

## SUMMARY OF CUP ANEMOMETER CLASSIFICATION

### Make and type: WindSensor P2546A-OPR & P2546C-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
<b>Average and final class index, <i>k</i></b>	<b>1.32</b>	<b>3.71</b>

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

- P2546A-OPR with switch output signal and two pulses per revolution
- P2546C-OPR with sinusoidal output signal and two periods per revolution

As required by IEC 61400-12-1:2005 two samples of the P2546A-OPR anemometer have been classified with the result indicated above according to the procedure described below.

By identical aerodynamic response, due to identical geometry, and by similarity in calibration this classification is also valid for the P2546C-OPR.

#### Basic cup anemometer data

Rotor diameter:	188 mm
Cup diameter:	70 mm (conical)
Cup area	0.00385 m <sup>2</sup>
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: *Characterization and Classification of the WindSensor P2546A-OPR Cup Anemometer*, Revision 1, November 2013.

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.

### 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

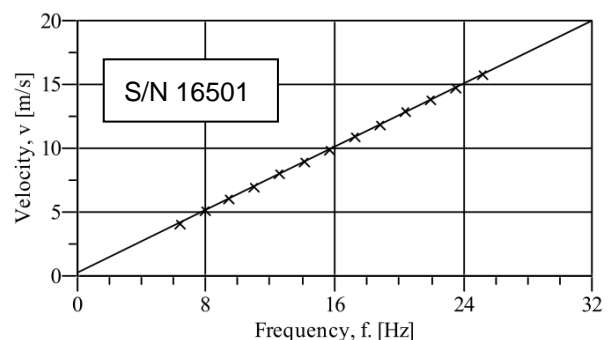
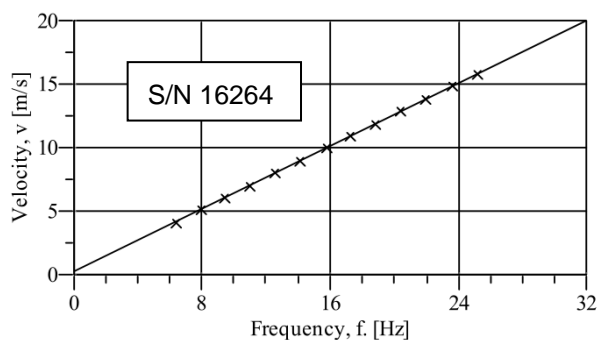
Measurement	Procedure
Calibration	IEC 61400-12-1:2005 Annex F
Angular response characteristics	IEC 61400-12-1:2005 Annex J.2.1
Torque coefficient measurements	IEC 61400-12-1 Annex J.2.4 *)
Bearing friction	IEC 61400-12-1:2005 Annex J.2.3
Rotor inertia	IEC 61400-12-1 Annex J.2.3 *)**)
Calculation of systematic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

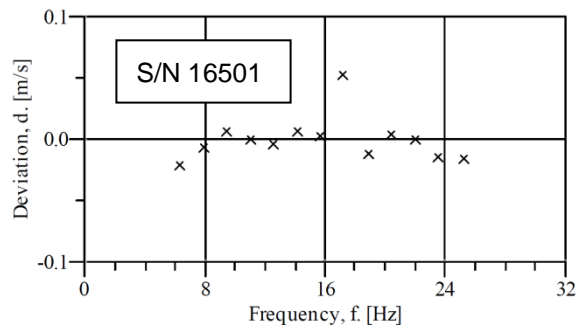
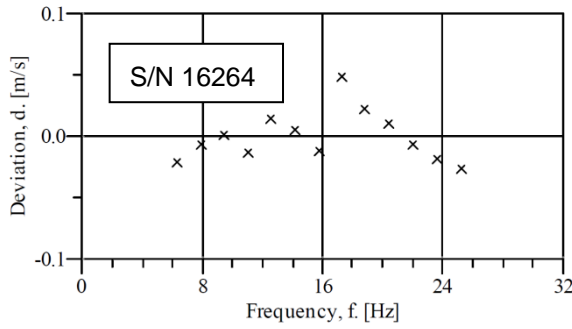
\*\*\*) Detailed procedure in report Risø-R-1364

### 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

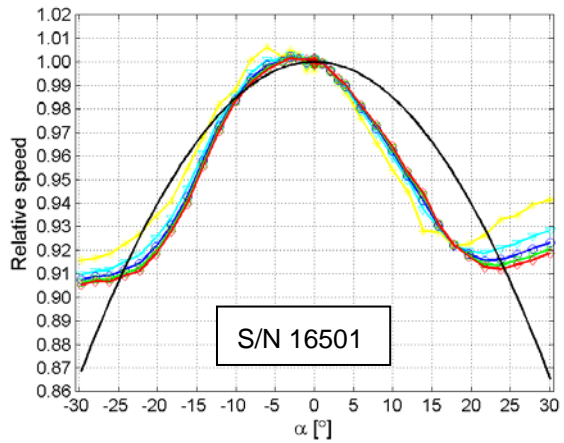
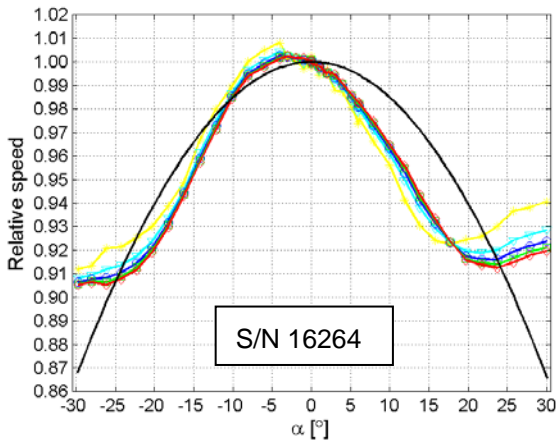


Calibration results



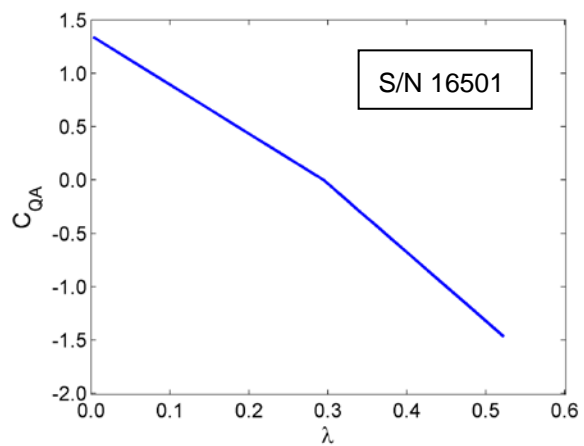
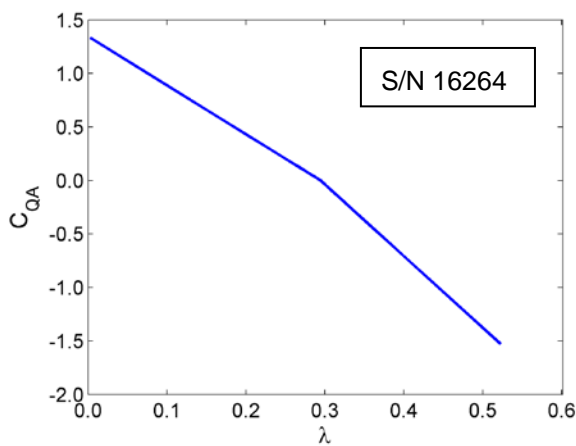
Calibration residuals

### Angular characteristics



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

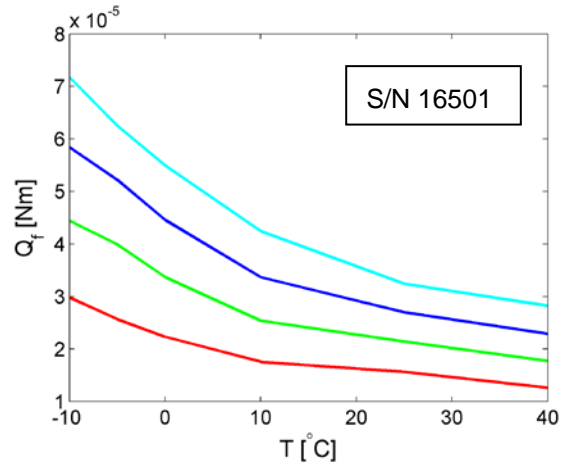
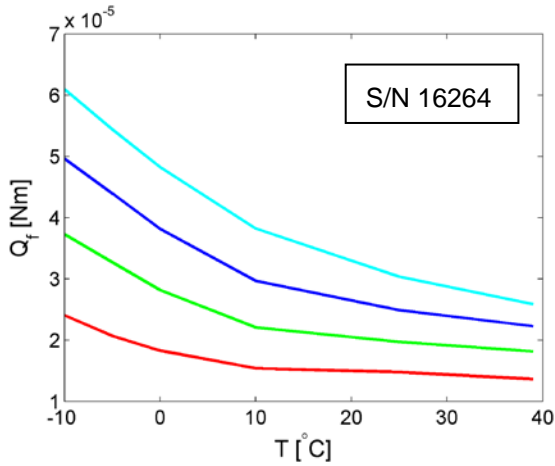
### Torque characteristics



Averaged torque curves as function of speed ratio,  $\lambda$

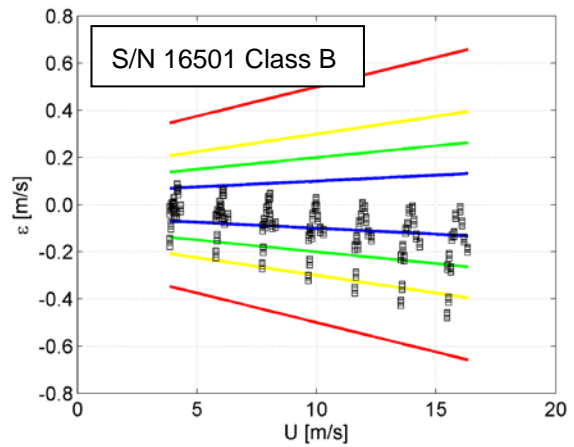
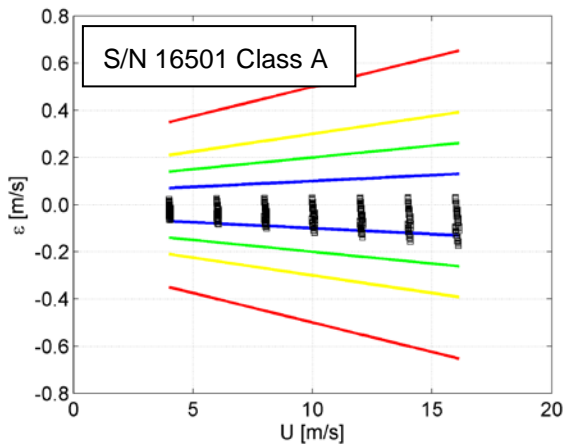
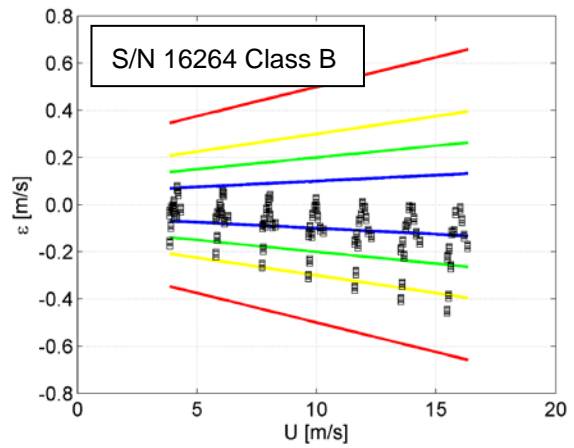
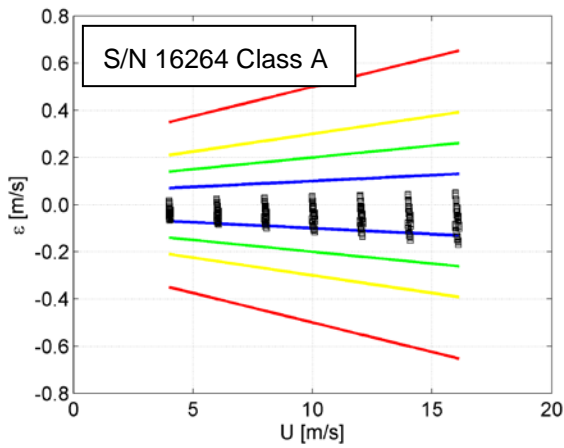
WindSensor P2546A-OPR Serial Number	Moment of inertia of cup rotor [ $\text{kg}\cdot\text{m}^2$ ]	Slope Low speed ratios	Slope High speed ratios
16264	$9.9212 \cdot 10^{-5}$	-4.6	-6.7
16501	$9.9370 \cdot 10^{-5}$	-4.6	-6.4

**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)

**Calculated deviations applying cup anemometer model**



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

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