



Wind Turbine Generator System Acoustic Noise Test Report for the Gaia Wind 11-kW Wind Turbine

Arlinda Huskey

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Technical Report
NREL/TP-5000-51828
November 2011

Contract No. DE-AC36-08GO28308

NOTICE

This report was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

Available electronically at <http://www.osti.gov/bridge>

Available for a processing fee to U.S. Department of Energy
and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: <mailto:reports@adonis.osti.gov>

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: <http://www.ntis.gov/help/ordermethods.aspx>

Cover Photos: (left to right) PIX 16416, PIX 17423, PIX 16560, PIX 17613, PIX 17436, PIX 17721



Printed on paper containing at least 50% wastepaper, including 10% post consumer waste.



Wind Turbine Generator System
Acoustic Noise Test Report
for the
Gaia Wind 11-kW Wind Turbine
in

Boulder, CO

Conducted for

National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401

Conducted by

Wind Energy Program
DOE / NREL

Arlinda Huskey

March 31, 2011

Notice

This report was prepared by the National Renewable Energy Laboratory (NREL), operated for the United States Department of Energy (DOE) by the Alliance for Sustainable Energy, LLC (Alliance), as an account of work sponsored by the United States government. The test results documented in this report define the characteristics of the test article as configured and under the conditions tested.

THIS REPORT IS PROVIDED "AS IS" AND NEITHER THE GOVERNMENT, ALLIANCE, NREL NOR ANY OF THEIR EMPLOYEES, MAKES ANY WARRANTY, EXPRESS OR IMPLIED, INCLUDING THE WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, OR ASSUMES ANY LEGAL LIABILITY OR RESPONSIBILITY FOR THE ACCURACY, COMPLETENESS, OR USEFULNESS OF ANY SUCH INFORMATION DISCLOSED IN THE REPORT, OR OF ANY APPARATUS, PRODUCT, OR PROCESS DISCLOSED, OR REPRESENTS THAT ITS USE WOULD NOT INFRINGE PRIVATELY OWNED RIGHTS.

Neither Alliance nor the U. S. Government shall be liable for special, consequential or incidental damages. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of the authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof or Alliance.

NREL is a DOE Laboratory, and as an adjunct of the United States government, cannot certify wind turbines. The information in this report is limited to NREL's knowledge and understanding as of this date.

NREL is accredited by the American Association for Laboratory Accreditation (A2LA) and the results shown in this test report have been determined in accordance with the NREL's terms of accreditation unless stated otherwise in the report.

This report shall not be reproduced, except in full, without the written approval of Alliance or successor operator of NREL.

Approval By: Arlinda Huskey 14 Nov 2011
Arlinda Huskey, NREL Test Engineer Date

Review By: Jeroen van Dam 14 Nov 2011
Jeroen van Dam, NREL Test Engineer Date

Table of Contents

1.0 Background	4
2.0 Test Summary	4
3.0 Test Turbine.....	4
4.0 Test Site	7
5.0 Test Equipment.....	8
5.1 Equipment Descriptions	8
5.2 Instrumentation Locations	10
6.0 Results	10
6.1 Test Conditions	10
6.2 Apparent Sound Power Level.....	10
6.3 One-Third Octave Analysis.....	12
6.4 Tonality	15
6.5 Uncertainty	16
7.0 Exceptions	17
7.1 Exceptions to the Standard	17
7.2 Exceptions to the Quality Assurance System	18
8.0 References	18
Appendix A. Picture of the soundboard	19
Appendix B. Equipment Calibration Sheets	20

List of Tables

Table 1. Test turbine Configuration and Operational Data	6
Table 2. Structures close to test turbine.....	8
Table 3. Equipment list for acoustic test	9
Table 4. Microphone positions for turbine and background measurements	10
Table 5. Sound power levels for integer wind speeds 6 m/s through 12 m/s.....	11
Table 6. One-third octave analysis for wind speed bins 6 through 9 m/s	13
Table 6 (continued). One-third octave analysis for wind speed bins 10 and 11 m/s	14
Table 7. Tonality results.....	16
Table 8. Type B uncertainty components for sound power levels and tonality	17

List of Figures

Figure 1. Gaia-Wind 11-kW test turbine at the NWTC. PIX #15705.	5
Figure 2. Test turbine location.....	7
Figure 3. Sound power levels as a function of the standardized wind speed.....	11
Figure 4. Measured sound pressure levels as a function of the standardized wind speed.....	12
Figure 5. One-third octave levels	15
Figure 6. Picture of sound board during the test.....	19

1.0 Background

This test is being conducted as part of the U.S. Department of Energy's (DOE) Independent Testing project. This project was established to help reduce the barriers of wind energy expansion by providing independent testing results for small turbines. In total, four turbines are being tested at the National Wind Technology Center (NWTC) as a part of this project. Acoustic noise testing is one of up to five tests that may be performed on the turbines; other tests may include duration, safety and function, power performance, and power quality tests.

2.0 Test Summary

The Gaia-Wind 11-kW wind turbine was installed at the National Wind Technology Center located south of Boulder, Colorado. The test turbine is a two-bladed, downwind wind turbine with a rated power of 11 kW. The test turbine was tested in accordance with the International Electrotechnical Commission standard, IEC 61400-11 Ed 2.1 2006-11 Wind Turbine Generator Systems – Part 11 Acoustic Noise Measurement Techniques, hereafter referred to as the Standard. Noise and meteorological data were collected on two days, 28 February 2009 and 11 March 2010. Standardized wind speed (at 10 meters) was determined from wind speed measured at hub height (at 18.2 meters).

3.0 Test Turbine

Figure 1 shows a picture of the test turbine and Table 1 lists the turbine configuration.



Figure 1. Gaia-Wind 11-kW test turbine at the NWTC. PIX #15705.

Table 1. Test turbine Configuration and Operational Data

	Test Turbine
Wind turbine details:	
Manufacturer	Gaia-Wind
Model number	Gaia-Wind 11-k/w
Serial number	10711114
Configuration:	
Vertical or horizontal axis	Horizontal
Upwind or downwind rotor	Downwind
Hub height	18.2 m
Horizontal distance from rotor center to tower axis	2.1 m
Diameter of rotor	13 m
Operating details:	
Passive/active stall or pitch-controlled turbine	Passive stall
Constant or variable speed	Constant
Rotational speed at standardized integer wind speed from 6 to 10 m/s	60-61 rpm
Pitch angle at standardized integer wind speeds from 6 to 10 m/s	0 degrees
Rated power output	11 kW
Control software version	Gaia-Wind IC-1000, Rev. 1:P00515\031020
Geometric Configuration:	
Tower type (lattice or tube)	Tubular
Rotor details:	
Rotor control devices	Tip brakes
Blade type	Gaia-Wind T202, glass fiber, centrifugally activated tip brake
Number of blades	2
Presence of vortex generators, stall strips, serrated trailing edges, etc.	None

4.0 Test Site

The test turbine is located at site 3.1 at the National Wind Technology Center, south of Boulder, Colorado. The topography surrounding the test site is flat with some small bushes. Figure 2 shows the turbine and meteorological tower locations. This figure also shows nearby turbines and topographical features of the site.

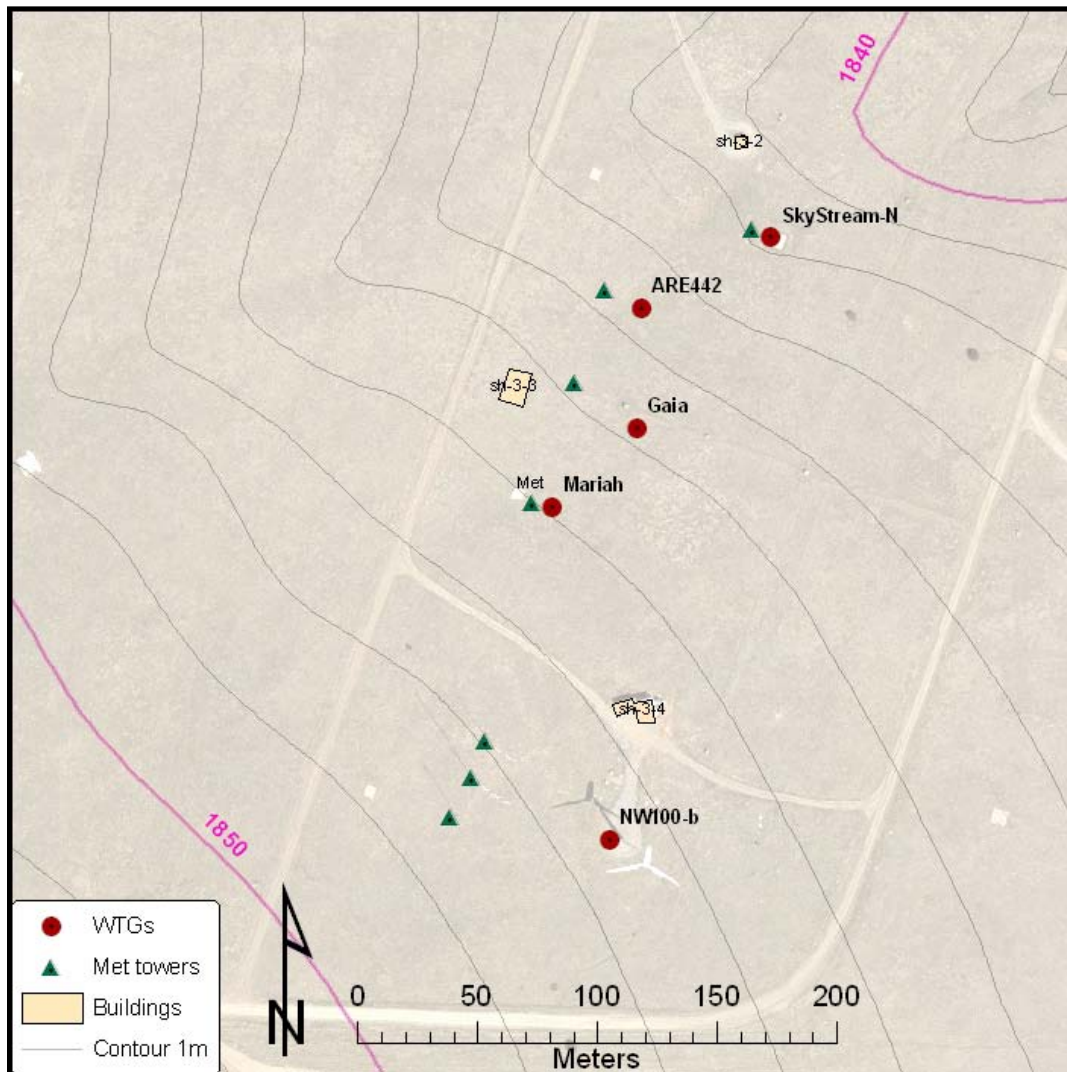


Figure 2. Test turbine location

Table 2. Structures close to test turbine

Source	Location	Shutdown for noise test
NW100b	3.4	Yes
ARE 442	3.3a	Yes
Southwest Windpower Skystream (2*)	3.2	Yes
Endurance	3.1	Yes
CART	4.2	No
EW50	1E1	Yes
Bergey Excel	1.4	No

5.0 Test Equipment

5.1 Equipment Descriptions

Table 3 shows the list of equipment used for the test. All instruments meet the requirements defined by the Standard.

Table 3. Equipment list for acoustic test

Instrument	Manufacturer	Model Number	Serial Number	Calibration Due Date
Digital Recorder and Signal Analyzer	Delta Acoustics	NoiseLab	1258E43	November 24, 2010
Microphone	Bruel & Kjaer	4189-A-021	2395206	November 21, 2010
Preamplifier	Bruel & Kjaer	4012	2373719	November 21, 2010
Calibrator	Bruel & Kjaer	4231	2326144	November 11, 2009 January 14, 2011
Anemometer (replaced during test)	Thies	First Class	0707890 0707892	April 7, 2009 February 4, 2010 Anemometer post-Test calibrated and was in compliance
Wind Vane	Met One	020C	X4357	April 7, 2009 March 18, 2010
Pressure Sensor (replacing during test)	Vaisala	PTB101B	T5030003	August 26, 2009 Pressure sensor Post-test calibrated and was in compliance
Temperature Sensor (replaced during test)	Met One	T-200 RTD	0789021	October 10, 2009 Temperature sensor post-test calibrated and was in compliance
Data acquisition (replaced during test)	National Instruments	Compact DAQ w/LabView cDAQ backplane NI 9229 NI 9217 NI 9205 NI 9229 NI 9217 NI 9205	 12E4DA3 12CBC7A 12BFEE2 12E9C99 140A596 140DCB9 140E2BD	 August 14, 2008 July 20, 2008 October 8, 2008 Modules post-test Calibrated and were In compliance February 10, 2010 February 12, 2010 February 10, 2010 Modules post-test calibrated and were in compliance

5.2 Instrumentation Locations

The anemometer and wind vane were on a meteorological tower located 32.7 meters from the test turbine at a bearing of 290° true. The anemometer was at hub height 18.3 m. The meteorological tower distance is 2.5 rotor diameters from the test turbine and within the range of between 2 and 4 rotor diameters specified in the IEC standard.

Table 4 gives the location of the microphone for the measurement sessions.

Table 4. Microphone positions for turbine and background measurements

Microphone	Distance to Turbine [m]	Slant Distance [m]	Position relative to turbine [degrees]
Reference	24.7	30.7	295

6.0 Results

6.1 Test Conditions

The analysis was done using the measured wind speed and 10-second averages of the data. NREL has found that noise from small wind turbines correlates better with measured wind speed than it does with derived wind speed. For the 24 February 2009 data, the range of standardized wind speeds and wind directions used for the analysis were 1.4 to 16.3 m/s and 118 to 355 degrees, respectively. The range of temperature and pressure were 14.6 to 16.3 C and 80.4 to 80.7 kPa, respectively. For the 11 March 2010 data, the range of standardized wind speeds and wind directions used for the analysis were 3.1 to 12.2 m/s and 256 to 309 degrees, respectively. The range of temperature and pressure were 3.9 to 6.2 C and 80.3 to 80.4 kPa, respectively.

6.2 Apparent Sound Power Level

The apparent sound power level at standardized wind speeds of 6, 7, 8, 9, 10, 11, and 12 m/s are shown in Table 5 and Figure 3. In this test, wind speed was measured at a hub height of 18.2 m and then standardized to a 10 m height, assuming an idealized wind profile based on a terrain roughness of 0.05 m.

Table 5. Sound power levels for integer wind speeds 6 m/s through 12 m/s

Wind Speed Bin [m/s]	Sound Power Level [dB (A)]	Combined Uncertainty [dB (A)]
6	84.2	1.4
7	85.5	1.3
8	86.5	1.4
9	88.0	1.4
10	88.9	1.3
11	90.0	1.3

Figure 3 shows sound power levels at the standard integer wind speeds. The sound pressure levels were binned by wind speed. The integer wind speed values were calculated by interpolation between bins.

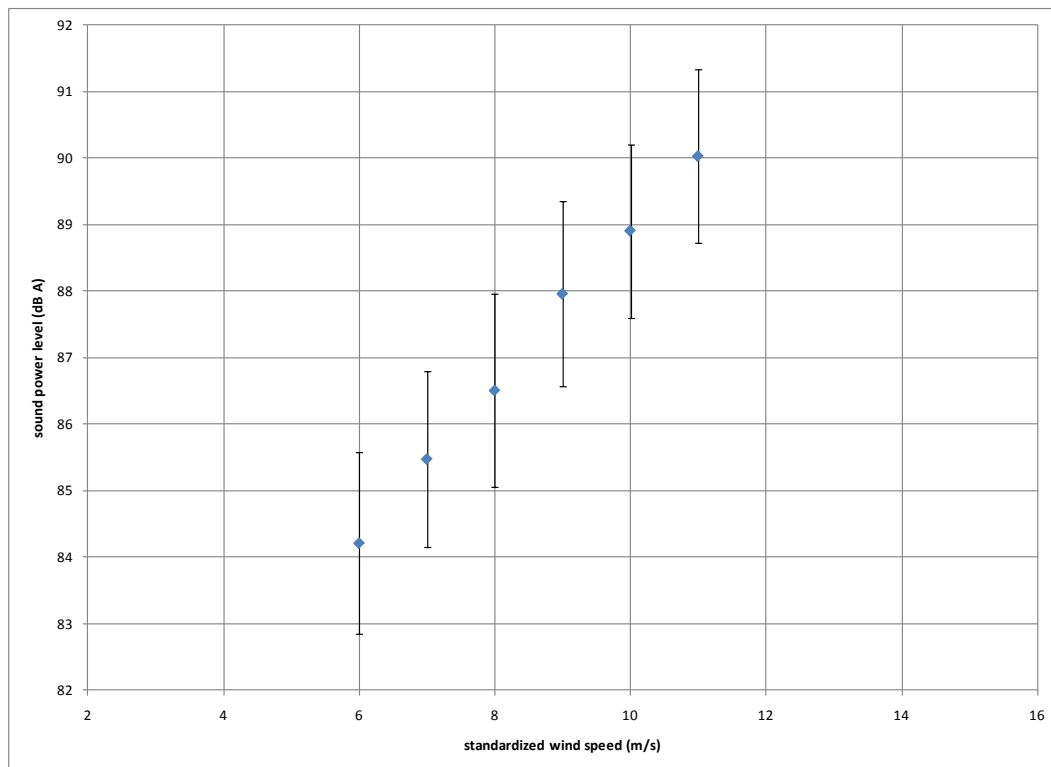


Figure 3. Sound power levels as a function of the standardized wind speed

Figure 4 shows the scatter plot of the sound pressure levels of the turbine and background noise.

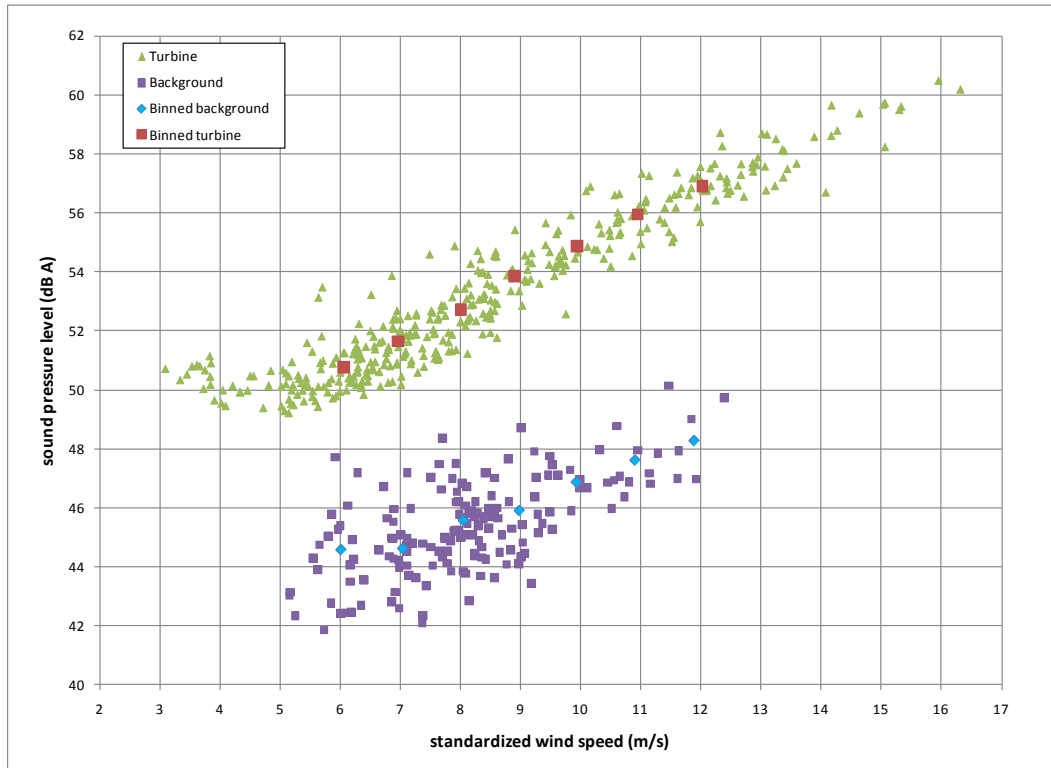


Figure 4. Measured sound pressure levels as a function of the standardized wind speed.

6.3 One-Third Octave Analysis

One-third octave levels were analyzed at standardized wind speed of 6, 7, 8, 9, 10, and 11 m/s. The results are given in Table 6 and Figure 5.

Table 6. One-third octave analysis for wind speed bins 6 through 9 m/s

Center Frequency	6 m/s one-third octave levels	7 m/s one-third octave levels	8 m/s one-third octave levels	9 m/s one-third octave levels
[Hz]	[dB A]	[dB A]	[dB A]	[dB A]
20	NR	NR	NR	NR
25	NR	NR	NR	NR
31.5	NR	NR	NR	NR
40	NR	NR	NR	NR
50	NR	NR	NR	NR
63	NR	NR	NR	NR
80	NR	NR	NR	NR
100	NR	32.2* \pm 2.4	32.8* \pm 2.2	NR
125	NR	NR	NR	NR
160	33.8* \pm 2.3	35.0* \pm 2.3	36.6* \pm 2.3	NR
200	NR	NR	NR	NR
250	39.2* \pm 2.3	40.1* \pm 2.3	41.0* \pm 2.2	NR
315	38.6* \pm 2.3	39.2* \pm 2.3	40.6* \pm 2.3	41.4* \pm 2.3
400	37.9* \pm 2.3	38.6* \pm 2.2	40.0* \pm 2.3	40.9* \pm 2.3
500	38.7* \pm 2.2	39.7 \pm 2.0	40.6* \pm 2.3	41.4* \pm 2.3
630	40.2 \pm 2.1	41.4 \pm 2.0	42.4 \pm 2.2	43.4* \pm 2.3
800	39.5 \pm 2.0	40.4 \pm 1.9	41.4 \pm 2.2	42.3* \pm 2.3
1000	39.3 \pm 1.9	39.4 \pm 1.9	40.2* \pm 2.3	41.5* \pm 2.4
1250	37.8 \pm 1.9	38.6 \pm 1.9	39.7 \pm 2.3	40.9* \pm 2.4
1600	39.4 \pm 1.9	40.6 \pm 1.9	42.0 \pm 2.0	42.5 \pm 2.2
2000	37.0 \pm 2.0	38.6 \pm 2.0	40.3 \pm 2.1	41.5 \pm 2.3
2500	36.1 \pm 2.1	38.1 \pm 2.1	40.3 \pm 2.1	41.9 \pm 2.2
3150	34.6 \pm 2.1	36.7 \pm 2.1	39.1 \pm 2.2	40.8 \pm 2.3
4000	32.1 \pm 2.0	33.9 \pm 2.0	36.1 \pm 2.2	37.6 \pm 2.4
5000	31.3 \pm 2.1	33.0 \pm 2.0	34.4 \pm 2.0	35.2 \pm 2.2
6300	30.8 \pm 2.0	32.1 \pm 2.0	32.9 \pm 2.0	33.0 \pm 2.1
8000	25.2* \pm 2.2	25.9* \pm 2.2	26.8* \pm 2.3	NR
10000	NR	NR	NR	NR

* The difference between total and background noise was less than 6 dB but greater than 3 dB. A standard background correction of 1.3 dB was applied.

NR The difference between total and background noise was less than 3 dB so no results are reported.

Table 6 (continued). One-third octave analysis for wind speed bins 10 and 11 m/s

Center Frequency	10 m/s one-third octave levels	11 m/s one-third octave levels
[Hz]	[dB A]	[dB A]
20	NR	16.8* ± 2.6
25	NR	19.2* ± 2.5
31.5	NR	22.0* ± 2.6
40	NR	NR
50	NR	25.6 ± 2.3
63	NR	28.3* ± 2.4
80	33.8 ± 2.5	31.8 ± 2.4
100	33.5* ± 2.4	35.8 ± 2.2
125	NR	39.1* ± 2.2
160	38.9* ± 2.3	38.8* ± 2.3
200	NR	NR
250	40.9* ± 2.3	41.7* ± 2.3
315	41.9* ± 2.3	43.2 ± 2.2
400	41.6* ± 2.3	43.0 ± 2.1
500	42.4 ± 2.1	43.6 ± 1.9
630	44.7 ± 1.9	45.7 ± 1.9
800	43.9 ± 1.9	44.8 ± 1.9
1000	43.4 ± 1.9	44.4 ± 1.9
1250	42.8 ± 2.0	43.9 ± 1.9
1600	43.8 ± 1.9	44.7 ± 1.9
2000	42.9 ± 1.9	43.8 ± 1.9
2500	42.8 ± 1.9	43.7 ± 1.9
3150	42.0 ± 1.9	42.9 ± 1.9
4000	39.1 ± 1.9	39.9 ± 1.9
5000	36.1 ± 1.9	36.7 ± 1.9
6300	33.5 ± 1.9	33.9 ± 1.9
8000	27.4* ± 2.3	28.3* ± 2.3
10000	NR	NR

* The difference between total and background noise was less than 6 dB but greater than 3 dB. A standard background correction of 1.3 dB was applied.

NR The difference between total and background noise was less than 3 dB so no results are reported.

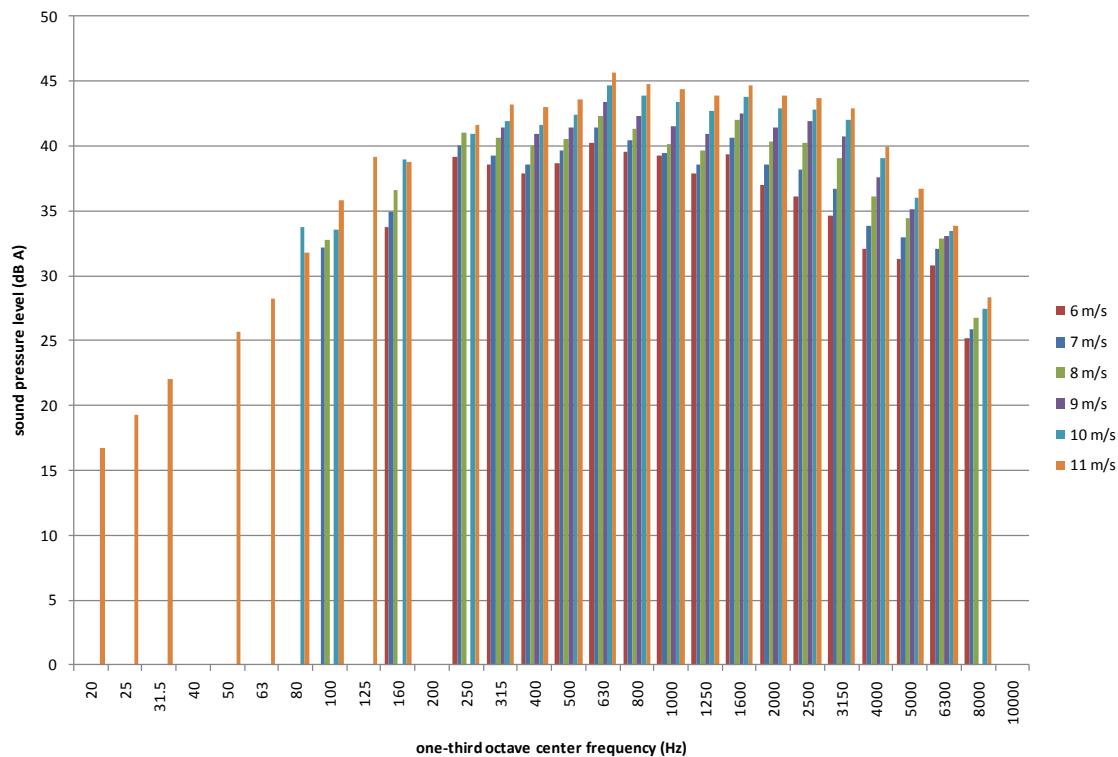


Figure 5. One-third octave levels

6.4 Tonality

The tonality analysis resulted in reportable tones for 6, 7, 8, and 9 m/s. The tonality analysis was not conducted for the 10 m/s wind speed bin because the data available was not suitable for assessing tonality. Table 7 shows the results for the tonality analysis.

Table 7. Tonality results

k (m/s)	6			7			8				9			
Freq (Hz)	807	1569	1614	810	1569	1620	648	810	1575	1623	651	813	1578	1623
$\Delta L_{tn1,k}$	-6.1	-8.8	-17.3	-0.7	-17.2	-4.3	-14.5	-1.9	-17.2	-17.3	-4.6	1.2	-17.2	-17.3
$\Delta L_{tn2,k}$	-5.2	-8.3	-17.3	-0.7	-17.2	-4.7	-3.3	1.8	-17.2	-5.8	-2.8	1.5	-17.2	-17.3
$\Delta L_{tn3,k}$	-6.7	-0.1	-17.3	-3.9	-8.8	-17.3	0.0	0.6	-17.2	-3.4	-7.8	-2.0	-17.2	-17.3
$\Delta L_{tn4,k}$	-5.8	-1.1	-17.3	-3.7	-8.5	-17.3	-4.4	-4.7	1.7	-17.3	-2.8	2.8	-17.2	-10.4
$\Delta L_{tn5,k}$	-2.8	1.8	2.2	-3.7	0.3	-17.3	-5.9	-3.1	-0.5	-17.3	-3.6	3.3	-17.2	-8.5
$\Delta L_{tn6,k}$	-4.2	-0.4	0.2	-5.7	-0.4	0.0	-5.3	-3.9	0.2	0.5	-3.2	3.1	-17.2	-8.6
$\Delta L_{tn7,k}$	-6.1	1.3	1.7	-2.2	-0.2	-17.3	-5.8	-5.0	-0.4	-17.3	-14.5	-6.0	-2.3	-1.6
$\Delta L_{tn8,k}$	-7.9	-2.3	-1.8	-5.9	-3.7	-3.3	-5.7	-5.6	-1.0	-17.3	-14.5	-7.1	-4.0	-2.7
$\Delta L_{tn9,k}$	-4.2	-1.3	-0.5	-4.3	0.0	0.2	-7.3	-5.0	-1.6	-1.0	-2.5	-2.0	0.6	0.7
$\Delta L_{tn10,k}$	-4.3	1.2	1.9	-5.1	-0.5	0.3	-5.9	-6.2	1.8	2.2	-3.2	-4.9	-1.0	-0.9
$\Delta L_{tn11,k}$	-14.9	-5.5	-17.3	-7.5	-1.0	-0.7	-5.1	-4.2	1.1	1.5	-2.4	-4.2	-2.5	-2.5
$\Delta L_{tn12,k}$	-4.1	-2.7	-1.8	-5.9	-1.7	-1.2	-14.5	-4.7	-1.3	-17.3	-5.2	-5.3	-1.4	-1.3
ΔL_k dB(A)	-5.3	-1.1	-1.7	-3.6	-2.3	-3.0	-5.1	-2.7	-1.1	-3.2	-4.3	-0.2	-4.5	-3.8
$\Delta L_{a,k}$ dB(A)	-2.7	2.2	1.5	-1.0	0.9	0.3	-2.6	-0.1	2.2	0.1	-1.8	2.5	-1.2	-0.5
U_A dB(A)	6.3	2.1	3.4	4.5	3.4	4.4	6.1	3.6	2.4	5.1	5.3	1.5	6.3	5.0
U_B dB(A)	2.0	1.9	1.9	2.0	1.9	1.9	2.1	2.1	1.9	1.9	1.9	2.0	1.9	1.9
U_C dB(A)	6.6	2.8	3.9	4.9	3.9	4.7	6.4	4.1	3.0	5.4	5.6	2.5	6.6	5.3

6.5 Uncertainty

The Type A uncertainties for sound power levels, one-third octave levels, and tonality were calculated using the methods prescribed in the Standard.

The type B uncertainty components are shown in Table 8.

Table 8. Type B uncertainty components for sound power levels and tonality

Variable	Description	Type B uncertainty for sound power level dB (A)	Type B uncertainty for one-third octave levels dB (A)	Type B uncertainty for tonality dB (A)	Comment
U _{B1}	Calibration	0.2	0.2	0.1	Assumption, used typical value
U _{B2}	Instrument	0.2	0.2	0.2	Assumption, used typical value
U _{B3}	Board	0.3	1.7	1.7	The board was placed well and used typical value.
U _{B4}	Distance	0.1	0.1	0.1	Assumption, used typical value.
U _{B5}	Impedance	0.1	0.1	0.1	Assumption, used typical value.
U _{B6}	Turbulence	0.4	0.4	0.2	Assumption, used typical value.
U _{B7}	Wind speed, measured	0.5 x slope	0.5 x slope	0.6	Calculated using an estimated 0.5 m/s uncertainty on the wind speed
U _{B8}	Direction	0.3	0.3	0.3	Assumption, used typical value.
U _{B9}	Background	Varies by bin	Varies by bin and one-third octave center frequency bin	Varies by tone.	Difference between the regression for turbine and background for sound power level.

7.0 Exceptions

7.1 Exceptions to the Standard

1. The tonality analysis for the 10m/s bin was not performed because the available data was not suitable. There were other turbines operating in the background and this would have caused unreliable tonality results.
2. Ten-second averages were used in the analysis instead of one-minute averages to better characterize the dynamic nature of this small wind turbine.

3. Pictures were not taken of the soundboard, turbine, and meteorological tower during the test. A picture of a soundboard is included that is representative of conditions during the test.

7.2 Exceptions to the Quality Assurance System

Meteorological instruments were used past the calibration due dates. The instruments were post-test calibrated to assure the instruments were within their tolerances.

8.0 References

IEC 61400-11 Ed 2.1 2006-11 Wind Turbine Generator Systems – Part 11 Acoustic Noise Measurement Techniques

Appendix A. Picture of the soundboard



Figure 6. Picture of sound board during the test. PIX #19420.

Appendix B. Equipment Calibration Sheets

Scantek, Inc.
CALIBRATION LABORATORY

ISO 17025: 2005, ANSI/NCCL Z540:1994 Part 1 and
relevant requirements of ISO 9002:1994 ACCREDITED
by NVLAP (an ILAC and APLAC signatory)



NVLAP Lab Code: 200625-0

Calibration Certificate No.22815

Instrument: Sound Level Meter
Model: noiseLab3-NI-9233
Manufacturer: Delta
Serial number: 1258E43

Tested with: Mic. 4189 s/n 2395206 & 2395209
Preamp. 2671 s/n 2373719 & 2373721
Type (class): 1

Customer: National Renewable Energy Laboratory
Tel/Fax: 303-384-7183 /

Date Calibrated: 11/9/2010 **Cal Due:**

Status:	Received	Sent
In tolerance:	X	X
Out of tolerance:		
See comments:		
Contains non-accredited tests:	Yes	No
Calibration service:	Basic	X Standard

Address: 16253 Denver West Parkway
Golden, CO 80401-3393

Tested in accordance with the following procedures and standards:
Calibration of Sound Level Meters, Scantek Inc., 06/07/2005
SLM & Dosimeters – Acoustical Tests, Scantek Inc., 06/15/2005

Instrumentation used for calibration: Nor-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence	Cal. Due
				Cal. Lab / Accreditation	
483B-Norsonic	SME Cal Unit	25747	Dec 24, 2009	Scantek, Inc./ NVLAP	Dec 24, 2010
DS-360-SRS	Function Generator	61646	Nov 13, 2009	ACR Env. / A2LA	Nov 13, 2011
34401A-Agilent Technologies	Digital Multimeter	MY41022043	Nov 12, 2009	ACR Env. / A2LA	Nov 12, 2010
DPI 141-Druck	Pressure Indicator	790/00-04	Nov 21, 2008	Transcat / NVLAP	Nov 21, 2010
HMP233-Vaisala Oyj	Humidity & Temp. Transmitter	V3820001	Nov 25, 2009	Transcat / NVLAP	May 25, 2011
PC Program 1019 Norsonic	Calibration software	v.5.0	Validated July 2009	-	-
1253-Norsonic	Calibrator	25726	Dec 7, 2009	Scantek, Inc./ NVLAP	Dec 7, 2010

Instrumentation and test results are traceable to SI (International System of Units) through standards maintained by NIST (USA) and NPL (UK).

Environmental conditions:

Temperature (°C)	Barometric Pressure (kPa)	Relative Humidity (%)
22.3 °C	100.105 kPa	54.1 %RH

Calibrated by	Valentin Buzduga	Checked by	Mariana Buzduga
Signature		Signature	
Date	11/09/2010	Date	11/10/2010

Calibration Certificates or Test Reports shall not be reproduced, except in full, without written approval of the laboratory.
This Calibration Certificate or Test Reports shall not be used to claim product certification, approval or endorsement by NVLAP, NIST, or any agency of the federal government.
Document stored as: Z:\Calibration Lab\SLM 2010\DeltaNoiseLab3-9233_1258E43-Ch1_M1.doc

Page 1 of 2

Scantek, Inc.

CALIBRATION LABORATORY

ISO 17025: 2005, ANSI/NCSL Z540:1994 Part 1 and
relevant requirements of ISO 9002:1994 ACCREDITED
by NVLAP (an ILAC and APLAC signatory)



NVLAP Lab Code: 200625-0

Calibration Certificate No.18951

Instrument: noiseLAB Platform
Model: noiseLAB3-NI-9233
Manufacturer: Delta
Serial number: 1258E43_3-0-16
Composed of: Laptop s/n 54018537H w/ noiseLAB v. 3.0.16
Type (class): 1
Customer: National Renewable Energy Laboratory, Inc.
Tel/Fax: 303-382-6987

Date Calibrated: 11/24/2008
Status: Received Sent
In tolerance: X X
Out of tolerance:
See comments:
Contains non-accredited tests: Yes X No
Calibration service: Basic X Standard
Address: 16253 Denver West Parkway
Golden, CO 80401

Tested in accordance with the following procedures and standards:

Calibration of Sound Level Meters, Scantek Inc., 06/07/2005
Calibration of Analyzers, Scantek, Inc., 06/07/2005

Instrumentation used for calibration: Nor-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence	Cal. Due
				Cal. Lab / Accreditation	
483B-Norsonic	SME Cal Unit	31052	Jan 15, 2008	Scantek, Inc.	Jan 15, 2009
DS-360-SRS	Function Generator	33584	Jan 3, 2008	Davis Calibration / AClass	Jan 3, 2009
34401A-Agilent Technologies	Digital Voltmeter	US36120731	Aug 19, 2008	ACR Env. / A2LA	Aug 14, 2009
HM30-Thommen	Meteo Station	1040170/39633	Dec 21, 2007	Transcat / A2LA	Jun 21, 2009
PC Program 1019 Norsonic	Calibration software	v.46	Validated Dec 2006	-	-

Instrumentation and test results are traceable to SI (International System of Units) through standards maintained by NIST (USA) and NPL (UK).

Environmental conditions:

Temperature (°C)	Barometric pressure (kPa)	Relative Humidity (%)
21 °C	99.54 kPa	34.8 %RH

Calibrated by	Javier Albarracin	Checked by	Mariana Buzduga
Signature	<i>Javier Albarracin</i>	Signature	<i>Mariana Buzduga</i>
Date	11/25/2008	Date	11/25/2008

Calibration Certificates or Test Reports shall not be reproduced, except in full, without written approval of the laboratory.
This Calibration Certificate or Test Reports shall not be used to claim product certification, approval or endorsement by NVLAP, NIST, or any agency of the federal government.
Document stored as: C:\Nor1504\SI\mCal\2008\Delta\NoiseLab3-9233_1258E43_3-0-16_M2.doc

Page 1 of 2

Scantek, Inc.
CALIBRATION LABORATORY

ISO 17025: 2005, ANSI/NCSL Z540: 1994 Part 1
and relevant requirements of ISO 9002: 1994

ACCREDITED by NVLAP
(an ILAC and APLAC signatory)



NVLAP Lab Code: 200625-0

Calibration Certificate No.21065

Instrument: Acoustical Calibrator
Model: 4231
Manufacturer: Brüel and Kjær
Serial number: 2326144
Class (IEC 60942): 1
Barometer type:
Barometer s/n:

Date Calibrated: 1/14/2010
Status:

Received	Sent
X	X

In tolerance:
Out of tolerance:
See comments:
Contains non-accredited tests: Yes ☒ No

Customer: National Renewable Energy Laboratory Address: 16253 Denver West Parkway
Tel/Fax: 303-384-6388/-6391 Golden, CO 80401
beverly.kay@nrel.gov

Tested in accordance with the following procedures and standards:
Calibration of Acoustical Calibrators, Scantek Inc., 06/06/2005

Instrumentation used for calibration: Nor-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence	Cal. Due
				Cal. Lab / Accreditation	
483B-Norsonic	SME Cal Unit	25747	Dec 24, 2009	Scantek, Inc./ NVLAP	Dec 24, 2010
DS-360-SRS	Function Generator	61646	Nov 13, 2009	ACR Env. / A2LA	Nov 13, 2011
34401A-Agilent Technologies	Digital Multimeter	MY41022043	Nov 12, 2009	ACR Env. / A2LA	Nov 12, 2010
DPI 141-Druck	Pressure Indicator	790/00-04	Nov 21, 2008	Transcat / NVLAP	Nov 21, 2010
8903A-HP	Audio Analyzer	2514A05691	Jan 2, 2008	Transcat/ NVLAP	Jan 2, 2011
HMP233-Vaisala Oyj	Humidity & Temp. Transmitter	V3820001	Nov 25, 2009	ACR Env. / A2LA	May 25, 2011
PC Program 1018 Norsonic	Calibration software	v.44	Validated May 2006	-	
1253-Norsonic	Calibrator	28326	Dec 7, 2009	Scantek, Inc. / NVLAP	Dec 7, 2010
1203-Norsonic	Preamplifier	14051	Jan 4, 2010	Scantek, Inc./ NVLAP	Jan 4, 2011
4180-Brüel&Kjær	Microphone	2246115	Mar 7, 2008	NPL (UK) / UKAS	Mar 7, 2010

Instrumentation and test results are traceable to SI (International System of Units) through standards maintained by NIST (USA) and NPL (UK)

Calibrated by	Valentin Buzduga	Checked by	Mariana Buzduga
Signature		Signature	
Date	1/14/2010	Date	1/14/2010

Calibration Certificates or Test Reports shall not be reproduced, except in full, without written approval of the laboratory.
This Calibration Certificate or Test Reports shall not be used to claim product certification, approval or endorsement by NVLAP, NIST, or any agency of the federal government.
Document stored as: Z:\Calibration Lab\Cal 2009\BNC4231_2326144_M1.doc

Page 1 of 2

DEUTSCHER KALIBRIERDIENST **DKD**

Kalibrierlaboratorium für Strömungsgeschwindigkeit von Luft
Calibration laboratory for velocity of air flow

Akkreditiert durch die / *accredited by the*

Akkreditierungsstelle des Deutschen Kalibrierdienstes



DEWI GmbH
Deutsches Windenergie-Institut



DKD-K-28901

Kalibrierschein *Calibration certificate*



Kalibrierzeichen
Calibration label

1499_09

DKD-K-
28901

15.07.09

Gegenstand <i>Object</i>	Cup Anemometer
Hersteller <i>Manufacturer</i>	Thies Clima D-37083 Göttingen
Typ <i>Type</i>	4.3350.00.000
Fabrikat/Serien-Nr. <i>Serial number</i>	body: 0707890 cup: -
Auftraggeber <i>Customer</i>	Thies Clima D-37083 Goettingen,
Auftragsnummer <i>Order No.</i>	AB0901617
Anzahl der Seiten des Kalibrierscheines <i>Number of pages of the certificate</i>	3+3
Datum der Kalibrierung <i>Date of calibration</i>	15.07.09

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).

Der DKD ist Unterzeichner der multilateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.

Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.

This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).

The DKD is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.

The user is obliged to have the object recalibrated at appropriate intervals.

Dieser Kalibrierschein darf nur vollständig und unverändert weiterverbreitet werden. Auszüge oder Änderungen bedürfen der Genehmigung sowohl der Akkreditierungsstelle des DKD als auch des ausstellenden Kalibrierlaboratoriums. Kalibrierscheine ohne Unterschrift und Stempel haben keine Gültigkeit.

This calibration certificate may not be reproduced other than in full except with the permission of both the Accreditation Body of the DKD and the issuing laboratory. Calibration certificates without signature and seal are not valid.

Stempel <i>Seal</i>	Datum <i>Date</i>	Stellv. Leiter des Kalibrierlaboratoriums <i>Deputy head of the calibration laboratory</i>	Bearbeiter <i>Person in charge</i>
	15.07.09	 Dipl.-Ing. (FH) P. Busche	 R. Kluin

DEWI GmbH DEUTSCHES WINDENERGIE - INSTITUT
Ebertstr. 96, D-26382 Wilhelmshaven
Tel. +49 (0)4421 4808-0, Fax. +49 (0)4421 4808-43



DEUTSCHER KALIBRIERDIENST **DKD**

Kalibrierlaboratorium für Strömungsgeschwindigkeit von Luft
Calibration laboratory for velocity of air flow

Akkreditiert durch die / *accredited by the*

Akkreditierungsstelle des DKD bei der

PHYSIKALISCH-TECHNISCHEN BUNDESANSTALT (PTB)



Deutsche WindGuard
Wind Tunnel Services GmbH
Varel



Kalibrierschein *Calibration Certificate*

Kalibrierzeichen
Calibration label

DKD-K-
36801
07_2411

Gegenstand
Object Cup Anemometer

Hersteller
Manufacturer Thies Clima
D-37083 Göttingen

Typ
Type 4.3350.00.000

Fabrikat/Serien-Nr.
Serial number Body: 0707892
Cup: 0707892

Auftraggeber
Customer Thies Clima
D-37083 Göttingen

Auftragsnummer
Order No. VT07255

Anzahl der Seiten des Kalibrierscheines
Number of pages of the certificate 3

Datum der Kalibrierung
Date of calibration 24.07.2007

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).

Der DKD ist Unterzeichner der multi-lateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.

Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.

This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).

The DKD is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.

The user is obliged to have the object recalibrated at appropriate intervals.

Dieser Kalibrierschein darf nur vollständig und unverändert weiterverbreitet werden. Auszüge oder Änderungen bedürfen der Genehmigung sowohl der Akkreditierungsstelle des DKD als auch des ausstellenden Kalibrierlaboratoriums. Kalibrierscheine ohne Unterschrift und Stempel haben keine Gültigkeit.

This calibration certificate may not be reproduced other than in full except with the permission of both the Accreditation Body of the DKD and the issuing laboratory. Calibration certificates without signature and seal are not valid.

Stempel <i>Seal</i>	Datum <i>Date</i>	Leiter des Kalibrierlaboratoriums <i>Head of the calibration laboratory</i>	Bearbeiter <i>Person in charge</i>
	24.07.2007	 Dipl. Phys. D. Westermann	 Tech. Ass. Inf. H. Westermann

Deutsche WindGuard Wind Tunnel Services GmbH
Oldenburger Str. 65
26316 Varel ; Tel. ++49 (0)4451 9515 0



Svend Ole Hansen ApS

SCT, JORGENSEN ALLÉ 7 · DK-1615 KØBENHAVN V · DENMARK
TEL: (+45) 33 25 38 38 · FAX: (+45) 33 25 38 39 · WWW.SOHANSEN.DK



WIND
ENGINEERING
FLUID
DYNAMICS

CERTIFICATE FOR CALIBRATION OF CUP ANEMOMETER

Certificate number: 10.02.6375

Date of issue: October 25, 2010

Type: Thies 4.3350.00.000

Serial number: 0707892

Manufacturer: ADOLF THIES GmbH & Co.KG, Hauptstrasse 76, 37083 Göttingen, Germany

Client: NREL Meteorology and Calibration Laboratory, 1617 Cole Blvd, Golden, CO 80401 USA

Anemometer received: October 21, 2010

Anemometer calibrated: October 24, 2010

Calibrated by: as

Calibration procedure: IEC 61400-12-1, MEASNET

Certificate prepared by: jsa

Approved by: Calibration engineer, soh

Calibration equation obtained: $v \text{ [m/s]} = 0.04848 \cdot f \text{ [Hz]} + 0.23944$

Svend Ole Hansen

Standard uncertainty, slope: 0.00128

Standard uncertainty, offset: 0.05695

Covariance: -0.0000008 (m/s)²/Hz

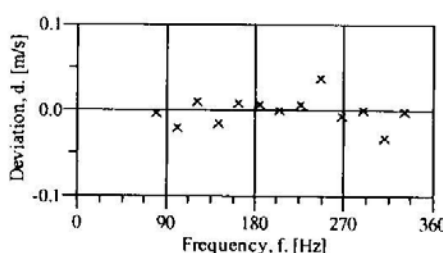
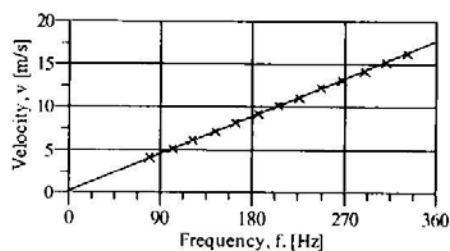
Coefficient of correlation: $\rho = 0.999991$

Absolute maximum deviation: 0.038 m/s at 12.231 m/s

Barometric pressure: 993.5 hPa

Relative humidity: 24.0%

Succession	Velocity pressure, q. [Pa]	Temperature in wind tunnel [°C]	Temperature in control room [°C]	Wind velocity, v. [m/s]	Frequency, f. [Hz]	Deviation, d. [m/s]	Uncertainty u _c (k=2) [m/s]
2	9.53	31.2	22.8	4.102	79.7246	-0.003	0.028
4	14.90	31.1	22.7	5.129	101.2622	-0.020	0.032
6	21.28	31.0	22.7	6.128	121.2465	0.010	0.037
8	28.98	30.9	22.7	7.150	142.8488	-0.015	0.043
10	37.92	30.8	22.7	8.178	163.5524	0.009	0.048
12	48.05	30.7	22.6	9.205	184.7626	0.007	0.054
13-last	58.92	30.7	22.6	10.193	205.2637	0.001	0.060
11	71.07	30.8	22.6	11.195	225.8104	0.008	0.066
9	84.82	30.8	22.7	12.231	246.5580	0.038	0.072
7	99.16	30.9	22.7	13.227	268.0057	-0.006	0.078
5	115.36	31.1	22.7	14.269	289.3657	0.001	0.084
3	132.33	31.2	22.8	15.285	310.9733	-0.031	0.090
1-first	150.50	31.4	22.8	16.307	331.4110	0.000	0.096



DANAK
CAL. Reg. nr. 452
Accreditation to ISO 17025



Page 1 of 2

Wind Vane Calibration Report

Calibration Laboratory:
National Wind Technology Center - Cert. Team
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401

Customer:
National Wind Technology Center - Certification Team
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401

Calibration Location:
National Wind Technology Center
Room 101, Building 256

Calibration Date: **13-Sep-07**

Report Number: X4357-070913

Procedure:
NWTC-CT: G124-000613, Wind Vane Calibration

Page: 1 of 1

Deviations from procedure: Calibrated on 5V range
Calibrated in Volts (not mV)


Item Calibrated:
Manufacturer Met One Instruments, Inc
Model 020C
Serial Number X4357
Vane Material Aluminum
Condition Refurbished

Results:
Slope: 71.12 deg/V
Offset to boom: 91.02 deg
Max error: 0.78 deg

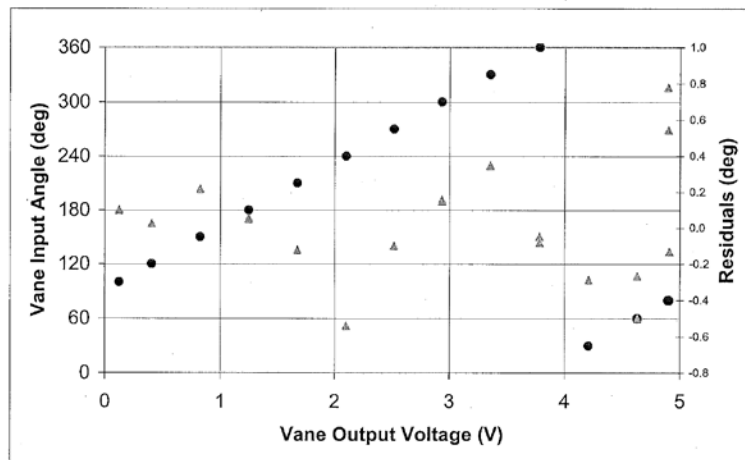
Estimated Uncertainty:

Inclinometer Uncertainty (deg)	Total Uncertainty (deg)
0.10	0.33

Traceability:	Mfg & Model	Serial Number	Cal Date
Inclinometer:	Spi-Tronic	31-038-3	22-Mar-07
Voltmeter:	Fluke743B	6965608	10-May-07

Calibration by: 
Mark Meadors

13-Sep-07
Date



Wind Vane Calibration Report

Calibration Laboratory:
National Wind Technology Center - Cert. Team
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401

Customer:
National Wind Technology Center - Certification Team
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401

Calibration Location:
National Wind Technology Center
Room 101, NWTC Bldg 256

Calibration Date: 13-Apr-10

Report Number: X4357-100413

Procedure:
NWTC-CT: CI04 Calibrate Wind Vane_091209.pdf

Page: 1 of 1

Deviations from procedure: Calibrated on 5V Range
Calibrated in Volts (not mV)
Post Calibration (Gaia)

Item Calibrated:
Manufacturer Met One Instruments, Inc
Model 020C
Serial Number X4357
Vane Material Aluminum
Condition Refurbished

Results:
Slope: 71.0530 deg/V
Offset to boom: 90.7 deg
Max error: 1.1 deg

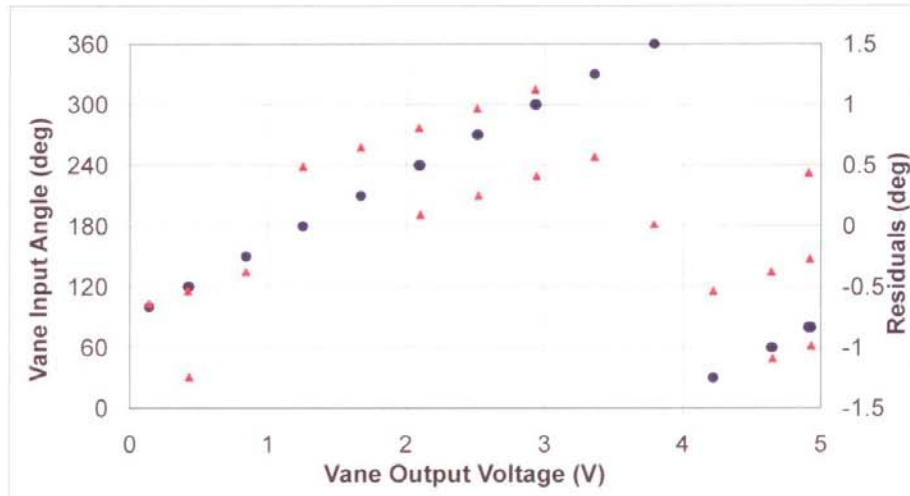
Estimated Uncertainty:
Inclinometer
Uncertainty (deg)
0.10

Total
Uncertainty (deg)
0.67

Traceability: Mfg & Mode Serial Number Cal Date
Inclinometer: SPI-Tronic 31-038-3 19-May-09
Voltmeter: HP 3458A 2823A05145 5-May-09

Calibration by: Jerry Huf

13 APR 10
Date



NREL METROLOGY LABORATORY

Test Report

Test Instrument: Pressure Transmitter

DOE #: 02729C

Model # : PTB101B

S/N : T5030003

Calibration Date: 08/26/2008

Due Date: 08/26/2009

No	Function Tested	Nominal Value (kPa)	Measured Output Voltage (VDC)		() Mfr. Specs. OR (X) Data only (mb)
			As Found	As Left	
*	Absolute Pressure				
		65	0.282		
		70	0.555		
		75	0.827		
		80	1.099		
		85	1.371		
		90	1.644		
		95	1.915		
		100	2.188		
		105	2.462		
Notes: 1. Expanded Uncertainty of the nominal value is ± 0.2 kPa, with $k = 2$. 2. Calibration was performed at 23°C and 37% RH. 3. Calibration was performed using standards that are traceable to NIST. DOE numbers: 02625C, 02727C, and 02301C.					

Calibrated By : Reda
 Date : 08/26/2008

Q.A. By: Bev
 Date : 08/26/2008

NREL METROLOGY LABORATORY

Test Report

Test Instrument: Pressure Transmitter

DOE #: 02729C

Model # : PTB101B

S/N : T5030003

Calibration Date: 04/14/2010

Due Date: 04/14/2011

N o	Function Tested	Nominal Value (kPa)	Measured Output Voltage (VDC)		()Mfr. Specs. OR (X)Data only (mb)
			As Found	As Left	
*	Absolute Pressure				
		65	0.272		
		70	0.544		
		75	0.815		
		80	1.087		
		85	1.358		
		90	1.629		
		95	1.900		
		100	2.173		
	Notes:				
	1. Expanded Uncertainty of the nominal value is ± 0.2 kPa, with $k = 2$.				
	2. Calibration was performed at 23°C and 40% RH.				
	3. Calibration was performed using standards that are traceable to NIST. DOE numbers: 02301C and 128120.				

Calibrated By : Reda
Date : 04/14/2010

Q.A. By: Bev
Date : 04/14/2010

sheet: 1 of: 1

Test Report

DOE #: 02883C

S/N : 0789021

Due Date: 10/10/2009

[illegible]

Date : 10/10/2008

Branch #: 5000

sheet: 1 of: 1

NREL METROLOGY LABORATORY

Test Report

Test Instrument: RTD-Probe

DOE #: 02883C

Model # : 78N01N00N

S/N : 0789021

Calibration Date: 04/14/2010

Due Date: 04/14/2011

No	Function Tested	Nominal Value (°C)	Measured Values (Ω)		()Mfr. Specs. OR (X)Data only
			AS Found	AS Left	
*	Temperature:	0	99.96	Same	
		30	111.63	"	
		60	123.19	"	
	Notes: - Calibration was performed using instruments that are traceable to NIST. DOE#s 124272, 108603, and 108604 - Calibration was performed at temperature = 23 °C and relative humidity = 40% - Uncertainty of Nominal Values = ± 0.03 °C, k = 2.				

Tested By: Reda

Date : 04/14/2010



*Certificate of
Calibration*

Board Information:

Serial Number: 12CBC7A
NI Part Number: 192580D-02
Description: NI 9229

Certificate Information:

Certificate Number: 793243
Date Printed: 20-NOV-08

Calibration Date: 14-AUG-07
Recommended Calibration Due Date: 14-AUG-08*

Ambient Temperature: 23 °C
Relative Humidity: 60 %

National Instruments certifies that at the time of manufacture, the above product was calibrated in accordance with applicable National Instruments procedures. These procedures are in compliance with relevant clauses of ISO 9001 and are designed to assure that the product listed above meets or exceeds National Instruments specifications.

National Instruments further certifies that the measurements standards and instruments used during the calibration of this product are traceable to National and/or International Standards administered by NIST or Euromet members or are derived from accepted values of natural physical constants.

The environment in which this product was calibrated is maintained within the operating specifications of the instrument and the standards.

The information shown on this certificate applies only to the instrument identified above and the certificate may not be reproduced, except in full, without prior written consent by National Instruments.

For questions or comments, please contact National Instruments Technical Support.

NI Hungary Software és
Hardware Gyártó Kft.
4031 Debrecen, Határ út
1/A.
HUNGARY

Signed,

Andrew Krupp
Quality Director

* Recommended calibration due date is based on a combination of calibration interval and, when applicable, calibration shelf life. This date may vary depending on your application requirements.

Board Information:

Serial Number: 12BFEE2
NI Part Number: 192547D-01
Description: NI 9217

Certificate Information:

Certificate Number: 775348
Date Printed: 20-NOV-08

Calibration Date: 20-JUL-07
Recommended Calibration Due Date: 20-JUL-08*

Ambient Temperature: 26 °C
Relative Humidity: 45 %

National Instruments certifies that at the time of manufacture, the above product was calibrated in accordance with applicable National Instruments procedures. These procedures are in compliance with relevant clauses of ISO 9001 and are designed to assure that the product listed above meets or exceeds National Instruments specifications.

National Instruments further certifies that the measurements standards and instruments used during the calibration of this product are traceable to National and/or International Standards administered by NIST or Euromet members or are derived from accepted values of natural physical constants.

The environment in which this product was calibrated is maintained within the operating specifications of the instrument and the standards.

The information shown on this certificate applies only to the instrument identified above and the certificate may not be reproduced, except in full, without prior written consent by National Instruments.

For questions or comments, please contact National Instruments Technical Support.

NI Hungary Software és
Hardware Gyártó Kft.
4031 Debrecen, Határ út
1/A.
HUNGARY

Signed,



Andrew Krupp
Quality Director

* Recommended calibration due date is based on a combination of calibration interval and, when applicable, calibration shelf life. This date may vary depending on your application requirements.

Board Information:

Serial Number: 12E9C99
NI Part Number: 193299F-01
Description: NI-9205

Certificate Information:

Certificate Number: 835019
Date Printed: 20-NOV-08

Calibration Date: 08-OCT-07
Recommended Calibration Due Date: 08-OCT-08*

Ambient Temperature: 23 °C
Relative Humidity: 38 %

National Instruments certifies that at the time of manufacture, the above product was calibrated in accordance with applicable National Instruments procedures. These procedures are in compliance with relevant clauses of ISO 9001 and are designed to assure that the product listed above meets or exceeds National Instruments specifications.

National Instruments further certifies that the measurements standards and instruments used during the calibration of this product are traceable to National and/or International Standards administered by NIST or Euromet members or are derived from accepted values of natural physical constants.

The environment in which this product was calibrated is maintained within the operating specifications of the instrument and the standards.

The information shown on this certificate applies only to the instrument identified above and the certificate may not be reproduced, except in full, without prior written consent by National Instruments.

For questions or comments, please contact National Instruments Technical Support.

NI Hungary Software és
Hardware Gyártó Kft.
4031 Debrecen, Határ út
1/A.
HUNGARY

Signed,



Andrew Krupp
Quality Director

* Recommended calibration due date is based on a combination of calibration interval and, when applicable, calibration shelf life. This date may vary depending on your application requirements.



Certificate of Calibration

3214337

Certificate Page 1 of 1

Instrument Identification

Company ID: 229037
NATIONAL INSTRUMENTS

PO Number: 337683

11500 N. MOPAC EXPWY
ATTN: RMA DEPT.
AUSTIN, TX 78759

Instrument ID: 12CBC7A

Model Number: NI 9229

Manufacturer: NATIONAL INSTRUMENTS

Serial Number: 12CBC7A

Description: 4-CHANNEL, ± 60 V, 24-BIT SIMULTANEOUS ANALOG INPUT

Accuracy: Mfr Specifications

Certificate Information

Reason For Service: CALIBRATION

Type of Cal: ACCREDITED 17025

As Found Condition: IN TOLERANCE

As Left Condition: LEFT AS FOUND

Procedure: NATIONAL INSTRUMENTS CAL EXECUTIVE REV 3.3.1

Remarks: Reference attached Data.

Technician: WAYNE GETCHELL

Cal Date: 06May2009

Cal Due Date: 06May2010

Interval: 12 MONTHS

Temperature: 23.0 C

Humidity: 44.0 %

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 (K=2, approx. 95% Confidence Level) was maintained unless otherwise stated.

Davis Calibration Laboratory is certified to ISO 9001:2000 by Eagle Registrations (certificate # 3046). Lab Operations meet the requirements of ANSI/NCISL Z540-1-1994, ISO 10012:2003, 10CFR30 AppxB, and 10CFR21.

ISO/IEC 17025:2005 accredited calibrations are per ACLASS certificate # AC-1187 within the scope for which the lab is accredited.

All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.

This certificate shall not be reproduced except in full, without written consent of Davis Calibration Laboratory.

Approved By: VICTOR PENA
Service Representative

Calibration Standards

<u>NIST Traceable#</u>	<u>Inst. ID#</u>	<u>Description</u>	<u>Model</u>	<u>Cal Date</u>	<u>Date Due</u>
3143038	15-0271	MULTIFUNCTION CALIBRATOR	5700A	15Apr2009	14Jul2009

Davis Calibration • 2324 Ridgepoint Drive, Suite D • Austin, TX 78754 • Phone: 800-365-0147 • Fax: 512-926-8450



Certificate of Calibration

3214181

Certificate Page 1 of 1

Instrument Identification

Company ID: 229037
NATIONAL INSTRUMENTS

PO Number: 337683

11500 N. MOPAC EXPWY
ATTN: RMA DEPT.
AUSTIN, TX 78759

Instrument ID: 12BFEE2
Manufacturer: NATIONAL INSTRUMENTS
Description: 4-CH 100 OHM 24-BIT RTD ANALOG INPUT

Model Number: NI 9217
Serial Number: 12BFEE2

Accuracy: Mfr. Specifications

Certificate Information

Reason For Service: CALIBRATION
Type of Cal: ACCREDITED 17025
As Found Condition: IN TOLERANCE
As Left Condition: LEFT AS FOUND
Procedure: CAL EXEC 3.3.1 CAL EXEC 3.3.1

Technician: WAYNE GETCHELL
Cal Date: 06May2009
Cal Due Date: 06May2010
Interval: 12 MONTHS
Temperature: 23.0 C
Humidity: 46.0 %

Remarks: Reference attached Data.

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [K=2, approx. 95% Confidence Level] was maintained unless otherwise stated.

Davis Calibration Laboratory is certified to ISO 9001:2000 by Eagle Registrations (certificate # 3046). Lab Operations meet the requirements of ANSI/NCSL Z540-1-1994, ISO 10012:2003, 10CFR35 AppxB, and 10CFR21.

ISO/IEC 17025:2005 accredited calibrations are per ACLASS certificate # AC-1187 within the scope for which the lab is accredited. All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.

This certificate shall not be reproduced except in full, without written consent of Davis Calibration Laboratory.

Approved By: VICTOR PENA
Service Representative

Calibration Standards

NIST Traceable#	Inst. ID#	Description	Model	Cal Date	Date Due
3078982	15-0011	DECADE RESISTOR	DB52	24Mar2009	24Mar2010
3004178	15-0060	DIGITAL MULTIMETER (GOLDEN CAL)	3458A OPT 002	17Feb2009	17May2009

Davis Calibration • 2324 Ridgepoint Drive, Suite D • Austin, TX 78754 • Phone: 800-365-0147 • Fax: 512-926-8450



Certificate of Calibration

3214135

Certificate Page 1 of 1

Instrument Identification

Company ID: 229037
NATIONAL INSTRUMENTS

PO Number: 337683

11500 N. MOPAC EXPWY
ATTN. RMA DEPT.
AUSTIN, TX 78759

Instrument ID: 12E9C99

Model Number: NI 9205

Manufacturer: NATIONAL INSTRUMENTS

Serial Number: 12E9C99

Description: 32-CH ± 200 MV TO ± 10 V, 16-BIT, 250 KS/S ANALOG INPUT MODULE

Accuracy: Mfr Specifications

Certificate Information

Reason For Service: CALIBRATION

Technician: WAYNE GETCHELL

Type of Cal: ACCREDITED 17025

Cal Date: 06May2009

As Found Condition: IN TOLERANCE

Cal Due Date: 06May2010

As Left Condition: LEFT AS FOUND

Interval: 12 MONTHS

Procedure: NATIONAL INSTRUMENTS CAL EXECUTIVE REV 3.3.1

Temperature: 23.0 C

Humidity: 47.0 %

Remarks: Reference attached Data.

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 ($K=2$, approx. 95% Confidence Level) was maintained unless otherwise stated.

Davis Calibration Laboratory is certified to ISO 9001:2000 by Eagle Registrations (certificate # 3046). Lab Operations meet the requirements of ANSI/NCSL Z540-1-1994, ISO 10012:2003, 10CPR50 AppxB, and 10CPR21.

ISO/IEC 17025-2005 accredited calibrations are per ACLASS certificate # AC-1187 within the scope for which the lab is accredited. All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.

This certificate shall not be reproduced except in full, without written consent of Davis Calibration Laboratory.

Approved By: VICTOR PENA
Service Representative

Calibration Standards

NIST Traceable#	Inst. ID#	Description	Model	Cal Date	Date Due
3143038	15-0271	MULTIFUNCTION CALIBRATOR	5700A	15Apr2009	14Jul2009

Board Information:

Serial Number: 140A596
NI Part Number: 192580G-02L
Description: NI 9229

Certificate Information:

Certificate Number: 1309509
Date Printed: 03-APR-09

Calibration Date: 10-FEB-09
Recommended Calibration Due Date: 10-FEB-10*

Ambient Temperature: 23 °C
Relative Humidity: 41 %

National Instruments certifies that at the time of manufacture, the above product was calibrated in accordance with applicable National Instruments procedures. These procedures are in compliance with relevant clauses of ISO 9001 and are designed to assure that the product listed above meets or exceeds National Instruments specifications.

National Instruments further certifies that the measurements standards and instruments used during the calibration of this product are traceable to National and/or International Standards administered by NIST or Euromet members or are derived from accepted values of natural physical constants.

The environment in which this product was calibrated is maintained within the operating specifications of the instrument and the standards.

The information shown on this certificate applies only to the instrument identified above and the certificate may not be reproduced, except in full, without prior written consent by National Instruments.

For questions or comments, please contact National Instruments Technical Support.

NI Hungary Software és
Hardware Gyártó Kft.
4031 Debrecen, Határ út
1/A.
HUNGARY

Signed,



Andrew Krupp
Vice President, Quality and
Continuous Improvement

* Recommended calibration due date is based on a combination of calibration interval and, when applicable, calibration shelf life. This date may vary depending on your application requirements.



Instrument Identification

Company ID: 120205
NREL
METROLOGY LAB / BEV KAY
16253 DENVER WEST PARKWAY
GOLDEN, CO, 80401

PO Number: CC-BEVERLY KAY

Instrument ID: **04074C**

Model Number: NI 9229

Manufacturer: NATIONAL INSTRUMENTS

Serial Number: 140A596

Description: 4-CHANNEL, ± 60 V, 24-BIT SIMULTANEOUS ANALOG INPUT

Accuracy: Mfr Specifications

Certificate Information

Reason For Service: CALIBRATION

Technician: COREY CLAXTON

Type of Cal: ACCREDITED 17025 WITH UNCERTAINTIES

Cal Date: 29Apr2010

As Found Condition: IN TOLERANCE

Cal Due Date: 29Apr2011

As Left Condition: LEFT AS FOUND

Interval: 12 MONTHS

Procedure: NATIONAL INSTRUMENTS CAL EXECUTIVE REV 3.3.2

Temperature: 23.0 C

Humidity: 58.0 %

Remarks: CALIBRATED WITH DATA, REFER TO ATTACHED DATA FOR BEFORE AND AFTER READINGS.

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [K=2, approx. 95% Confidence Level] was maintained unless otherwise stated.

Davis Calibration Laboratory is certified to ISO 9001:2008 by Eagle Registrations (certificate # 3046). Lab Operations meet the requirements of ANSI/ISO/IEC 17025:2005 (R2002), ISO 10012:2003, IECFR50 AppB, and IECFR21.

ISO/IEC 17025:2005 accredited calibrations are per ACLASS certificate # AC-1187 within the scope for which the lab is accredited.

When uncertainty measurement calculations have been calculated per customer request, reported condition statements do not take into account uncertainty of measurement.

All results contained within this certification relate only to item(s) calibrated. Any number of factory may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.

This certificate shall not be reproduced except in full, without written consent of Davis Calibration Laboratory.

Approved By: COREY CLAXTON
Service Representative

Calibration Standards

NIST Traceable#	Inst. ID#	Description	Model	Cal Date	Date Due
4047816	15-0048	MULTIFUNCTION CALIBRATOR	5700A	07Apr2010	06Jul2010

Board Information:

Serial Number: 140DCB9
NI Part Number: 192547E-01L
Description: NI 9217

Certificate Information:

Certificate Number: 1313164
Date Printed: 06-APR-09

Calibration Date: 12-FEB-09
Recommended Calibration Due Date: 12-FEB-10*

Ambient Temperature: 22 °C
Relative Humidity: 42 %

National Instruments certifies that at the time of manufacture, the above product was calibrated in accordance with applicable National Instruments procedures. These procedures are in compliance with relevant clauses of ISO 9001 and are designed to assure that the product listed above meets or exceeds National Instruments specifications.

National Instruments further certifies that the measurements standards and instruments used during the calibration of this product are traceable to National and/or International Standards administered by NIST or Euromet members or are derived from accepted values of natural physical constants.

The environment in which this product was calibrated is maintained within the operating specifications of the instrument and the standards.

The information shown on this certificate applies only to the instrument identified above and the certificate may not be reproduced, except in full, without prior written consent by National Instruments.

For questions or comments, please contact National Instruments Technical Support.

NI Hungary Software és
Hardware Gyártó Kft.
4031 Debrecen, Határ út
1/A.
HUNGARY

Signed,



Andrew Krupp
Vice President, Quality and
Continuous Improvement

* Recommended calibration due date is based on a combination of calibration interval and, when applicable, calibration shelf life. This date may vary depending on your application requirements.

Davis Calibration



Certificate of Calibration



4111821

Certificate Page 1 of 1

Instrument Identification

Company ID: 120205
NREL
METROLOGY LAB / BEV KAY
16253 DENVER WEST PARKWAY
GOLDEN, CO, 80401

PO Number: CC-BEVERLY KAY

Instrument ID: **04072C**
Manufacturer: NATIONAL INSTRUMENTS
Description: 4-CH 100 OHM 24-BIT RTD ANALOG INPUT
Accuracy: Mfr. Specifications

Model Number: NI 9217
Serial Number: 140DCB9

Certificate Information

Reason For Service: CALIBRATION
Type of Cal: ACCREDITED 17025 WITH UNCERTAINTIES
As Found Condition: IN TOLERANCE
As Left Condition: LEFT AS FOUND
Procedure: NATIONAL INSTRUMENTS CAL EXECUTIVE REV 3.3.2

Technician: COREY CLAXTON
Cal Date: 29Apr2010
Cal Due Date: 29Apr2011
Interval: 12 MONTHS
Temperature: 23.0 C
Humidity: 58.0 %

Remarks: CALIBRATED WITH DATA, REFER TO ATTACHED DATA FOR BEFORE AND AFTER READINGS.

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [K=2, approx. 95% Confidence Level] was maintained unless otherwise stated.

Davis Calibration Laboratory is certified to ISO 9001:2008 by Eagle Registrations (certificate # 3046). Lab Operations meet the requirements of ANSI/ISO/IEC 17025-2005 (R2002), ISO 10012:2003, 10CFR50 AppB, and 10CFR21.

ISO/IEC 17025-2005 accredited calibrations are per ACLASS certificate # AC-1187 within the scope for which the lab is accredited. When uncertainty measurement calculations have been calculated per customer request, reported condition statements do not take into account uncertainty of measurement. All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.

This certificate shall not be reproduced except in full, without written consent of Davis Calibration Laboratory.

Approved By: COREY CLAXTON
Service Representative

Calibration Standards

NIST Traceable#	Inst. ID#	Description	Model	Cal Date	Date Due
4085286	15-0060	DIGITAL MULTIMETER (GOLDEN CAL)	3458A OPT 002	15Apr2010	14Jul2010

Davis Calibration • 2324 Ridgepoint Drive, Suite D • Austin, TX 78754 • Phone: 800-365-0147 • Fax: 512-926-8450

Board Information:

Serial Number: 140E2BD
NI Part Number: 193299F-01
Description: NI-9205

Certificate Information:

Certificate Number: 1308869
Date Printed: 06-APR-09

Calibration Date: 10-FEB-09
Recommended Calibration Due Date: 10-FEB-10*

Ambient Temperature: 23 °C
Relative Humidity: 40 %

National Instruments certifies that at the time of manufacture, the above product was calibrated in accordance with applicable National Instruments procedures. These procedures are in compliance with relevant clauses of ISO 9001 and are designed to assure that the product listed above meets or exceeds National Instruments specifications.

National Instruments further certifies that the measurements standards and instruments used during the calibration of this product are traceable to National and/or International Standards administered by NIST or Euromet members or are derived from accepted values of natural physical constants.

The environment in which this product was calibrated is maintained within the operating specifications of the instrument and the standards.

The information shown on this certificate applies only to the instrument identified above and the certificate may not be reproduced, except in full, without prior written consent by National Instruments.

For questions or comments, please contact National Instruments Technical Support.

NI Hungary Software és
Hardware Gyártó Kft.
4031 Debrecen, Határ út
1/A.
HUNGARY

Signed,



Andrew Krupp
Vice President, Quality and
Continuous Improvement

* Recommended calibration due date is based on a combination of calibration interval and, when applicable, calibration shelf life. This date may vary depending on your application requirements.



Certificate of Calibration



4111826

Certificate Page 1 of 1

Instrument Identification

Company ID: 120205
NREL
METROLOGY LAB / BEV KAY
16253 DENVER WEST PARKWAY
GOLDEN, CO, 80401

PO Number: CC-BEVERLY KAY

Instrument ID: **04071C** Model Number: NI 9205
Manufacturer: NATIONAL INSTRUMENTS Serial Number: 140E2BD
Description: 32-CH ± 200 MV TO ± 10 V, 16-BIT, 250 KS/S ANALOG INPUT MODULE

Accuracy: Mfr Specifications

Certificate Information

Reason For Service: CALIBRATION Technician: COREY CLAXTON
Type of Cal: ACCREDITED 17025 WITH UNCERTAINTIES Cal Date 29Apr2010
As Found Condition: IN TOLERANCE Cal Due Date: 29Apr2011
As Left Condition: LEFT AS FOUND Interval: 12 MONTHS
Procedure: NATIONAL INSTRUMENTS CAL EXECUTIVE REV 3.3.2 Temperature: 23.0 C
Humidity: 58.0 %
Remarks: CALIBRATED WITH DATA, REFER TO ATTACHED DATA FOR BEFORE AND AFTER READINGS.

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [K=2, approx. 95% Confidence Level] was maintained unless otherwise stated.

Davis Calibration Laboratory is certified to ISO 9001:2008 by Eagle Registrations (certificate # 3046). Lab Operations meet the requirements of ANSI/NCSL Z540-1-1994 (R2002), ISO 10012:2003, 10CFR50 AppxB, and 10CFR21.

ISO/IEC 17025-2005 accredited calibrations are per ACLASS certificate # AC-1187 within the scope for which the lab is accredited.

When uncertainty measurement calculations have been calculated per customer request, reported condition statements do not take into account uncertainty of measurement.

All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.

This certificate shall not be reproduced except in full, without written consent of Davis Calibration Laboratory.

Approved By: COREY CLAXTON
Service Representative

Calibration Standards

NIST Traceable#	Inst. ID#	Description	Model	Cal Date	Date Due
4047816	15-0048	MULTIFUNCTION CALIBRATOR	5700A	07Apr2010	06Jul2010