response of the 425NWS to rapid fluctuations in speed which is especially true in gusty wind conditions. Overall the peak from the 425NWS was within ±2 knots of the comparison anemometer 98.5% Of the time.

Agreement in direction is within ±4° 97.7% of the time and within ±7° 99.3% of the time. The R.M. Young anemometer was used when possible for this comparison because of its ability to respond more quickly to changes in wind direction than the Belfort. This is especially true when winds are light.

### 4.2 Wind Test Results for 425NWS to 425NWS Anemometer Comparability

At the Sterling test site there were two 425NWS anemometers operating simultaneously at the same height and over a period of about 8 months. This permitted analysis of anemometer to anemometer comparability which is shown in Figure 6.

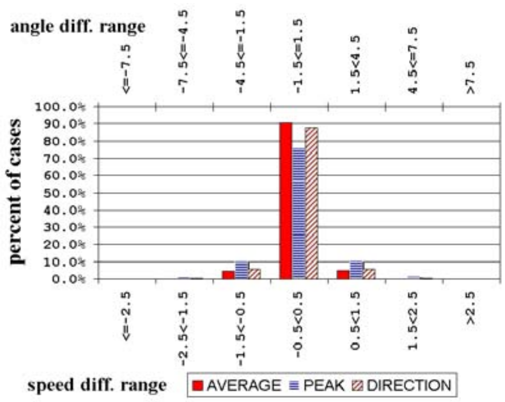


**Figure 6.** Average speed, peak speed, and direction differences histogram for 425NWSs.

The difference in average speed was within ±2 knots 100% of the time and within ±1 knots 99.9% of the time. The difference in peak speed was within ±2 knots 99.5% of the time and within ±1 knots 97.1% of the time. The difference in average direction was within ± 7° 99.9% of the time and within ± 4° 99.2% of the time. This demonstrates the high degree of precision between 425NWS anemometers operating side-by-side in the field.

### 4.3 Operational Test Results

The following sections comprise over 4300 minutes of data gathered and analyzed from Aurora, Illinois (KARR). These results are representative of test results gathered from the other operational sites. In each of the following figures, the text box on the lower left represents the total number of minutes in each precipitation category. The box on the lower right represents the average of the differences and the standard deviation respectively.

#### 4.3.1 Wind Speed Differences

Test results are displayed in figure 7 showing average speed differences in intervals of one knot (x-axis). Agreement in wind speed between the two sensors were within ± 2 knots 100% of the time. The average of the differences were ½ knot with a bias toward slightly higher speeds reported by the Belfort.

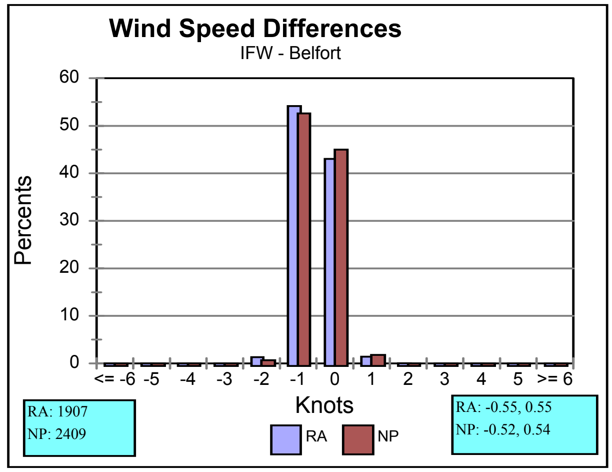


**Figure 7.** Average speed difference histogram in all wind speeds.

#### 4.3.2 Wind Direction Differences

Test results are displayed in figure 8 showing average direction differences in intervals of one degree (x-axis). Agreement in wind direction between the two sensors were within ± 4° 99.1% of the time in rain and 99.3% of the time in no precipitation.

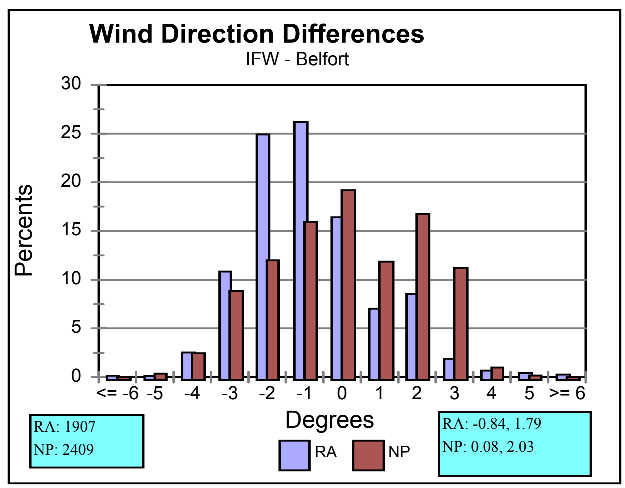


**Figure 8.** Average direction difference histogram in all wind speeds.

### 4.3.3 Peak Wind Speed Differences

Test results are displayed in figure 9 showing average speed differences in intervals of one knot (x-axis). Agreement in wind speed between the two sensors were within ± 2 knots 99.6% of the time in rain and 99.4% of the time in no precipitation.

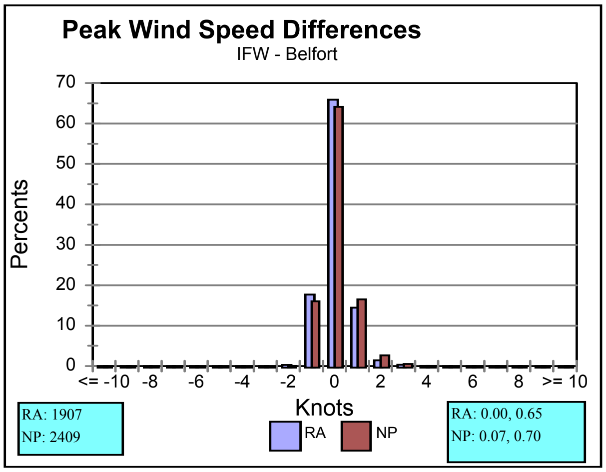


**Figure 9.** Peak wind speed difference histogram in all wind speeds.

### 4.3.4 Peak Wind Direction Differences

Test results are displayed in figure 10 showing average direction differences in intervals of one degree (x-axis). Agreement in wind direction were within ± 4° 70% of the time and ± 10° 95% of the time.

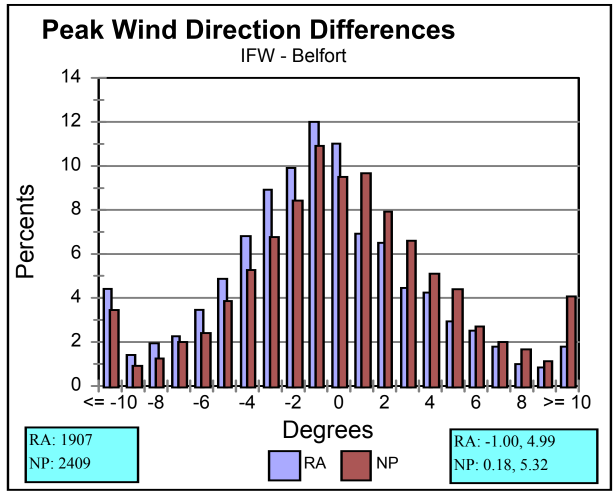


**Figure 10.** Peak wind direction difference histogram in all wind speeds.

## REFERENCES


Childs, B. and R. Lewis,2001: Investigating the impact of changing the ASOS wind gust averaging period from five to three seconds; AMS 11th Symposium on Meteorological Observations and Instrumentation, January 14-18, Albuquerque, NM, Amer. Meteor. Soc., Boston, MA, 46-49.

Hyson, P., 1972: Cup anemometer response to fluctuating wind speed. *J. Appl. Meteor.*, **11**, 843-848.

Winans, L.J. and R. Lewis, 1999: Gust measurements: cup and vane vs. sonic anemometer; 15th International Conference on Interactive Information and Processing Systems, January 10-15, Dallas, TX, Amer. Meteor. Soc., Boston, MA, 201-204.