

Calibration Uncertainty Comparisons Between Various Anemometers

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INTRODUCTION

This poster presents a comparison of calibration uncertainties from various types of anemometers commonly used in the wind energy industry. The anemometers were calibrated in the wind tunnel laboratory at Otech Engineering, Inc located in Davis, California. Calibration test protocols were based on procedures defined in IEC 61400-12-1, ASTM D 5096, and ISO 17713-1. Anemometer calibration uncertainty values presented here were calculated based on the guidelines provided in the Windpower 2007 podium presentation, "Anemometer Calibration Uncertainty". According to the IEC standard, the uncertainty to be reported in anemometer calibration reports is the uncertainty in the wind tunnel reference speed. The presentation given in Windpower 2007 expands the anemometer calibration uncertainty methodology by including the uncertainty in the anemometer output and in the linear regression analysis. This expanded uncertainty analysis provides a more complete representation of the linear performance of an anemometer under controlled test conditions and gives a method of understanding the differences between various anemometer types.

OTECH WIND TUNNEL FACILITY



Suction-Type



Closed Test Section



LabVIEW Data Acquisition

REFERENCE WIND SPEED MEASUREMENT



Pitot-static Tube System

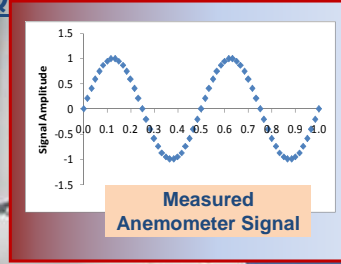
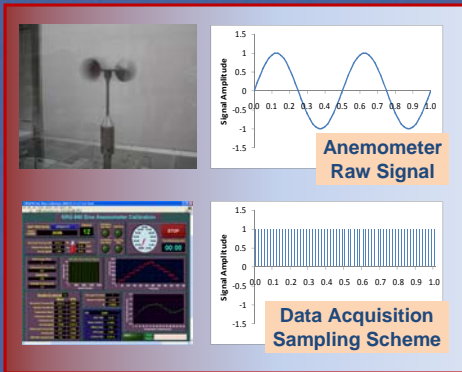


Temp/RH Probe



Barometer

ANEMOMETER SIGNAL ACQUISITION



Perform FFT analysis using LabVIEW to obtain anemometer signal frequency

CALIBRATION EXPANDED UNCERTAINTY ANALYSIS

$$U_{cal} = \sqrt{(U_V)^2 + (U_{IUT})^2 + (U_{LR})^2}$$

REFERENCE WIND SPEED UNCERTAINTY

$$U_V = \sqrt{B_V^2 + (tS_V)^2}$$

- Bias Errors**
- Manufacturer's spec
 - Calibration errors
 - Data acquisition
- Random Errors**
- Standard deviations in instrument readings
- $\Delta p, P, T, \rho, \phi$

ANEMOMETER SIGNAL UNCERTAINTY

$$U_{IUT} = \sqrt{B_{IUT}^2 + (tS_{IUT})^2}$$

- Bias Errors**
- Data acquisition
- Random Errors**
- Standard deviations in anemometer frequency

LINEAR REGRESSION UNCERTAINTY

$$U_{LR} = \sqrt{\left(t \frac{STE_V}{V_i} \right)^2}$$

Uncertainty in the curve fit based on the standard error of the linear regression

Expanded Uncertainty Analysis For Vestas Cup

Wind Speed (m/s)	Wind Speed STD (m/s)	Wind Speed Bias Error (m/s)	Wind Speed Random Error (m/s)	Wind Speed Relative Uncertainty (%)	Relative Wind Speed Uncertainty (%)	Anemometer Output (m/s)	Anemometer STD (m/s)	Anemometer Bias Error (m/s)	Anemometer Random Error (m/s)	Anemometer Relative Uncertainty (%)	Relative Anemometer Uncertainty (%)	Relative Regression Uncertainty (%)	Total Relative Uncertainty (%)	Total Uncertainty (m/s)
3.97	0.004	0.018	0.004	0.10%	0.11%	14.34	0.015	0.00143	0.015	0.10%	0.94%	0.94%	1.50%	0.59
4.97	0.007	0.027	0.007	0.14%	0.15%	21.50	0.023	0.00215	0.023	0.11%	0.87%	0.87%	1.39%	0.71
7.83	0.004	0.036	0.004	0.05%	0.07%	28.88	0.010	0.00289	0.010	0.34%	1.9%	1.9%	1.39%	0.11
9.81	0.005	0.045	0.005	0.05%	0.07%	36.16	0.016	0.00362	0.016	0.33%	0.8%	0.8%	1.2%	0.11
11.78	0.009	0.064	0.009	0.07%	0.09%	43.45	0.021	0.00434	0.021	0.40%	0.9%	0.9%	1.12%	0.13
13.73	0.008	0.083	0.008	0.06%	0.08%	50.86	0.022	0.00509	0.022	0.4%	1.0%	1.0%	1.22%	0.16
15.71	0.009	0.072	0.009	0.05%	0.07%	58.25	0.024	0.00583	0.024	0.58%	1.0%	1.0%	1.14%	0.18
17.69	0.010	0.081	0.010	0.06%	0.08%	65.70	0.024	0.00657	0.024	0.59%	0.8%	0.8%	1.0%	0.17
19.62	0.015	0.090	0.015	0.08%	0.09%	73.11	0.028	0.00731	0.028	0.47%	0.6%	0.6%	0.88%	0.16
21.59	0.014	0.099	0.014	0.06%	0.08%	80.41	0.025	0.00804	0.025	0.59%	0.6%	0.6%	0.85%	0.16
23.55	0.015	0.108	0.015	0.12%	0.09%	88.03	0.029	0.00880	0.029	0.78%	0.6%	0.6%	0.9%	0.23
25.51	0.019	0.117	0.019	0.20%	0.12%	95.11	0.038	0.00951	0.038	0.75%	0.6%	0.6%	0.9%	0.20
AVE	0.009	0.068	0.009	0.07%	0.08%	AVE	0.027	0.0055	0.027	0.45%	0.34%	0.34%	1.05%	0.15

