SUMMARY OF CUP ANEMOMETER CLASSIFICATION
Make and type: WindSensor P2546A-OPR & P2546C-OPR & P2546D-OPR

Reference procedure: IEC 61400-12-1:2005
Power performance measurements of electricity producing wind turbines

Classification result

WindSensor P2546A-OPR Serial Number	Class A	Class B
16264	1.30	3.63
16501	1.34	3.78
Average and final class index, *k*	**1.32**	**3.71**

Currently, three versions of the WindSensor P2546-OPR anemometer are available:

- P2546A-OPR with digital output switching and two pulses per revolution
- P2546C-OPR with sinusoidal output signal and two periods per revolution
- P2546D-OPR with digital output switching and two pulses per revolution

As required by IEC 61400-12-1:2005 two samples of the P2546A-OPR anemometer have been classified with the classification result indicated above according to the procedure described below.
Due to identical geometry and construction except for the internal signal detection, and due to verified similarity in design, materials and calibrations this classification is also valid for P2546C-OPR and P2546D-OPR.

Basic cup anemometer data

Rotor diameter:	188 mm
Cup diameter:	70 mm (conical)
Cup area	0.00385 m^2
Height of cup anemometer:	282 mm

Overview of classification

Danish Technical University (DTU) Wind Energy Department has classified the WindSensor P2546A-OPR anemometer in compliance with the procedures outlined in IEC 61400-12-1:2005 Annex I. All measurements were carried out by Svend Ole Hansen ApS, a laboratory accredited according to ISO 17025 to perform flow calibration and a member of MEASNET. The measurements were reported in the document: *Characterisation and Classification of the WindSensor P2546A-OPR and P2546C-OPR Cup Anemometers*, Revision 0, March 2014.
All wind tunnel and laboratory measurements comply with the requirements set forth in IEC 61400-12-1:2005 annex J.
Classification results obtained by DTU are identical to classification results obtained by Svend Ole Hansen ApS.

Technical University of Denmark
Department of Wind Energy
Frederiksborgvej 399
Building 118
4000 Roskilde
Denmark
Tel 45 46 77 50 85
Dir. 45 2133 0042
www.vindenergi.dtu.dk

Classification procedure

The classification procedure complies with the requirements set forth in IEC 61400-12-1:2005 Annex I describing the two class categories A and B. Table 1 specifies the ranges of the relevant influence parameters and Table 2 lists the measurement procedures.

Table 1. Input parameter ranges of Class A and B

Classification category	Class A Terrain meets requirements in IEC 61400-12-1:2005 Annex B		Class B Terrain does not meet requirements IEC 61400-12-1:2005 Annex B	
	Min	Max	Min	Max
Wind speed range [m/s]	4	16	4	16
Turbulence Intensity	0.03	0.12 + 0.48/V	0.03	0.12 + 0.96/V
Turbulence Structure $\sigma_u/\sigma_v/\sigma_w$	1/0.8/0.5 Non-isotropic turbulence. Kaimal wind spectrum with a longitudinal turbulence length scale of 350 m		1/1/1 Isotropic turbulence. Von Karman wind spectrum with a longitudinal turbulence length scale of 350 m	
Air Temperature [°C]	0	40	-10	40
Air Density [kg/m]	0.9	1.35	0.9	1.35
Average flow inclination [°]	-3	3	-15	15

Table 2. Measurement procedures

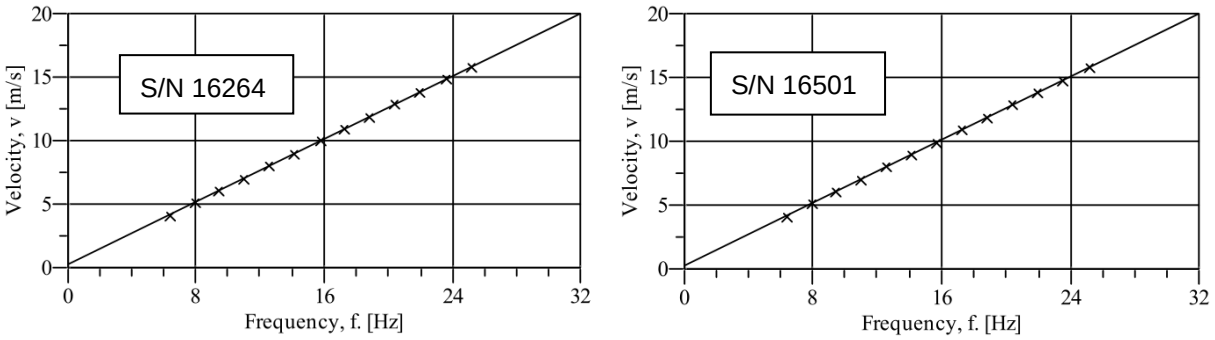
Measurement	Procedure
Calibration	IEC 61400-12-1:2005 Annex F
Angular response characteristics	IEC 61400-12-1:2005 Annex J.2.1
Torque coefficient measurements	IEC 61400-12-1 Annex J.2.4 *)
Bearing friction	IEC 61400-12-1:2005 Annex J.2.3
Rotor inertia	IEC 61400-12-1 Annex J.2.3 *)**)
Calculation of systematic deviations	IEC 61400-12-1:2005 Annex J.4.3
Calculation of classification indices	IEC 61400-12-1:2005 Annex I.2

*) IEC document 88_460e_CD IEC 61400-12-1 (draft document of IEC61400-12-1 Ed. 2)

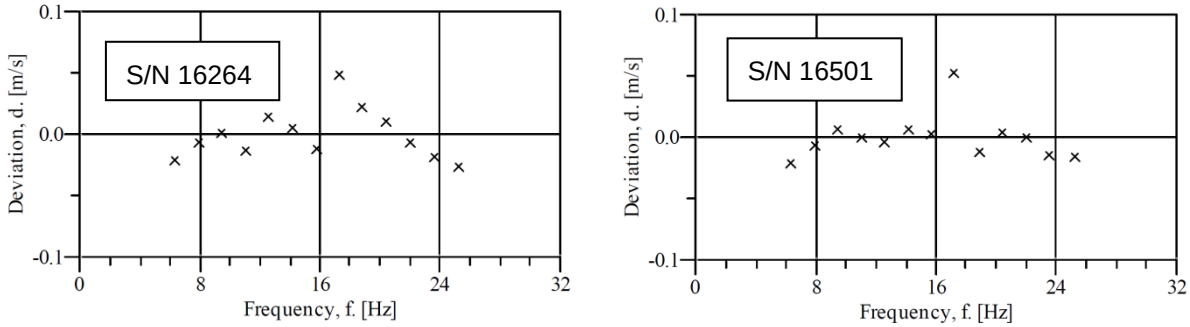
**) Detailed procedure in report Risø-R-1364

Standard wind tunnel calibration

WindSensor P2546A-OPR Serial Number	Slope [m]	Offset [m/s]	Correlation
16264	0.61950	0.2062	0.999986
16501	0.61948	0.2157	0.999988

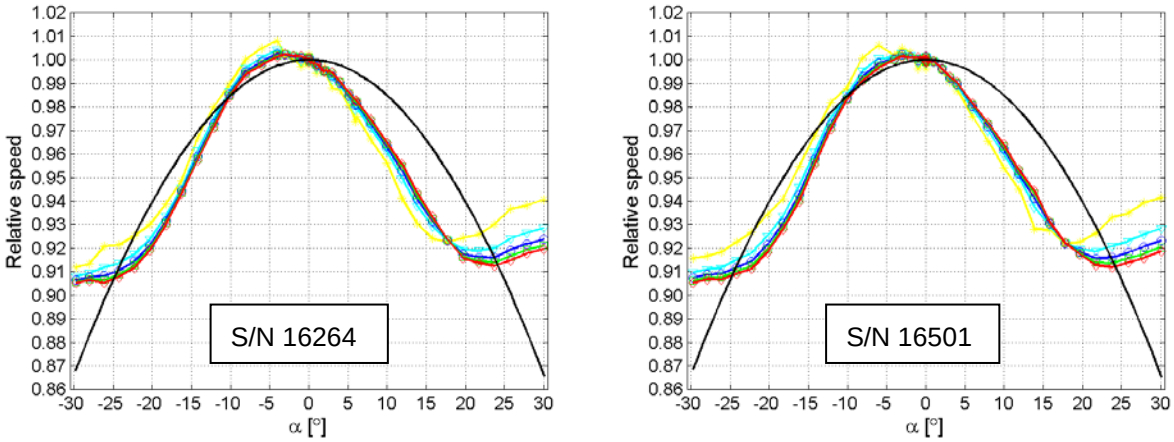


Calibration results



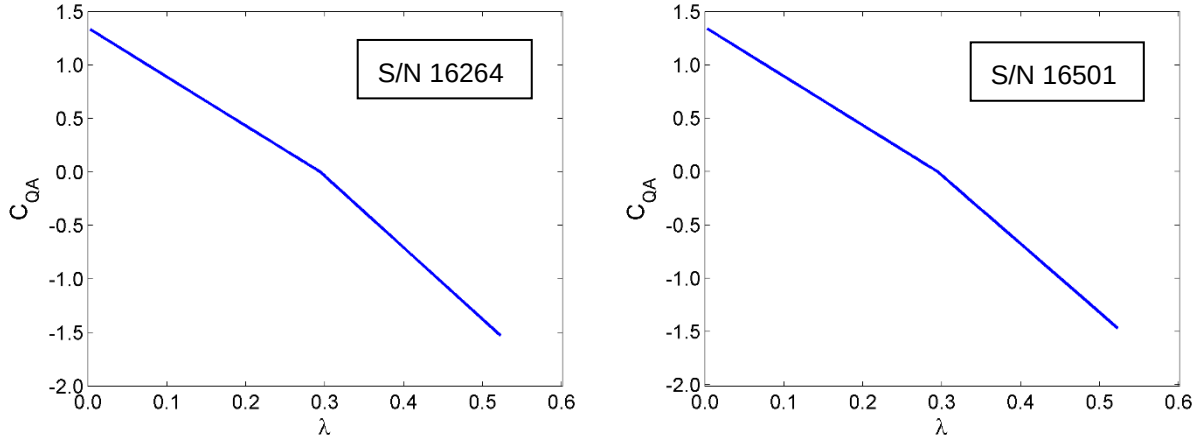
Calibration residuals

Angular characteristics



Relative wind speed as function of tilt angle, α, at 4, 7, 10, 13 and 16 m/s (yellow, cyan, blue, green and red)

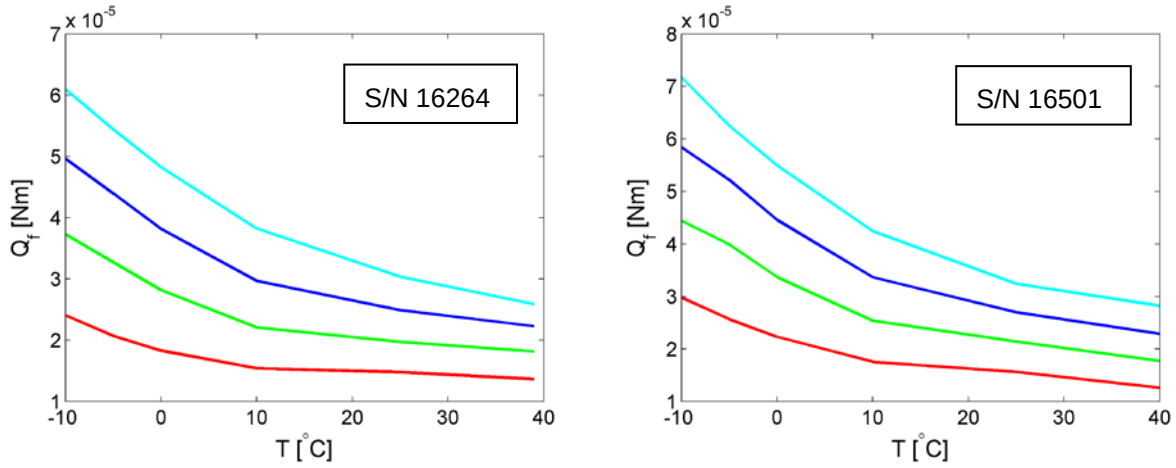
Torque characteristics



Averaged torque curves as function of speed ratio, λ

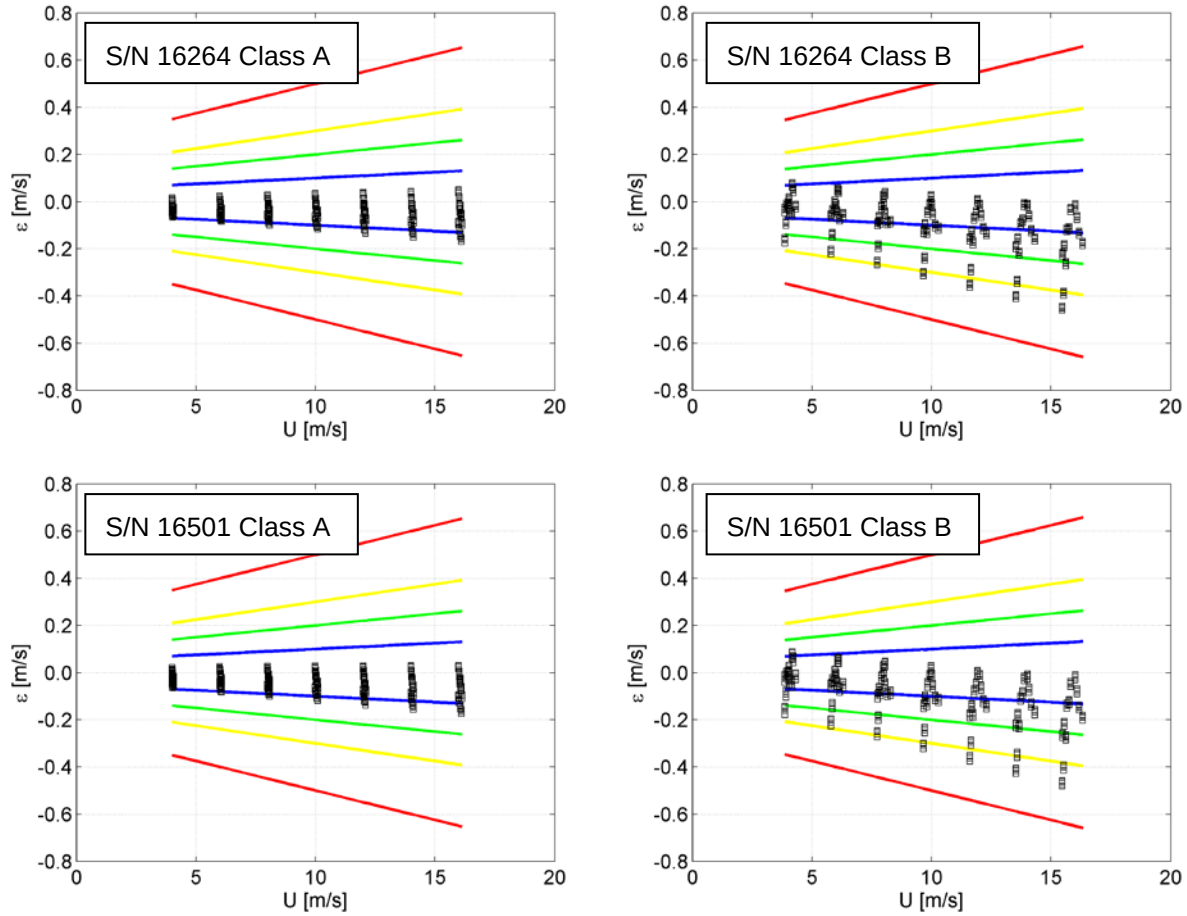
WindSensor P2546A-OPR Serial Number	Moment of inertia of cup rotor [kg·m²]	Slope Low speed ratios	Slope High speed ratios
16264	$9.9212 \cdot 10^{-5}$	-4.6	-6.7
16501	$9.9370 \cdot 10^{-5}$	-4.6	-6.4

Bearing friction characteristics



Friction torque as a function of temperature at angular speeds of 20, 40, 60 and 80 rad/s (red, green, blue and cyan)

Maximum deviations applying the cup anemometer model



Maximum deviations shown with boundaries for classification indices of 1, 2, 3, and 5 (blue, green, yellow and red)

Date: 20 December 2017

Troels Friis Pedersen, Professor – DTU Wind Energy