Summary report VT121243 - Version 1.1

Sonic Anemometer Classification

According to IEC 61400-12-1 Edition 2.0 (2017- 03) Classification Scheme

Description of Anemometer

Manufacturer: Adolf Thies GmbH & Co. KG
Hauptstrasse 76
37083 Göttingen

Identification: **Ultrasonic Anemometer 2D**

4.382X.XX.XX
SN 10125744;
SN 10125745;
SN 10125746;
SN 10125748;
SN 09137528

Dimension: Ø 424 mm x 287 mm
Mounting diameter: 48 mm

Reference:

Deutsche WindGuard Wind Tunnel Services GmbH
Measuring period: 2016 - 2017
Wind Tunnel: Deutsche WindGuard Wind Tunnel Services GmbH, Varel

Procedure:

The classification is based on a numerical calculation of the response of a sonic anemometer to fluctuating wind speeds. The chosen spectrum of the wind speed time series was a *Kaimal* spectrum for non-isotropic condition (turbulence length scale 350 m. The time series have been generated with a software tool provided by Risø - National Laboratory, Denmark. Other parameters which may influence the response of an anemometer in fluctuating wind conditions are:

- Off axis response for different tilt angles
- Different ambient temperatures and air pressure

All relevant parameters have been measured in various wind tunnels of Deutsche WindGuard Wind Tunnels Services GmbH which fulfils the requirements described in IEC 61400-12-1 Edition 2.0, Annex F. The influence of air temperature was measured using a specially designed variable air density wind tunnel.
The determination of the anemometer's response to quasi statically inclined/and or yawed air flow was performed with the help of an automatic tilt and yaw angle device installed in the wind tunnel. During the yaw measurements the tilt angle of the sonic was fixed for the following tilt angles: 0°, ±2°, ±5°, ±10°, ±15°, ±20°, ±30°. The yaw direction was continuously yawed with a sweep rate of about 0.2°/s. The measurements were performed for the wind speeds: 4 m/s, 8 m/s, 12 m/s, and 16 m/s. For each direction, the deviation of the indicated wind speed of the sonic anemometer from the ordinary calibration at the reference direction was derived.

Directional characteristic

Reference:

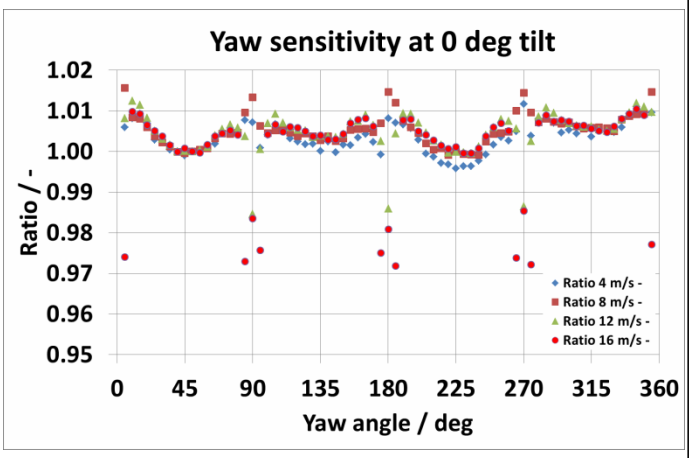
WindGuard quality system procedure for calibration of wind direction sensors: *D 5836*

Accredited according to IEC 17025

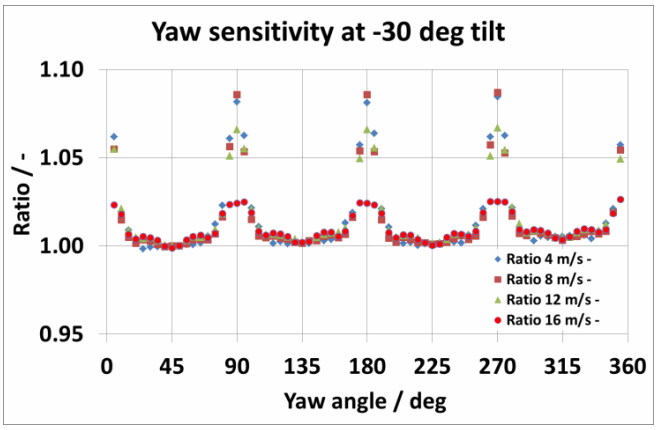
Result:

Figures showing the of axis response of Thies 2D Ultrasonic Anemometer 4.3820.30.340 (exemplary serial number 09137528).
The sensor was yawed for 0-400 deg and back to 0 deg at different tilt angles according to IEC.
The information presented show the bin averaged data for 5 deg bin's.

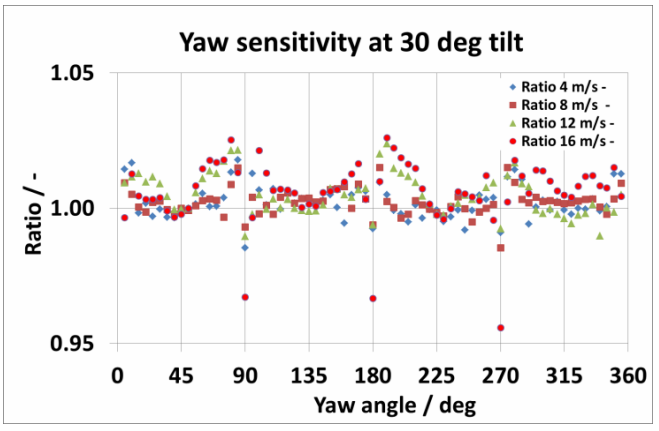
Five anemometers were tested. Each individual yaw sensitivity was used for classification.



Yaw sensitivity of SN 09137528 at 0 deg tilt;



Yaw sensitivity of SN 09137528 at – 30 deg tilt;



Yaw sensitivity of SN 09137528 at 30 deg tilt;

Air temperature induced effects

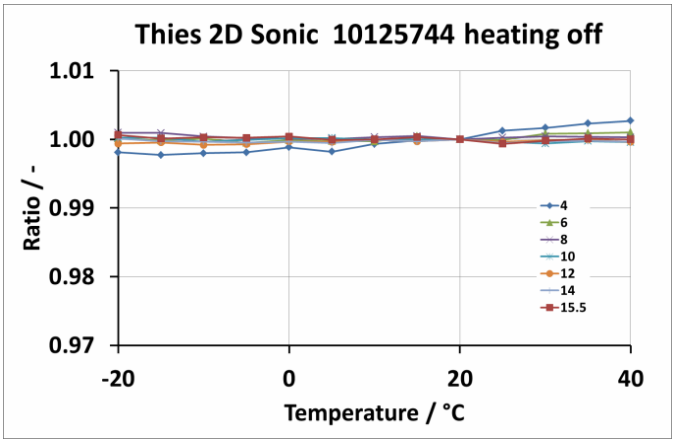
Reference:

WindGuard quality system procedure for calibration of wind speed sensors at variable air temperature *(in preparation).*

Result:

Figure showing the influence of air temperature on the anemometer behavior at tunnel speeds of 4, 6, 8, 10, 12, 14 and 15.5 m/s (exemplary serial number 10125744).
Internal heating OFF

Uncertainty in temperature: <1 K
Uncertainty in flow speed: < 0.1 m/s



Five 2D Sonic anemometers were tested. As there is only a very small variation due to temperature in all sonic's visible the influence of temperature was not taken into account for classification.

Air temperature induced effects

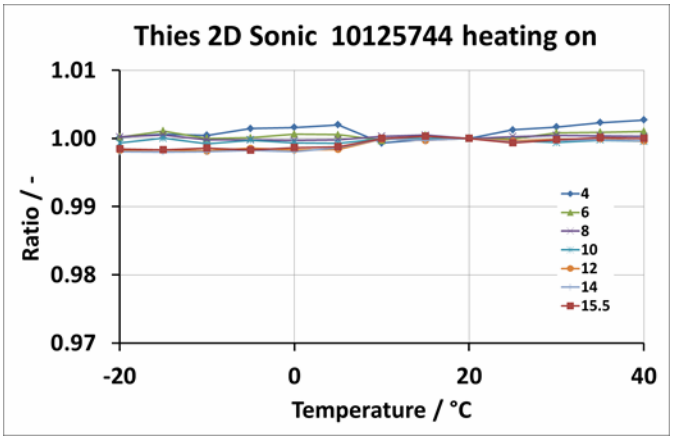
Reference:

WindGuard quality system procedure for calibration of wind speed sensors at variable air temperature *(in preparation).*

Result:

Figure showing the influence of air temperature on the anemometer behavior at tunnel speeds of 4, 6, 8, 10, 12, 14 and 15.5 m/s (exemplary serial number 10125744).
Internal heating ON

Uncertainty in temperature: <1 K
Uncertainty in flow speed: < 0.1 m/s



Five 2D Sonic anemometers were tested. As there is only a very small variation due to temperature in all sonic's visible the influence of temperature was not taken into account for classification.

Tilt angular response

Reference:

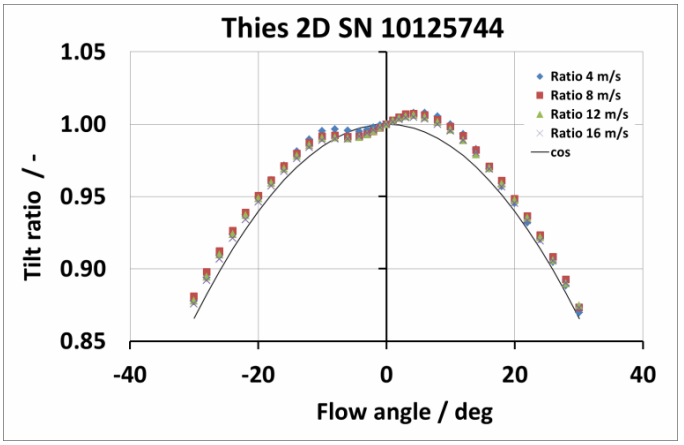
IEC 61400-12-1 Edition 2.0
Wind Turbine Power Performance Testing 2017-03

WindGuard quality system procedure for calibration of wind speed sensors at non-horizontal inflow conditions: *D 5832*

Accredited according to IEC 17025

Result:

Figure showing the of axis response of Thies 2D Ultrasonic Anemometer 4.3820.30.340 (exemplary for serial number 10125744), for tunnel speeds of 4 m/s, 8 m/s, 12 m/s and 16 m/s.



Five anemometers have been tested. Each individual tilt data was used for classification check.

Classification parameters

	Class A Terrain meets requirements in Annex B	Class B Terrain not meet requirements in Annex B	Class C Terrain meets requirements in Annex B	Class D Terrain meets requirements in Annex B	Class S Special Class with user defined range
	Range	Range	Range	Range	Range
Wind speed V (m/s)	4 to 16	4 to 16	4 to 16	4 to 16	4 to 16
Turbulence intensity	0.03 to 0.12 + 0.48/V	0.03 to 0.12 + 0.96/V	0.03 to 0.12 + 0.48/V	0.03 to 0.12 + 0.96V	0.03 to 0.12 + 0.96/V
Turbulence structure $\sigma_U/\sigma_V/\sigma_W$	1/0.8/0.5*	1/0.8/0.5*	1/0.8/0.5*	1/0.8/0.5*	1/0.8/0.5*
Air Temperature (°C)	0 to 40	-10 to 40	-20 to 40	-20 to 40	-20 to 40
Air density (kg/m³)	0.9 to 1.35	0.9 to 1.35	0.9 to 1.35	0.9 to 1.35	1.05 to 1.35
Average upflow angle (°)	-3 to 3	-15 to 15	-3 to 3	-15 to 15	-15 to -5
Wind direction (°)	0 to 360	0 to 360	0 to 360	0 to 360	15 to 75 105 to 165 195 to 255 285 to 245
* a non-isotropic Kaimal turbulence spectrum with turbulence length scale 350 m.					

Table 1 Classification parameters according to IEC 61400-12-1 Edition 2.0 2017-03 used for classification

Class A/C Classification

Reference:

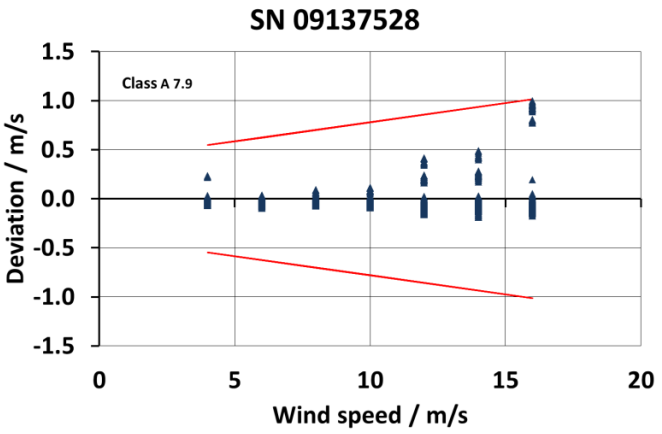
IEC 61400-12-1 Edition 2.0
Wind Turbine Power Performance Testing 2017-03

Result:

Figure showing the calculated total deviation of the Thies 2 D Sonic anemometer type 4.3820.30.240, taking into account all influencing parameters according to **Class A** definition.

Internal shaft heating: ON / OFF

Classification index: A/C 8.1
(average of five sensors)



As there is only a very small variation due to temperature in sonic's visible the influence of temperature was not taken into account for classification. Therefore **Class C** is assumed to be identical to **Class A**

Class B/D Classification

Reference:

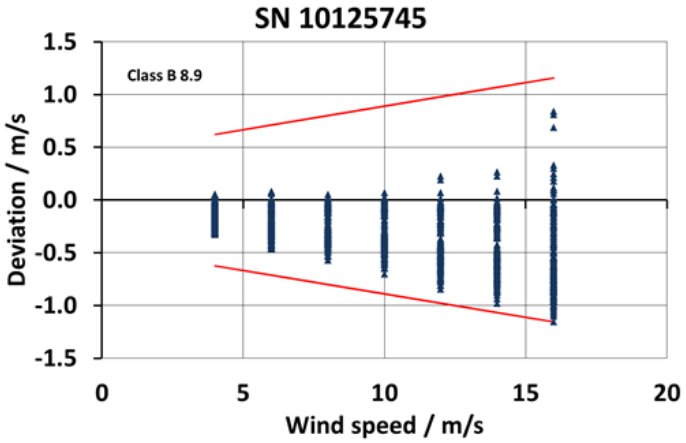
IEC 61400-12-1 Edition 2.0
Wind Turbine Power Performance Testing 2017-03

Result:

Figure showing the calculated total deviation of the Thies 2 D Sonic anemometer type 4.3820.30.240 taking into account all influencing parameters according to **Class B** definition.

Internal shaft heating ON / OFF

Classification index: B/D 8.1
(average of five sensors)



As there is only a very small variation due to temperature in sonic's visible the influence of temperature was not taken into account for classification. Therefore **Class D** is assumed to be identical to **Class B**

Class S Classification

Reference:

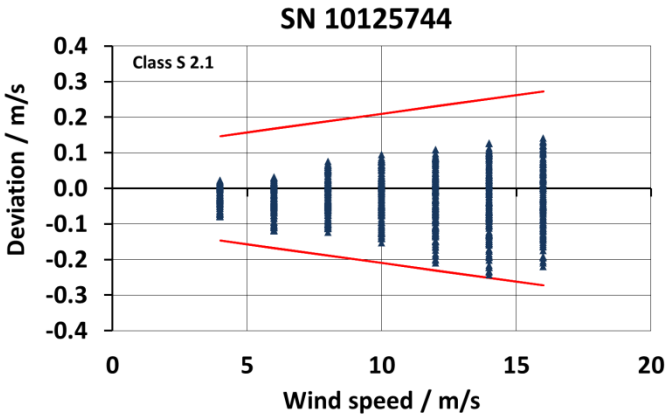
IEC 61400-12-1 Edition 2.0
Wind Turbine Power Performance Testing 2017-03

Result:

Figure showing the calculated total deviation of the Thies 2D Sonic anemometer type 4.3820.30.240 taking into account all influencing parameters according to **Class S** definition.

Internal shaft heating ON / OFF

Classification index: S 2.1
(average of five sensors)



The **Class S** calculation was done with excluding the flow direction data passing the four sensor heads +- 15 deg

Results presented in this report are valid for the item tested only.

Deutsche WindGuard *Wind Tunnel Services GmbH*
Oldenburger Str. 65, 26316 Varel
Tel. #49 (0)4451 9515 0; Fax: #49 (0) 4451 9515 29
e-mail d.westermann@windguard.de, www.windguard.de

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Deutsche WindGuard
Wind Tunnel Services GmbH
Oldenburger Straße 65
D-26316 Varel
Tel.: 04451 / 95 15 - 0 · Fax: 95 15 - 29

Dipl. Phys. Dieter Westermann