

## Summary report AK151023-1.3

# Cup Anemometer Classification

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

Description of Anemometer	
<b>Manufacturer:</b>	Adolf Thies GmbH&Co.KG Hauptstrasse 76 37083 Göttingen
<b>Identification:</b>	<b>First Class Advanced II</b> 4.3352.00.000; 4.3352.10.000 SN: 0113001; 0113002;0113003;0113004;0113005
<b>Dimension:</b>	
Body diameter: 50 mm	Body length: 95 mm
Total length: 290 mm	Shaft diameter: 18 mm
Top: 38 mm	
Rotor diameter: 240 mm	Cup diameter: 80 mm
Cup tilt angle: 2.5 deg	Flaps (approx): 28 x 31 mm



### Reference:

Deutsche WindGuard Wind Tunnel Services GmbH  
 Measuring period: 04.2014 – 05.2017  
 Test site: Varel, Germany  
 Wind Tunnel: Deutsche WindGuard Wind Tunnel Services GmbH, Varel

### Procedure:

The classification is based on numerical integration of the differential equation which describes the response of a cup 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 influence the response of an anemometer in fluctuating wind conditions are:

- Off axis response for different tilt angles
- Friction changes in bearings due different ambient temperatures and air pressure
- Driving and braking torque of the cups during rotation
- Inertia of the rotor
- Air density

All relevant parameters have been measured in various wind tunnels of Deutsche WindGuard Wind Tunnels Services GmbH. The driving and braking forces used in the numerical model have been derived from the measured step response (step up and step down test) of the tested anemometer according to IEC 61400-12-1 Edition 2.0. The direct influence of air density was measured using a specially designed variable air density wind tunnel, instead of calculating the influence of the air density by using torque measurements.

In addition, results of the field comparison are presented in this summary.

Summary report of cup anemometer classification

**Tilt angular response**

**Reference:**

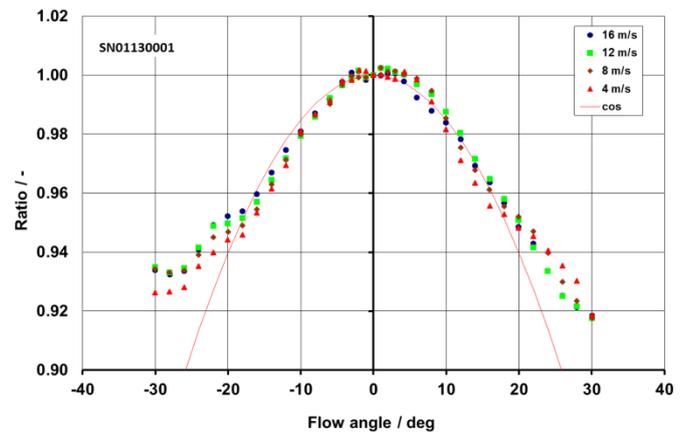
IEC 61400-12-1 Edition 2.0  
Wind Turbine Power Performance Testing  
2017-03

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  
First Class advanced anemometer type  
4.3352.00.000 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 have been used for classification

Tested anemometer:

- SN 01130001
- SN 01130002
- SN 01130003
- SN 01130004
- SN 01130005

**Step response**

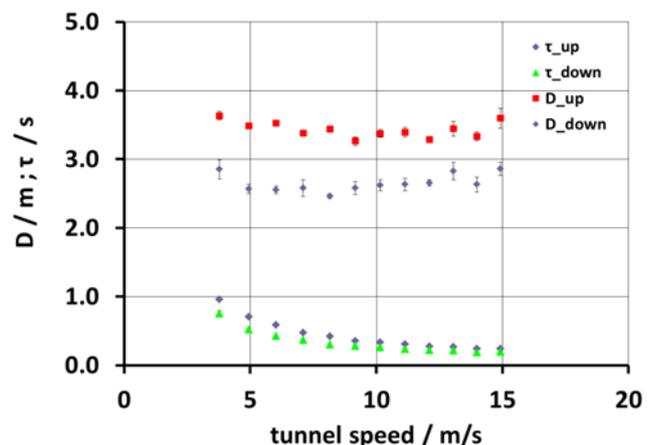
**Reference:**

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

**Result:**

Figure showing the step up und step down  
time constants "τ" of Thies First Class  
Advanced anemometer type 4.3352.00.000 for  
different wind tunnel speeds. The calculated  
distance constant "D" for step up is 2.6 m and  
3.5 m for step down.

Uncertainty: 0.1 m



Tested anemometer:

- SN 01130001
- SN 01130002
- SN 01130003
- SN 01130004
- SN 01130005

Summary report of cup anemometer classification

**Directional characteristic**

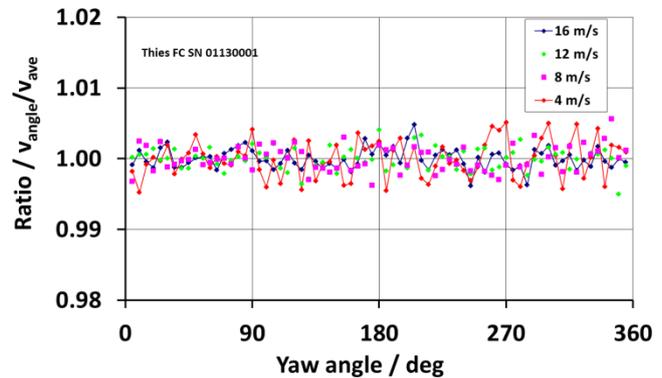
**Reference:**

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

Accredited according to IEC 17025

**Result:**

Figure showing the yaw sensitivity of the Thies First Class Advanced anemometer type 4.3352.00.000. The sensor was yawed for 0-400 deg and back to 0 deg. The information presented show the bin averaged data for 5 deg bin's. The variation is due to statistical scatter.



Tested anemometer:  
SN 01130001

**Air temperature induced effects**

**Reference:**

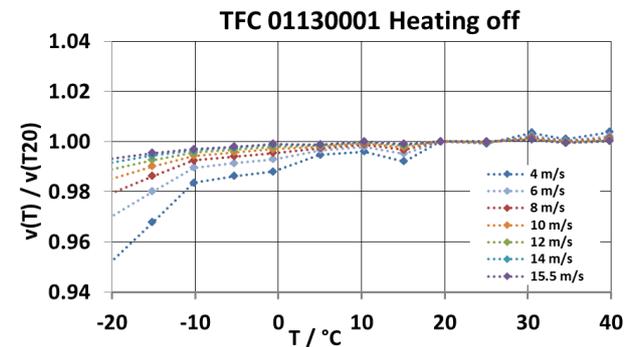
WindGuard quality system procedure for calibration of wind speed sensors at variable air temperature (in preparation).

**Result:**

Figure showing the influence of air density on the anemometer behaviour at tunnel speeds of 4, 6, 8, 10, 12, 14 and 15.5 m/s. Thies First Class Advanced anemometer type 4.3352.00.000.

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

Internal shaft heating OFF



Five anemometers have been tested. Each individual temperature-ratio data have been used for classification

Tested anemometer:

- SN 01130001
- SN 01130002
- SN 01130003
- SN 01130004
- SN 01130005

Summary report of cup anemometer classification

**Air temperature induced effects**

**Reference:**

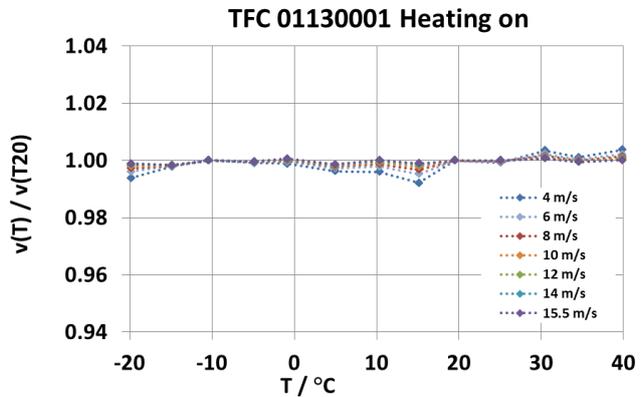
WindGuard quality system procedure for calibration of wind speed sensors at variable air temperature (in preparation).

**Result:**

Figure showing the influence of air density on the anemometer behaviour at tunnel speeds of 4, 6, 8, 10, 12, 14 and 15.5 m/s.  
Thies First Class Advanced anemometer type 4.3352.00.000.

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

Internal shaft heating ON



Five anemometers have been tested. Each individual temperature-ratio data have been used for classification

Tested anemometer:

- SN 01130001
- SN 01130002
- SN 01130003
- SN 01130004
- SN 01130005

**Air density induced effects**

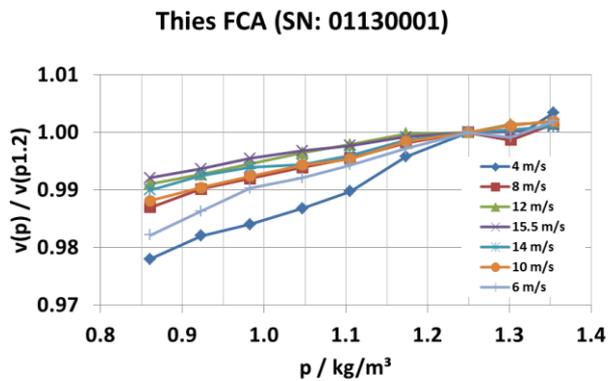
**Reference:**

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

**Result:**

Figure showing the influence of air density on the anemometer behaviour at tunnel speed of 4, 6, 8, 10,12, 14 and 15.5 m/s.  
Thies First Class Advanced anemometer type 4.3352.00.000.

Uncertainty in temperature: <1 K  
Uncertainty in air pressure : < 2 hPa  
Uncertainty in flow speed: < 0.1 m/s



Five anemometers have been tested. Each individual air density-ratio data have been used for classification

Tested anemometer:

- SN 01130001
- SN 01130002
- SN 01130003
- SN 01130004
- SN 01130005

**Classification parameters**

	<b>Class A</b> Terrain meets requirements in Annex B	<b>Class B</b> Terrain does not meet requirements in Annex B	<b>Class C</b> Terrain meets requirements in Annex B	<b>Class D</b> Terrain does not meet requirements in Annex B	<b>Class S<sup>34</sup></b> Special class with user defined ranges
	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 + 0,96/V	<b>0,03 to 0,12 + 0,96/V</b>
Turbulence <sup>35</sup> 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*	<b>1/0,8/0,5</b>
Air temperature (°C)	0 to 40	-10 to 40	-20 to 40	-20 to 40	<b>-20 to 40</b>
Air density (kg/m <sup>3</sup> )	0,9 to 1,35	0,9 to 1,35	0,9 to 1,35	0,9 to 1,35	<b>1,05 to 1,35</b>
Average upflow angle (°)	-3 to 3	-15 to 15	-3 to 3	-15 to 15	<b>-15 to 15</b>
Wind direction (°) <sup>36</sup>	Cups and sonics: 0° to 360°	Cups and sonics: 0° to 360°	Cups and sonics: 0° to 360°	Cups and sonics: 0° to 360°	Cups: 0° to 360° Sonics: user defined

\* 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

Summary report of cup anemometer classification

**Class A Classification**

**Reference:**

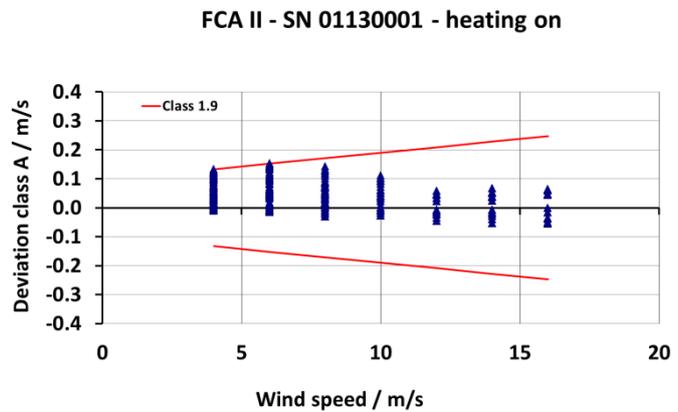
IEC 61400-12-1 Edition 2.0  
Wind Turbine Power Performance Testing  
2017-03

**Result:**

Figure showing the calculated total deviation of the Thies First Class Advanced anemometer type 4.3352.00.000 taking into account all influencing parameters according to Class A definition.

Internal shaft heating: ON

**Classification index: A 1.8**  
(average of five sensors)



**Class A Classification**

**Reference:**

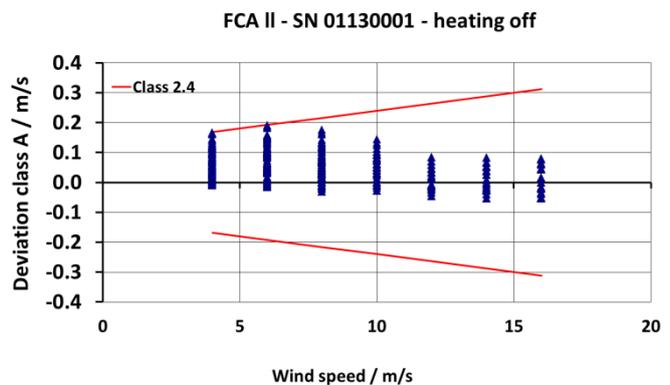
IEC 61400-12-1 Edition 2.0  
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2017-03

**Result:**

Figure showing the calculated total deviation of the Thies First Class Advanced anemometer type 4.3352.00.000 taking into account all influencing parameters according to Class A definition.

Internal shaft heating: OFF

**Classification index: A 2.3**  
(average of five sensors)



Summary report of cup anemometer classification

**Class B Classification**

**Reference:**

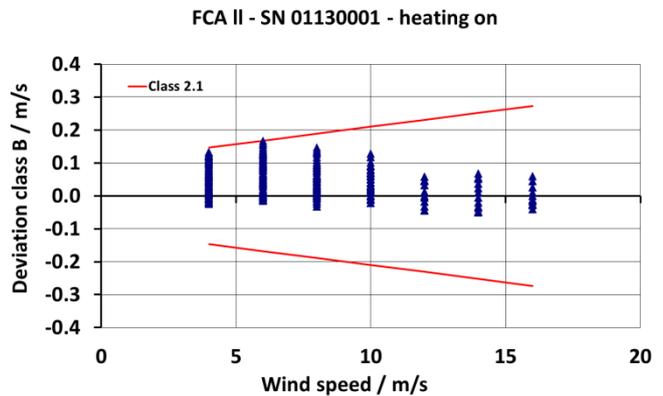
IEC 61400-12-1 Edition 2.0  
Wind Turbine Power Performance Testing  
2017-03

**Result:**

Figure showing the calculated total deviation of the Thies First Class Advanced anemometer type 4.3352.00.000 taking into account all influencing parameters according to Class B definition.

Internal shaft heating ON

**Classification index: B 2.0**  
(average of five sensors )



**Class B Classification**

**Reference:**

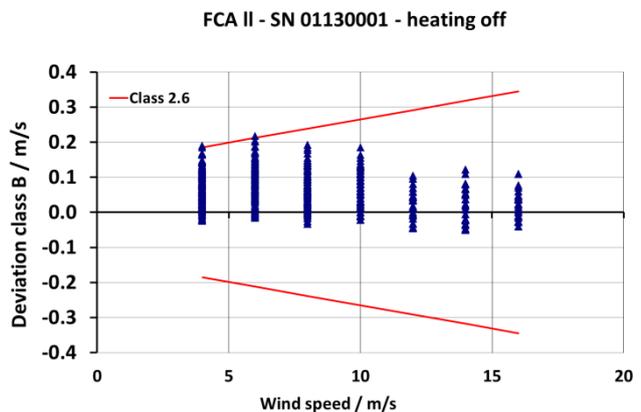
IEC 61400-12-1 Edition 2.0  
Wind Turbine Power Performance Testing  
2017-03

**Result:**

Figure showing the calculated total deviation of the Thies First Class Advanced anemometer type 4.3352.00.000 taking into account all influencing parameters according to Class B definition.

Internal shaft heating OFF

**Classification index: B 2.7**  
(average of five sensors) :



Summary report of cup anemometer classification

**Class C Classification**

**Reference:**

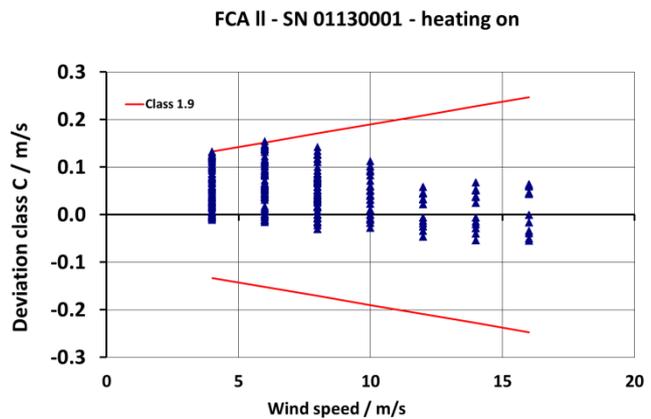
IEC 61400-12-1 Edition 2.0  
Wind Turbine Power Performance Testing  
2017-03

**Result:**

Figure showing the calculated total deviation of the Thies First Class Advanced anemometer type 4.3352.00.000 taking into account all influencing parameters according to Class C definition.

Internal shaft heating ON

**Classification index: C 1.8**  
(average of five sensors )



**Class C Classification**

**Reference:**

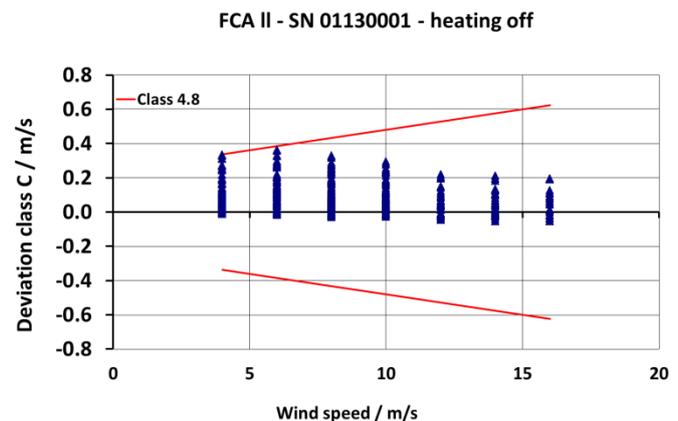
IEC 61400-12-1 Edition 2.0  
Wind Turbine Power Performance Testing  
2017-03

**Result:**

Figure showing the calculated total deviation of the Thies First Class Advanced anemometer type 4.3352.00.000 taking into account all influencing parameters according to Class C definition.

Internal shaft heating OFF

**Classification index C 4.4**  
(average of five sensors ) :



Summary report of cup anemometer classification

**Class D Classification**

**Reference:**

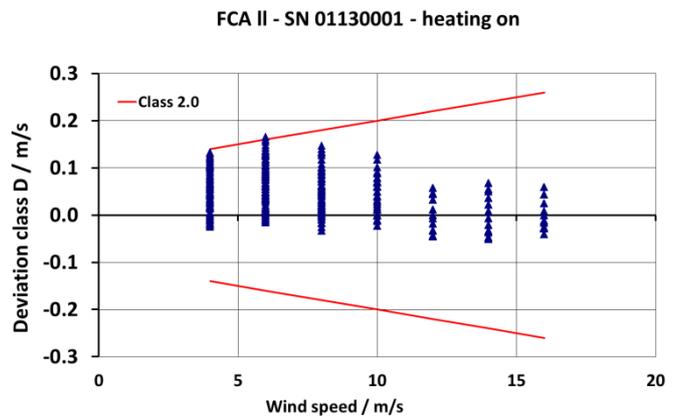
IEC 61400-12-1 Edition 2.0  
Wind Turbine Power Performance Testing  
2017-03

**Result:**

Figure showing the calculated total deviation of the Thies First Class Advanced anemometer type 4.3352.00.000 taking into account all influencing parameters according to Class D definition.

Internal shaft heating ON

**Classification index: D 2.0**  
(average of five sensors)



**Class D Classification**

**Reference:**

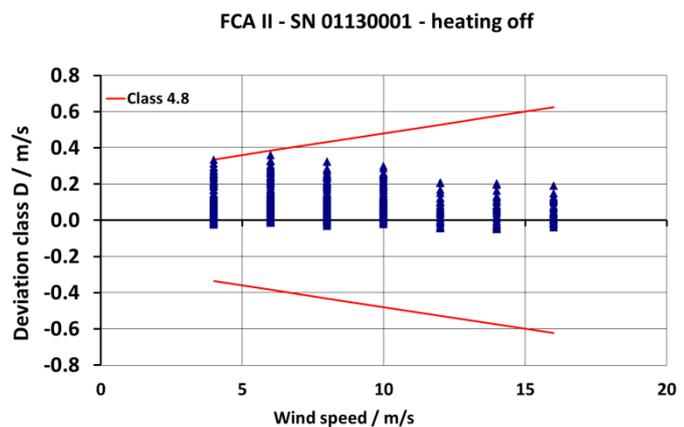
IEC 61400-12-1 Edition 2.0  
Wind Turbine Power Performance Testing  
2017-03

**Result:**

Figure showing the calculated total deviation of the Thies First Class Advanced anemometer type 4.3352.00.000 taking into account all influencing parameters according to Class D definition.

Internal shaft heating OFF

**Classification index: D 4.6**  
(average of five sensors)



Summary report of cup anemometer classification

**Class S Classification**

**Reference:**

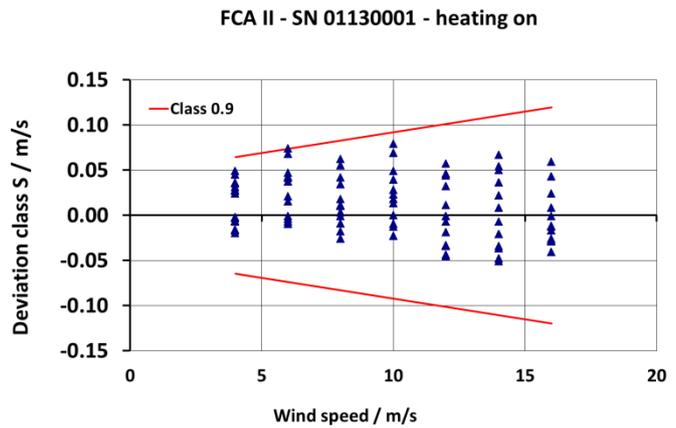
IEC 61400-12-1 Edition 2.0  
Wind Turbine Power Performance Testing  
2017-03

**Result:**

Figure showing the calculated total deviation of the Thies First Class Advanced anemometer type 4.3352.00.000 taking into account all influencing parameters according to Class S definition.

Internal shaft heating ON

**Classification index: S 0.9**  
(average of five sensors)



**Class S Classification**

**Reference:**

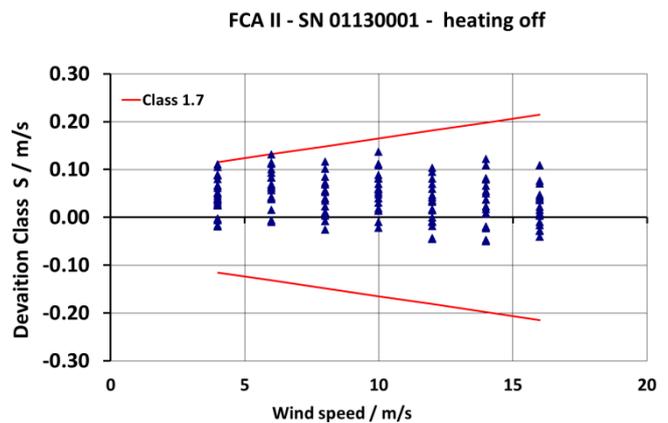
IEC 61400-12-1 Edition 2.0  
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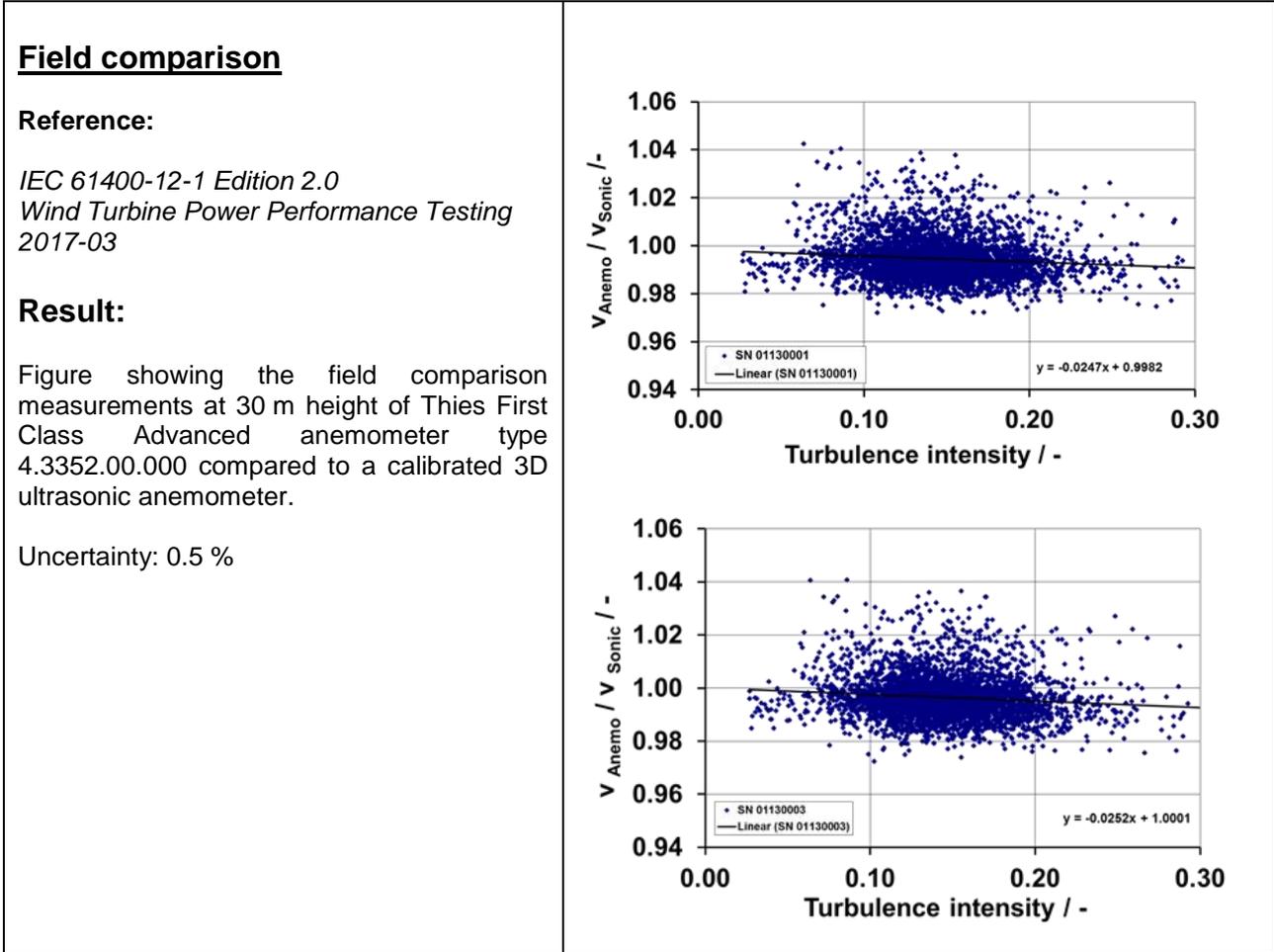
**Result:**

Figure showing the calculated total deviation of the Thies First Class Advanced anemometer type 4.3352.00.000 taking into account all influencing parameters according to Class S definition.

Internal shaft heating OFF

**Classification index: S 1.7**  
(average of five sensors)





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

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Varel, 2017 - 09 - 18

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