Influence of mounting tube diameter on anemometer output

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Deutsche WindGuard Wind Tunnel Services GmbH is accredited by Deutsche Akkreditierungsstelle GmbH(DAkkS) as a calibration laboratory according to DIN EN ISO/IEC 17025:2005 (DAkkS registry-no: D-K-15140) for the calibration in the field of fluid quantities of velocity of gases (anemometers) and direction of flow (wind vanes).

Deutsche Akkreditierungsstelle
D-K-15140-01-00

Deutsche WindGuard Wind Tunnel Services GmbH is an associated Member of MEASNET and is accepted by MEASNET for the Calibration of Anemometers.

Deutsche WindGuard Wind Tunnel Services GmbH is an approved testing laboratory for the anemometer calibration competence area within the IECRE scheme.

Revision History

Revision No.	Date	Status	Amendment
Rev0	20.11.2017	1st issue	

Note: The last revision replaces all previous versions of the report.

Contents

1 Introduction

In March 2017 a new edition of the IEC 61400-12-01 [1] international standard for wind energy generation systems was released. Part 12-1 deals with the power performance measurements of electricity producing turbines. In annex G.2 Single top-mounted anemometer and G.4 Site mounted instruments, the standard instructs:

'The anemometer shall be mounted on a round vertical tube of the same (± 0,1 mm) outer diameter as used during calibration (and classification), but of no larger diameter than the body of the anemometer.'

For the stainless steel tube production, the DIN EN 10217 [2] states different tolerance classes for the outer diameter of welded tubes. The most precise class is called D4 and allows the diameter to be within ± 0.5 % with a minimum of ± 0.1 mm. Therefore, the allowed tolerance for tubes with an outer diameter between 30 mm and 40 mm lies between ± 0.15 mm and ±0.2 mm. The tolerance for commonly used steel tubes is even larger with ± 1.0 % with a minimum of ± 0.5 mm. These values exceed the specifications given in the new IEC standard. To purchase a tube for the mounting of the anemometer, which meets the specifications of the IEC standard, could be a difficult task.

In this study the influence of the variation in mounting tube diameter to the measurement result of an anemometer is evaluated.

This study was done in cooperation with Adolf Thies GmbH & Co. KG. For the study mounting tubes with four different diameters were supplied by Thies. The tube diameters are between 33 mm and 34 mm and were tested with our SQC cup anemometer 'REF10', a Thies First Class Advanced (type 4.3351.xx.xxx). The bases for this study are the results listed in the calibration certificates which are listed in Annex 7.2.

2 Test procedure

First the diameters of all mounting tubes were measured with a digital caliper. Afterwards calibration measurements with each mounting tube and the SQC anemometer, 'REF10', were done. All measurements were carried out consecutively and by one operator. The different tubes were tested in increasing diameter size. After setting up the mounting tube with the anemometer two successive measurements, using the same tube diameter, were carried out without changing the setup. The measurement procedure followed the MEASNET / IEC 61400-12-1 standard and covered a wind speed range of 4 m/s – 16 m/s.

General information:

- All tests in a speed range of 4 - 16 m/s were performed in wind tunnel 'Varel 1'. A detailed description of this wind tunnel is given in Annex 7.1
- The ambient conditions during the calibrations are documented in the calibration certificates in Annex 7.2
- The inclination angle for all setups was 90° ± 0.1°

2.1 Setup

The setup of the SQC anemometer 'REF 10' (type 4.3351.XX.XXX) in wind tunnel 'Varel 1' is shown in Figure 1. The view is into the nozzle of the wind tunnel.

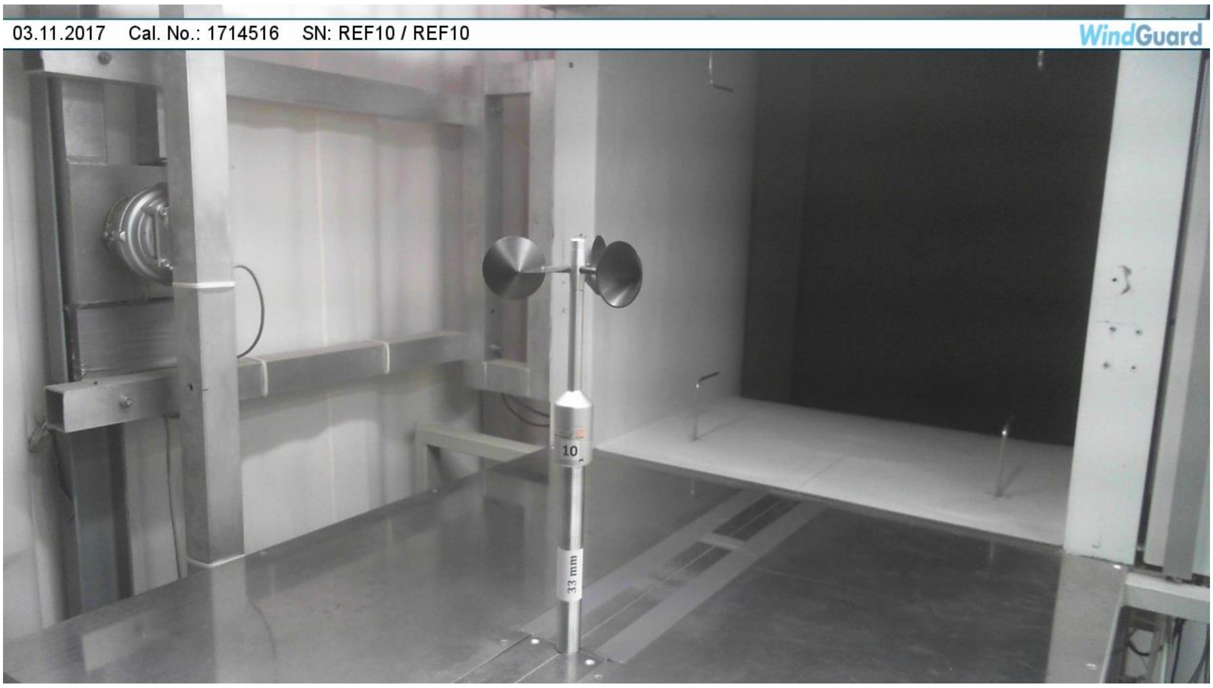

Figure 1: Setup of the SQC anemometer 'REF10', type 4.3351.xx.xxx in wind tunnel 'Varel 1'.

3 Results

The four different tubes are shown in Figure 2. They are labeled with the nominal-value of the diameter. Note the increasing shaft diameter at the anemometer position to allow proper anemometer seating.

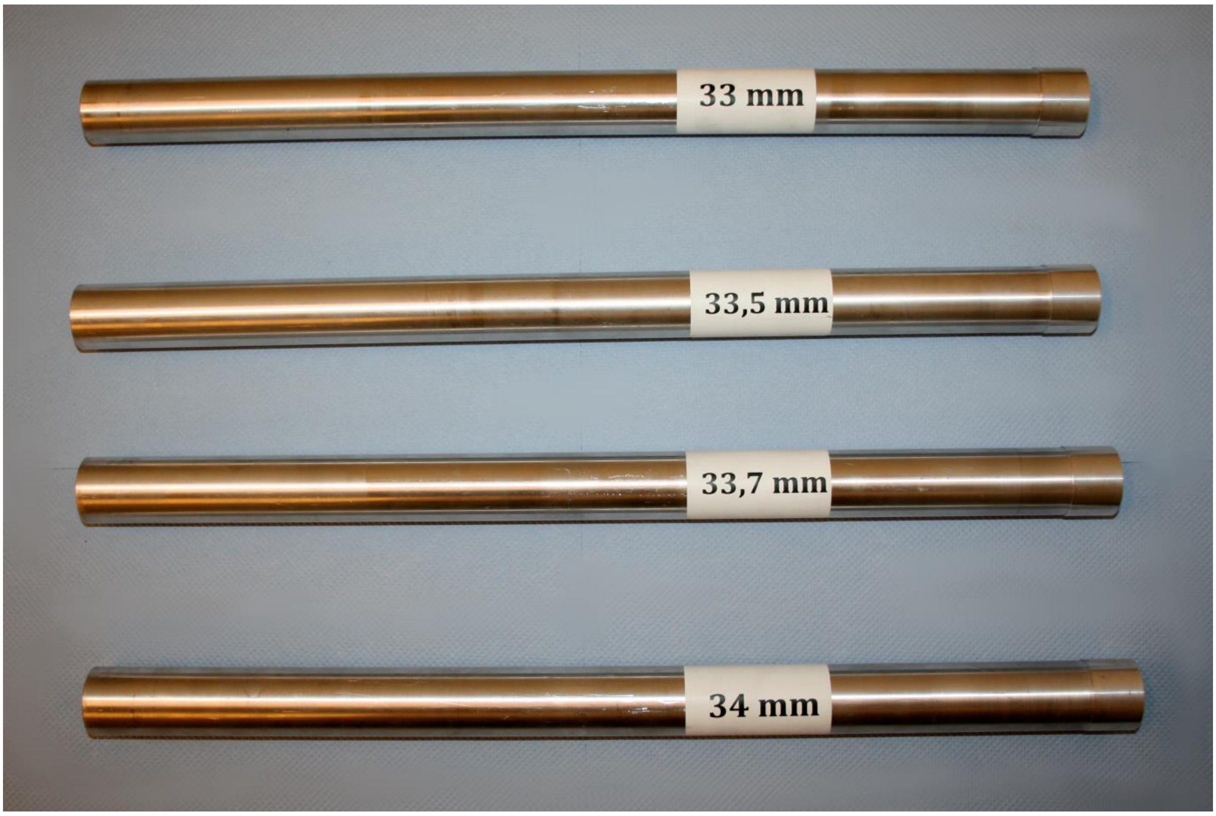

Figure 2: Four mounting pipes with different diameters supplied by Thies.

Three different points at the tube were measured with a digital caliper. The results of the measurements are listed in Table 1.

Table 1: Results of measuring the diameter of the mounting tubes.

Nominal-value / mm	Measured value at position:		
	1 / mm	2 / mm	3 /mm
33.0	33.01 ±0.03	33.03 ±0.03	33.06 ±0.03
33.5	33.49 ±0.03	33.51 ±0.03	33.53 ±0.03
33.7	33.70 ±0.03	33.73 ±0.03	33.75 ±0.03
34.0	33.99 ±0.03	33.97 ±0.03	33.98 ±0.03

The maximum difference among all results between the nominal-value of the tube diameter and the measurement is 0.06 ± 0.03 mm.

In the next step, the calibration of the SQC anemometer with the four different mounting tubes was done. The results are listed in Table 2.

Table 2: Calibration results for four different mounting tube diameters.

Nominal-value / mm	Calibration Number	Slope / (m/s)/Hz	Offset / m/s	Calculated Frequency at 10 m/s ±0.04 m/s / Hz	Deviation of Frequency at 10 m/s compared to mean value
33.0	1714516	0.04578 ±0.00008	0.2158 ±0.018	213.72215	0.99934
	1714517	0.04578 ±0.00008	0.2071 ±0.019	213.91219	1.00023
33.5	1714518	0.04584 ±0.00006	0.2011 ±0.014	213.76309	0.99953
	1714519	0.04578 ±0.00007	0.2031 ±0.015	213.99956	1.00064
33.7	1714520	0.04576 ±0.00007	0.2107 ±0.015	213.92701	1.00030
	1714521	0.04588 ±0.00007	0.1860 ±0.016	213.90584	1.00020
34.0	1714522	0.04581 ±0.00009	0.1997 ±0.020	213.93364	1.00033
	1714523	0.04587 ±0.00004	0.1958 ±0.008	213.73883	0.99942

The deviation of the calculated frequencies at 10 m/s compared to their mean value is illustrated in Figure 3 for each calibration. The results lie between 0.99934 and 1.00064 and seem to have an arbitrary distribution, which is not related to the tube diameter.

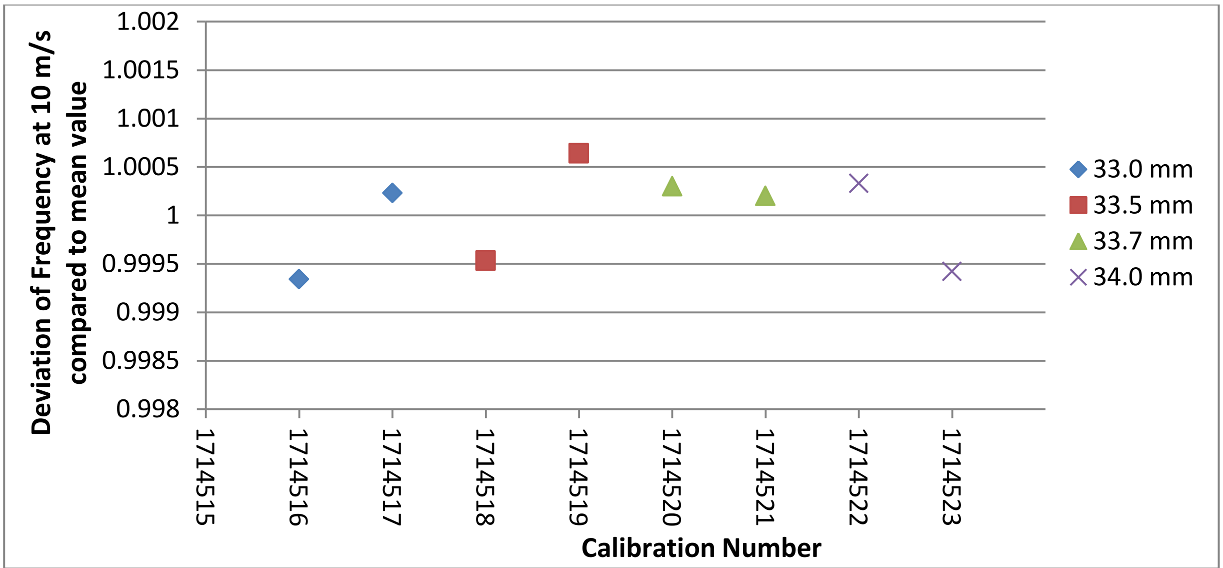

Figure 3: Diagram of the deviation of the calculated frequency at 10 m/s compared to the mean value for each calibration.

4 Measurement uncertainty

Tests were carried out in wind tunnel 'Varel 1'. The attributed uncertainties in flow speed are specified below:

- Flow speed wind tunnel 'Varel 1': The accredited uncertainty in flow speed is specified as 0.05 m/s in a speed range from 4 m/s to 16 m/s.

Uncertainty values are specified as an expanded uncertainty with a coverage probability of 95% (coverage factor of *k*=2). It has been determined in accordance with DAkkS-DKD-3. The value of the measurand lies within the assigned range of values with a probability of 95 %.

The long term deviation between the mean value of all measurements and each measurement of the 'REF10' anemometer fluctuate between ± 0.1 %.

5 Conclusion

The measurements of the tube diameters illustrate the variance in diameter due to production tolerances. The maximum deviation of the nominal-value among all measurements is 0.06 ± 0.03 mm which is almost the tolerance given by the new IEC standard.

The calculated frequencies for 10 m/s compared to their mean value don't show a diameter related change. The variation of the 10 m/s value in Figure 3 is apparently du to statistical scatter. The maximum deviation is 0.07 %, which is within the measurement uncertainty.

The measurements indicate that a change in mounting tube diameter of 1 mm doesn't have an influence on the calibration result of Thies First Class anemometers. The restriction in the IEC 61400-12-01 international standard for wind energy generation systems of 0.1 mm should be reviewed. A further investigation is necessary to set a feasible maximum value for the tolerated difference between outer mounting tube diameter during calibration and on site measurement. Furthermore tests for different anemometer types should be done.

6 References

[1] IEC 61400-12-1, Edition 2.0, WIND TURBINE GENERATOR SYSTEMS, Power performance measurements of electricity producing wind turbines, Annex F, March 2017

[2] DIN EN 10217, Geschweißte Stahlrohre für Druckbeanspruchungen - Technische Lieferbedingungen, 2005

[3] MEASNET, ANEMOMETER CALIBRATION PROCEDURE Version 2, October 2009

[4] Quality management documentation of WindGuard Wind Tunnel Services GmbH is part of the accreditation according to DAkkS [5] and DIN ISO EN 17025:2005 below an excerpt of the quality management documentation most relevant for the tests conducted
- H Handbuch Kalibrierlabor, ID: D5927, Revision: 30, August 2017
- VA Verfahrensanweisung Anemometerkalibrierung, ID: D5831, Revision: 13, July 2017
- AA Arbeitsanweisung Kalibrierung von Standard Cup-Anemometern, ID: D5829, Revision: 0, March 2013

[5] DAkkS Accreditation certificate D-K-15140-01-00, July 2017

7 Appendix

7.1 Description of wind tunnel 'Varel 1' of Deutsche WindGuard Wind Tunnel services GmbH

As of 2016 Deutsche WindGuard Wind Tunnel Services GmbH is operating four calibration wind tunnels and two research wind tunnels at the Varel facility. All four calibration tunnels are of the 'Göttinger" wind tunnel layout with a closed return design. The basic layout of the calibration wind tunnels can be seen in Figure 4.

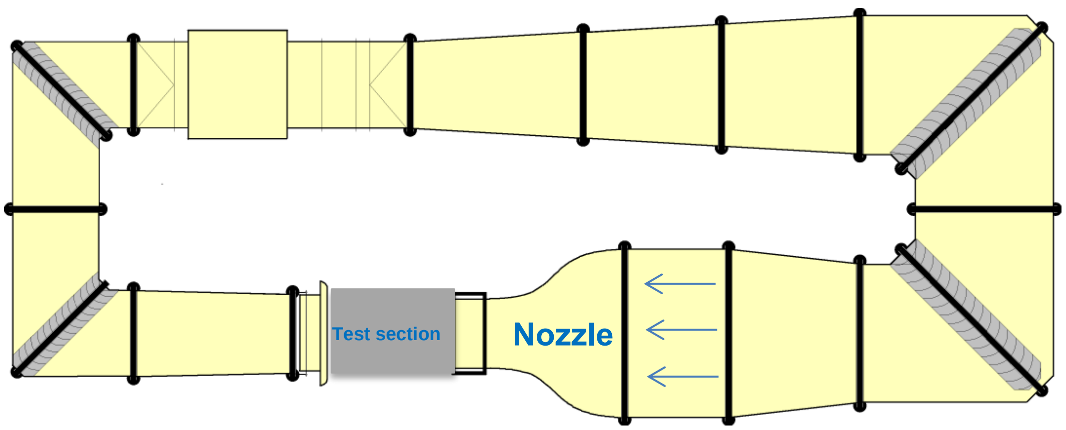

Figure 4: Basic layout of WindGuard calibration tunnels at the Varel facility.

All measurement surveys conducted for this report were performed in wind tunnel 'Varel 1'.

Features of wind tunnel 'Varel 1':

- Test section size of 1 m x 1 m
- Length of test section 1.75 m
- Turbulence intensity < 0.2%
- Excellent flow quality in space and time
- Test section layout of semi open design, thus reducing blockage effects substantially
- Accredited speed range: 4 – 16 m/s
- Recognized by MEASNET following / IEC 61400-12-1 Annex F [1] anemometer calibration procedure

7.2 Calibration certificates of project VT170985

The calibration certificates belonging to the project VT170985 have the numbers:

- 17141516
- 17141517
- 17141518
- 17141519
- 17141520
- 17141521
- 17141522
- 17141523

On request access can be given.