Summary of

Cup Anemometer Classification

According to IEC 61400-12-1 (2005-12) Classification Scheme

Description of Anemometer

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

Identification: 4.3351.00.000; SN.0806002

4.3351.00.000; SN 0806005

Thies First Class Advanced

Dimension:

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:	3.5 deg;	Flaps (approx):	28 x 31 mm

Reference:

Deutsche WindGuard Wind Tunnel Services GmbH AK 08 1662.01
Measuring period: 09.2007 – 05.2008
Test site: Varel, Germany
Wind Tunnel: Deutsche WindGuard 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 spectra of the wind speed time series was a *Kaimal* spectrum for non-isotropic condition (for Class A classification) and a *von Karman* spectrum for isotropic conditions (for class B classification). 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:

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

All relevant parameters have been measured in the wind tunnel of Deutsche WindGuard GmbH. The driving and braking forces used in the numerical model have been derived from the measured step response of the tested anemometer and a cup torque model.

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

Off Axis Response

According to:

WindGuard Calibration Procedure 04/2008

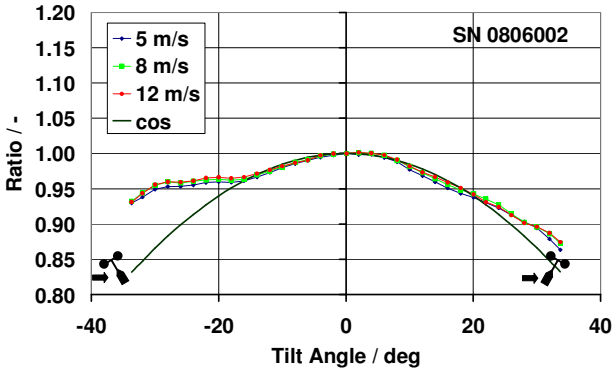
IEC 61400-12-1
Wind Turbine Power Performance Testing
2005-12

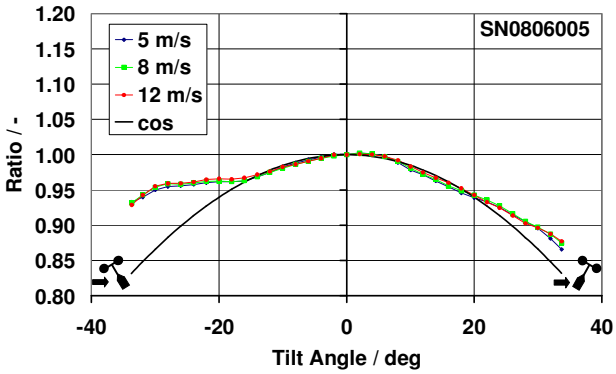
ISO 17713-1
Wind tunnel test methods for rotating anemometer performance
2007-05

Result:

Figures showing the of axis response of Thies First Class for tunnel speed of 5 m/s, 8 m/s and 12 m/s.
Average deviation to cosine response 0.1 percent in the range of ± 16 degree.

Uncertainty in angle measurement : 0.2 deg
Uncertainty in zero tilt angle < 0.1 deg
Uncertainty due to wind tunnel < 0.1 m/s





Bearing Friction

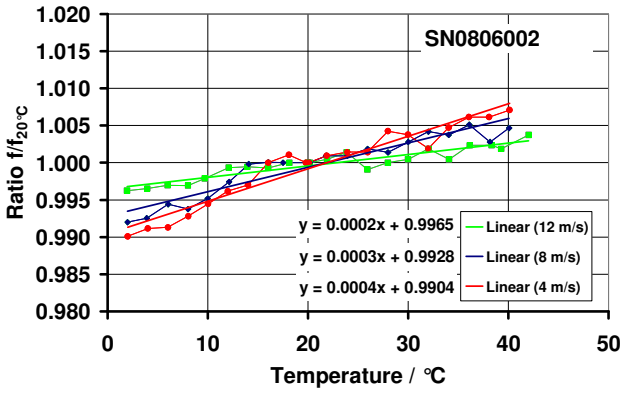
Reference:

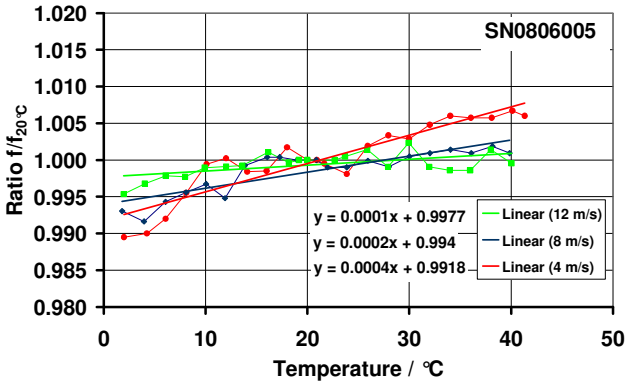
WindGuard AK081662.01

Result:

Figures showing the influence of temperature on the friction of bearings at tunnel speed of 4, 8 and 12 m/s.
The measurements have been stopped at temperatures below 1 °C because of icing. For classification purpose, the response curve has been extrapolated to 0 °C for class A classification and to
-10 °C for class B classification.

Uncertainty in temperature measurement : <2 deg
Uncertainty due to wind tunnel: < 0.2 m/s
Uncertainty due to linear fit (rsd): 0.4 %





Class A Classification

According to:

IEC 61400-12-1
Wind Turbine Power Performance Testing
2005-12

ACCUWIND – Method for Classification of Cup Anemometers
Risø-R-1555

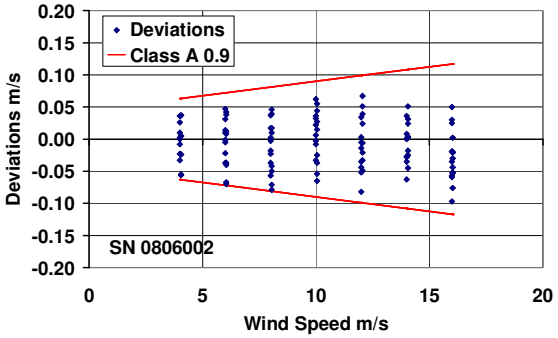
Influence parameter range:

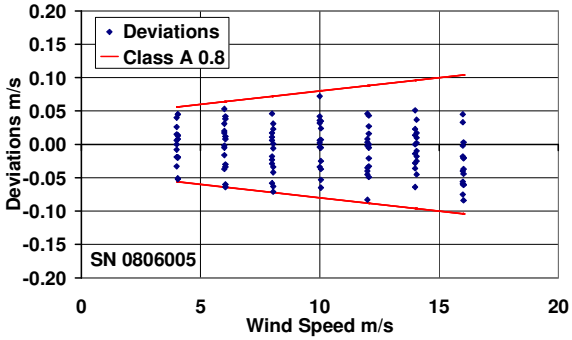
Wind speed range:	V = 4 m/s – 16 m/s
Turbulence intensity range:	0.03 – 0.12+0.48/V
Turbulence structure:	1.0/0.8/0.5
Air temperature:	0°C – +40°C
Air density:	0.8 – 1.3 kg/m³
Flow angle:	-3 deg – 3 deg
Wind simulation:	Kaimal wind spectrum with longitudinal turbulence length scale of 350 m

Result:

Figures showing the calculated total measurement error of the Thies First Class Advanced anemometer taking into account all influencing parameters. Negative sign: underestimation of wind speed.

Classification index : **A 0.9**





Class B Classification

According to:
IEC 61400-12-1
Wind Turbine Power Performance Testing
2005-12

ACCUWIND – Method for Classification of Cup Anemometers
Riso-R-1555

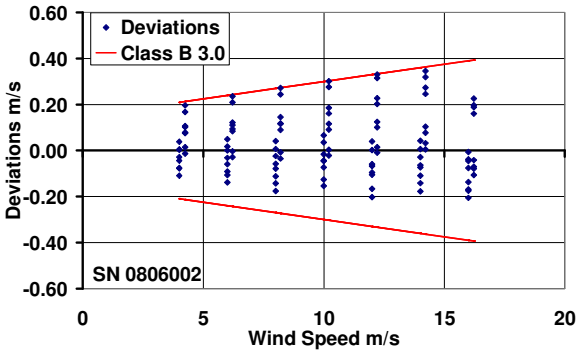
Influence parameter range:

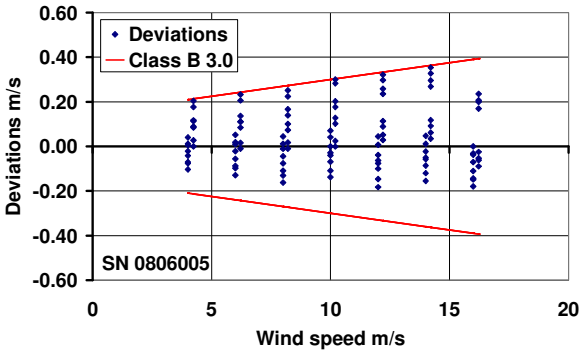
Wind speed range:	V = 4 m/s – 16 m/s
Turbulence intensity range:	0.03 – 0.12+0.96/V
Turbulence structure:	1.0/1.0/1.0
Air temperature:	-10°C – +40°C
Air density:	0.8 – 1.3 kg/m³
Flow angle:	-15 deg – 15 deg
Wind simulation:	Karman wind spectrum with longitudinal turbulence length scale of 170 m

Result:

Figures showing the calculated total measurement error of the Thies First Class Advanced anemometer taking into account all influencing parameters. Negative sign: underestimation of wind speed.

Classification index : **B 3.0**





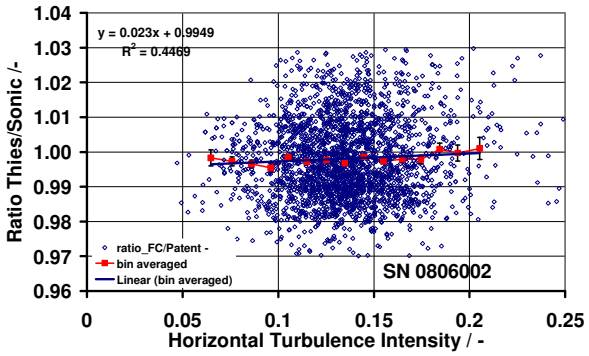
Field comparison

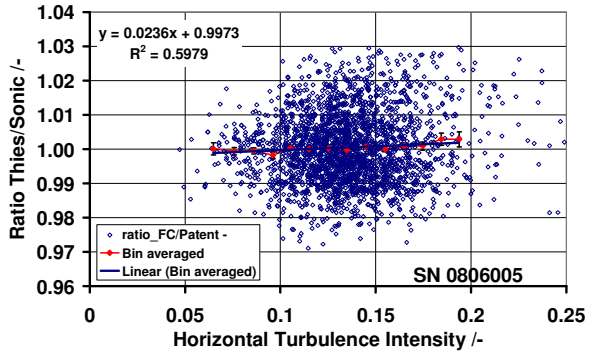
According to:
IEC 61400-12-1
Wind Turbine Power Performance Testing
2005-12

Result:

Figures showing the field comparison measurements at 30 m height of Thies First Class Advanced compared to a calibrated ultra sonic anemometer.

Uncertainty: 0.5 %





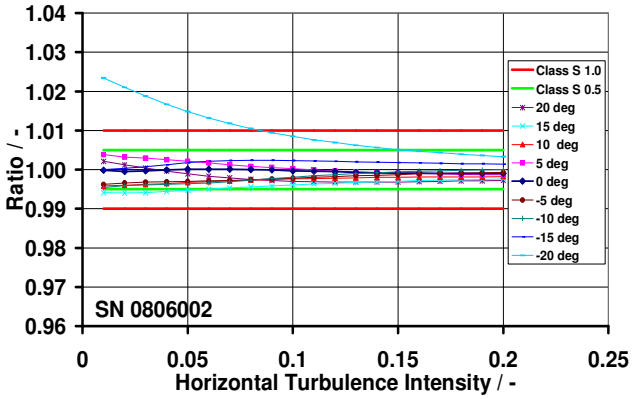
S Classification

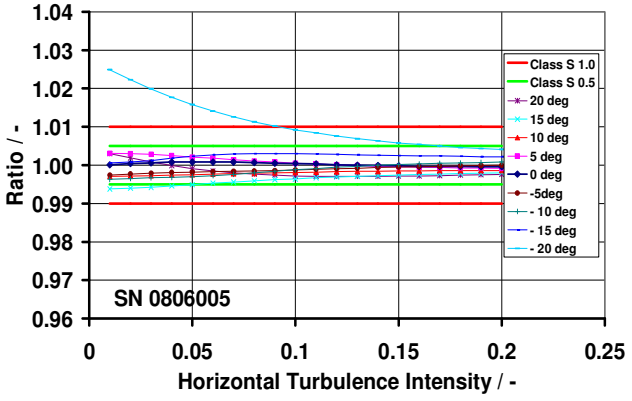
According to:
IEC 61400-12-1
Wind Turbine Power Performance Testing
2005-12

Result:

Figures showing the angular characteristics of the Thies First Class Advanced anemometer for different mean flow angles in turbulent airflow.

Class S 0.5 for flow inclination angles up to 15 deg.
(no friction and dynamic effects)



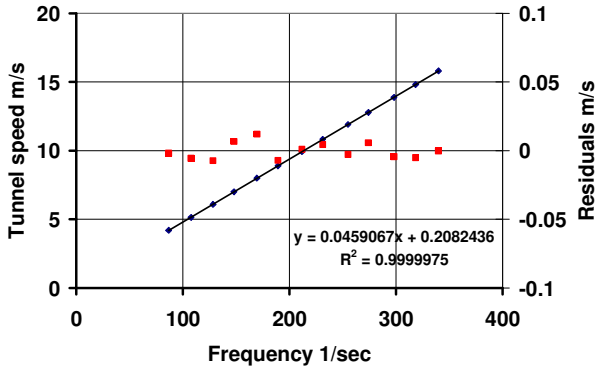


Linearity

According to:

WindGuard Calibration Procedure 04/2008

IEC 61400-12-1
Wind Turbine Power Performance Testing
2005-12



Result:

Calibration average of 5 different anemometers Thies First Class Advanced.
Slope: 0.0459 m
Offset: 0.21 m/s
Correlation: 0.999995
Uncertainty (K=2): 0.06 m/s
Remark:
The results do not replace an individual calibration.

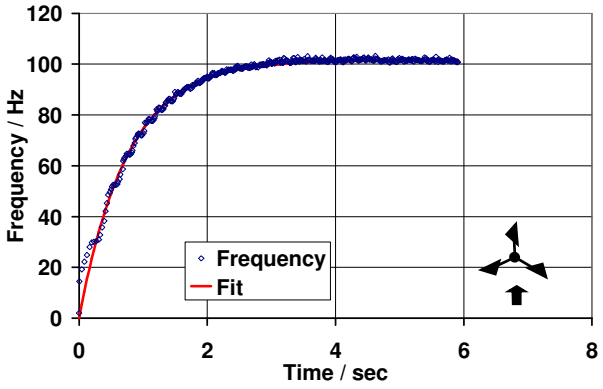
Distance Constant

According to:
ISO 17713-1
Wind tunnel test methods for rotating anemometer performance
2007-05

Result:

Figure showing the time constant of Thies First Class Advanced 0806005 for tunnel speed of 5 m/s. The calculated distance constant is 3.0 m to 3.9 m (depending on starting angle) for both probes.

Uncertainty: 0.1 m



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