

REVIEW OF ANEMOMETER CALIBRATION STANDARDS

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SUMMARY

Anemometer calibration relates the anemometer signal output to a traceable measurement of a controlled wind speed. There are three published standards that present test protocols for rotating anemometers: ASTM D 5096-02, ISO 17713-1, and IEC 61400-12-1. For sonic anemometers, two published standards are referenced: ASTM D 6011-96 and ISO 16622. This poster presents a review and comparison of anemometer calibration procedures presented in these published standards.

CALIBRATION TEST FACILITY REQUIREMENTS

All standards require that anemometer calibration is to be performed in a steady state wind tunnel, where controlled conditions isolate sensor performance from disturbances such as vibrations and off-angle winds. Procedures in IEC 61400-12-1 specify that wind tunnel reference speeds are to be measured using a Pitot tube system. Requirements in ASTM D 5096-02, ISO 17713-1, ASTM D 6011-96, and ISO 16622 allow the possibility of incorporating other types of wind measurement systems. All standards also specify that instruments used to determine the reference wind speed are traceable to a national laboratory or an equivalent recognized calibration facility such as the National Institute of Standards and Technology (NIST) in the United States.

Wind Tunnel Characteristic	Description	Summary of Minimum Requirements from Standards
Blockage	Ratio of the projected area of the anemometer plus mount to the test section cross-sectional area	IEC 61400-12-1: not to exceed 10% for open test sections and 5% for closed test sections ASTM & ISO: less than 5%, preferably closer to 1%
Wind Speed Capability	Controlled wind speed range	IEC 61400-12-1: generate controlled speeds from 4 to 16 m/s ASTM D 5096-02, ISO 17713-1: produce speeds at least from 0 to 50% of the application speed for the anemometer under test with the controlled steady speed maintained within +/- 0.2 m/s ASTM D 6011-96: generate speeds of at least 1 to 10 m/s within +/- 0.1 m/s or better ISO 16622: produce speeds over full application range for the anemometer under test with the controlled steady speed maintained within +/- 0.2 m/s, preferably +/- 0.1 m/s
Flow Uniformity	Percent difference in wind speed or velocity profile within the test section volume	IEC 61400-12-1: less than 0.2% ASTM & ISO: uniform velocity profile to within 1%
Horizontal Wind Gradient	Pressure differential at the area covered by a rotating sensor	IEC 61400-12-1: must be less than 0.2%
Turbulence Intensity	Ratio between the wind speed standard deviation to its mean	IEC 61400-12-1: must be less than 2% ASTM & ISO: must be less than 1%
Air Density Uniformity	Percent difference in density within test section volume	ASTM D 5096-02 & ISO 17713-1: less than 3% difference
Data Acquisition	Method of collecting reference wind speed data	IEC 61400-12-1: maintain resolution of 0.02 m/s, sampling frequency of at least 1 Hz for 30 sec ASTM & ISO: maintain resolution of 0.02 m/s, sampling frequency of at least 10 Hz for 30 to 100 sec

COMPARISON OF ANEMOMETER CALIBRATION TEST PROTOCOLS

For **ROTATING ANEMOMETERS** (cup and propeller type), calibration test speed protocols typically cover the application range of the anemometer. Test speed range is typically limited by the maximum speed capability of the calibration facility. Overall, most wind tunnel facilities are able to perform the recommended test speed protocols defined by published standards.

For **SONIC ANEMOMETERS**, base calibration is performed in a zero wind chamber. Wind tunnel testing is done to determine the deviations of the anemometer wind speed reading due to the angle of the incoming flow. Due to the rigorous steps offered by standards, test protocols are normally revised according to the application of the sensor and its manufacturer recommendations.

Standard	Test Speed Protocol for Rotating Anemometers																						
IEC 61400-12-1	4 to 16 m/s at 1 m/s increasing & decreasing increments (i.e. 4, 6, 8, 10, 12, 14, 16, 15, 13, 11, 9, 7, and 5 m/s)																						
ASTM D 5096-02	Test speeds start at 2 times the anemometer threshold, U_o , up to 0.5 times the maximum application speed, U_{max} , in the following ascending and descending speeds: <table border="0" style="width: 100%;"> <tr> <td style="text-align: center;"><u>Ascending Speeds</u></td> <td style="text-align: center;"><u>Descending Speeds</u></td> </tr> <tr> <td style="text-align: center;">2 times U_o</td> <td style="text-align: center;">0.5 times U_{max}</td> </tr> <tr> <td style="text-align: center;">3 times U_o</td> <td style="text-align: center;">0.4 times U_{max}</td> </tr> <tr> <td style="text-align: center;">4 times U_o</td> <td style="text-align: center;">0.3 times U_{max}</td> </tr> <tr> <td style="text-align: center;">5 times U_o</td> <td style="text-align: center;">0.2 times U_{max}</td> </tr> <tr> <td style="text-align: center;">6 times U_o</td> <td style="text-align: center;">0.1 times U_{max}</td> </tr> <tr> <td style="text-align: center;">0.1 times U_{max}</td> <td style="text-align: center;">6 times U_o</td> </tr> <tr> <td style="text-align: center;">0.2 times U_{max}</td> <td style="text-align: center;">5 times U_o</td> </tr> <tr> <td style="text-align: center;">0.3 times U_{max}</td> <td style="text-align: center;">4 times U_o</td> </tr> <tr> <td style="text-align: center;">0.4 times U_{max}</td> <td style="text-align: center;">3 times U_o</td> </tr> <tr> <td style="text-align: center;">0.5 times U_{max}</td> <td style="text-align: center;">2 times U_o</td> </tr> </table>	<u>Ascending Speeds</u>	<u>Descending Speeds</u>	2 times U_o	0.5 times U_{max}	3 times U_o	0.4 times U_{max}	4 times U_o	0.3 times U_{max}	5 times U_o	0.2 times U_{max}	6 times U_o	0.1 times U_{max}	0.1 times U_{max}	6 times U_o	0.2 times U_{max}	5 times U_o	0.3 times U_{max}	4 times U_o	0.4 times U_{max}	3 times U_o	0.5 times U_{max}	2 times U_o
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ISO 17713-1	Test speeds cover the range of intended use for the anemometer and the working range of the wind tunnel, which includes 5 points in the non-linear range of the anemometer (near threshold, U_o). Typical test protocols are as follows: <table border="0" style="width: 100%;"> <tr> <td style="text-align: center;">2 times U_o</td> <td style="text-align: center;">0.1 times U_{max}</td> <td style="text-align: center;">0.6 times U_{max}</td> </tr> <tr> <td style="text-align: center;">3 times U_o</td> <td style="text-align: center;">0.2 times U_{max}</td> <td style="text-align: center;">0.7 times U_{max}</td> </tr> <tr> <td style="text-align: center;">4 times U_o</td> <td style="text-align: center;">0.3 times U_{max}</td> <td style="text-align: center;">0.8 times U_{max}</td> </tr> <tr> <td style="text-align: center;">5 times U_o</td> <td style="text-align: center;">0.4 times U_{max}</td> <td style="text-align: center;">0.9 times U_{max}</td> </tr> <tr> <td style="text-align: center;">6 times U_o</td> <td style="text-align: center;">0.5 times U_{max}</td> <td style="text-align: center;">U_{max}</td> </tr> </table>	2 times U_o	0.1 times U_{max}	0.6 times U_{max}	3 times U_o	0.2 times U_{max}	0.7 times U_{max}	4 times U_o	0.3 times U_{max}	0.8 times U_{max}	5 times U_o	0.4 times U_{max}	0.9 times U_{max}	6 times U_o	0.5 times U_{max}	U_{max}							
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Standard	Wind Tunnel Test Protocol for Sonic Anemometers
ASTM D 6011-96	Step 1: With the sensor positioned vertically at zero angle of attack, select a low wind speed (about 2 m/s or lower) to test for orientations +/- 60 deg around its vertical axis at 10 deg increments. Repeat this procedure for a mid-range speed (about 5 to 6 m/s) and then for a high wind speed (about 10 m/s or greater). Step 2: Repeat Step 1 for angles of attack at 5 deg increments starting with the sensor tilted 15 deg into the wind to 15 deg tilted away from the wind.
ISO 16622	Step 1: With the sensor positioned vertically at zero angle of attack, select a low wind speed (about 10% of the maximum test speed) to test for orientation +/- 360 deg around its vertical axis at 5 deg increments. Repeat step for 18%, 32%, 56%, and 100% of the maximum test speed. Step 2: With the sensor positioned vertically at zero angle of attack and rotated at the worst case orientation (where the sensor reading is most disturbed by support structures), perform tests at 1%, 1.7%, 2.8%, 4.6%, 7.7%, 13%, 21%, 36%, 60%, and 100% of the maximum test speed. If such a wind speed range is not feasible for the wind tunnel lab, perform tests at 2%, 3%, 5%, 7%, 11%, 18%, 27%, 42%, 65%, and 100% of the maximum test speed. Repeat step for the best case orientation (where the sensor is least disturbed by support structures). Step 3: Repeat Steps 1 and 2 with the sensor tilted 15 into the wind and then 15 deg tilted away from the wind.