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Wind Turbine Generator System Power Performance Test Report for the Gaia-Wind 11-kW Wind Turbine

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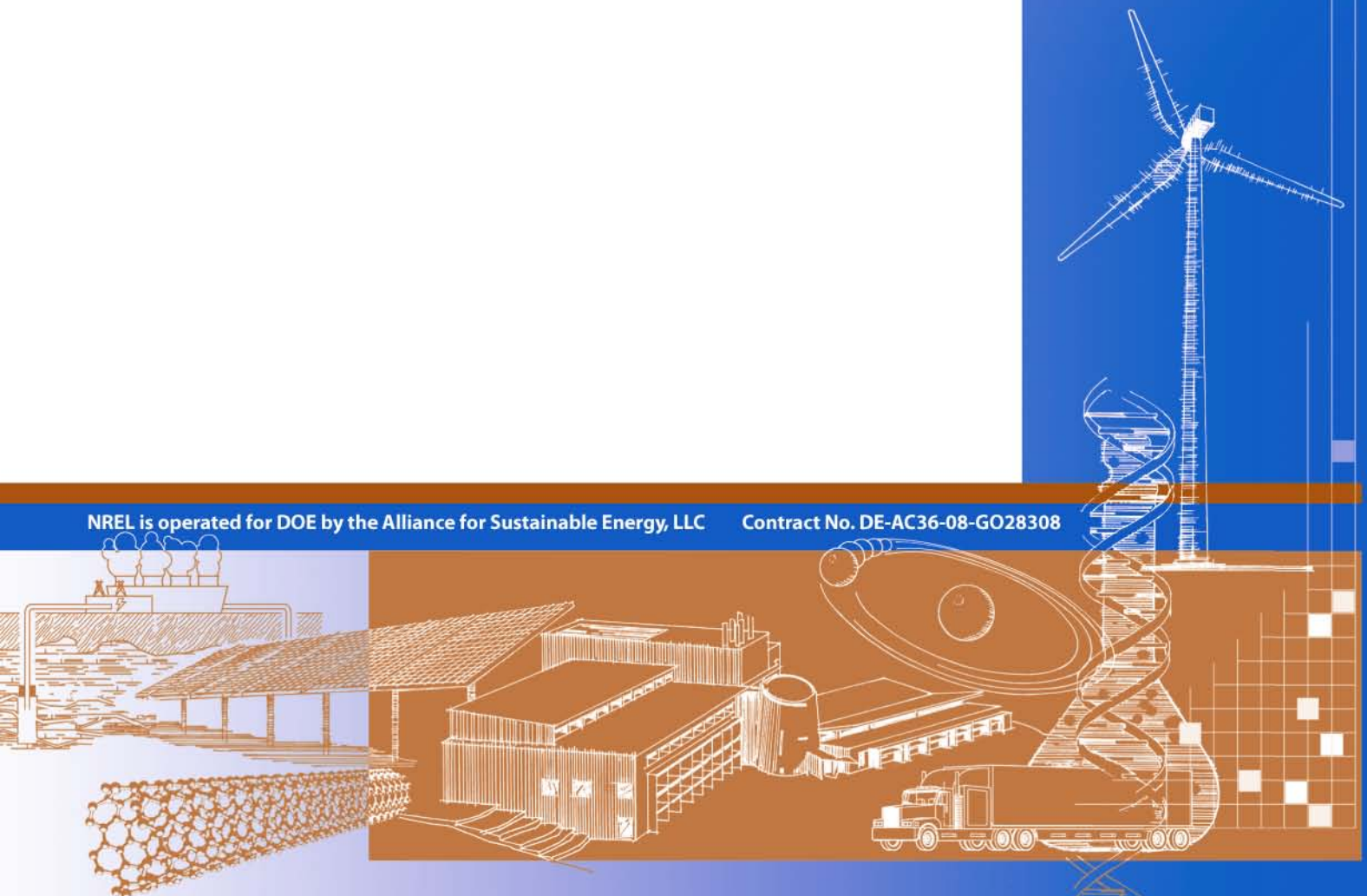

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Wind Turbine Generator System
Power Performance Test Report
for the
Gaia-Wind 11-kW Wind Turbine

Conducted for

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Conducted by

National Wind Technology Center
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June 11, 2009

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Approval By: _____

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1. 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. Power performance testing is one of up to 5 tests that may be performed on the turbines, including duration, safety and function, noise, and power quality tests.

2. Test Summary

Figure 1 is a summary of the results of a power performance test that the National Renewable Energy Laboratory (NREL) conducted on the Gaia-Wind 11-kW small wind turbine (shown in Figure 2). In this test, the Gaia-Wind 11-kW turbine was installed at the NWTC near Boulder, Colorado. This test was conducted in accordance with the International Electrotechnical Commission (IEC) standard, *Wind Turbine Generator Systems Part 12: Power Performance Measurements of Electricity Producing Wind Turbines*, IEC 61400-12-1 Ed.1.0, 2005-12. Because the Gaia-Wind 11-kW is a small turbine according to the IEC definition, NREL also followed Annex H, which applies to small wind turbines. This test report refers to these procedures as the "Standard."

In these summary results, power is normalized to sea-level air density. This test began on June 9, 2008, and ended on October 27, 2008. In all, NREL collected 1070.03 hours of valid data during that period. The highest bin filled was the 20.0 m/s bin. The amount of test data is sufficient to meet the requirements of the Standard.

National Renewable Energy Laboratory

Power Performance Test

Gaia-Wind 11-kW

Sea-Level Air Density Normalized Power Curve

Turbine Specifications:

Serial Number:	10711114	
Rated Power:	11	kW
Cut-in Wind Speed:	3.50	m/s
Cut-out Wind Speed:	25	m/s
Rated Wind Speed:	9.5	m/s
Rotor Diameter:	13	m
Control Type:	Stall	
Pitch Setting:	Fixed	

Site Conditions:

Location:	NWTC, Boulder, CO	
Average Air Density:	0.97	kg/m^3
Measurement Sectors:	257-332	degrees true
	147-197	degrees true

Test Statistics:

Start Date:	9-Jun-2008	
End Date:	27-Oct-2008	
Amount of Data Collected:	1070.03	hours
Highest Bin Filled:	20.00	m/s
Test Completed?	Yes	

Bin Wind Speed (m/s)	Bin Power (kW)	Number Data Points	Cp
0.49	-0.08	1,313	-8.43
1.03	-0.08	2,467	-0.93
1.52	-0.08	4,301	-0.29
2.01	-0.08	6,209	-0.12
2.50	-0.08	7,672	-0.07
3.00	-0.10	7,347	-0.04
3.49	-0.11	6,270	-0.03
3.99	0.31	5,193	0.06
4.49	1.15	3,951	0.16
4.99	2.28	3,021	0.23
5.49	3.67	2,381	0.27
5.99	5.00	2,017	0.29
6.49	6.27	1,706	0.28
7.00	7.57	1,455	0.27
7.49	8.70	1,358	0.25
7.99	9.80	1,142	0.24
8.49	10.77	970	0.22
9.00	11.67	873	0.20
9.50	12.36	713	0.18
10.00	13.12	604	0.16
10.49	13.69	520	0.15
11.00	14.15	417	0.13
11.49	14.59	336	0.12
12.00	14.80	317	0.11
12.49	14.90	280	0.09
13.00	15.00	225	0.08
13.49	14.93	187	0.07
13.99	14.80	180	0.07
14.48	14.60	146	0.06
15.00	14.40	117	0.05
15.48	14.49	100	0.05
16.03	14.42	87	0.04
16.50	14.15	70	0.04
16.99	14.24	66	0.04
17.50	14.13	59	0.03
17.99	14.08	53	0.03
18.48	13.91	31	0.03
18.99	14.00	25	0.03
19.45	14.11	13	0.02
19.92	13.74	10	0.02

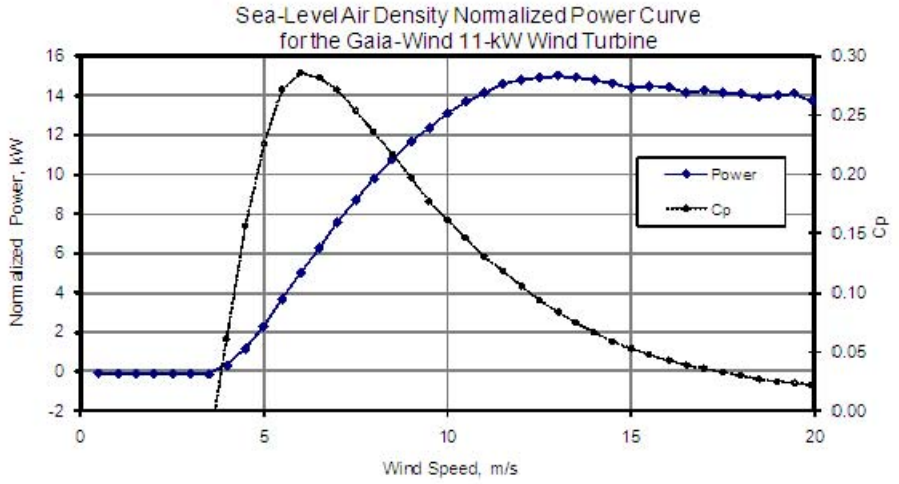

Figure 1. Power curve summary

Figure 2. Gaia-Wind 11-kW test turbine at the NWTC

3. Test Turbine Configuration

Table 1 lists the configuration of the Gaia-Wind 11-kW that was tested at the NWTC.

Table 1. Test turbine configuration

Turbine make, model, serial number, production year	Gaia-Wind 11-kW, 10711114, 2007
Rotor diameter (m)	13
Hub height (m)	18.2
Tower type	Tubular
Rated electrical power (kW)	11
Rated wind speed (m/s)	9.5
Rotor speed range (rpm)	56–62
Fixed or variable pitch	Fixed blade, variable tip
Number of blades	2
Blade tip pitch angle (deg)	90
Blade make, type, serial number	Gaia-Wind T202, glass fiber, centrifugally activated tip brake, 2007/22
Control system (device and software version)	Gaia-Wind IC-1000, Rev.1:P00515\031020

Measurements verified the rotor diameter. The tip pitch changed when deployed.

4. Test Site Description

The test turbine is located at site 3.3B at the NWTC, which is 8 miles south of Boulder, Colorado. The terrain consists of mostly flat terrain with short vegetation (see Appendix A for photos of the test site). The site has prevailing winds bearing 292 degrees relative to true north. For measurements for which it is important to accurately measure wind speed, NREL uses data obtained when the wind direction is between 257 and 332, and between 147 and 197 degrees true. In this measurement sector, the influence of terrain and obstructions on the anemometer is small. Figure 3 shows the turbine and meteorological tower locations as well as nearby obstructions and topographical features of the site. Table 2 gives sizes and distances of nearby obstructions.

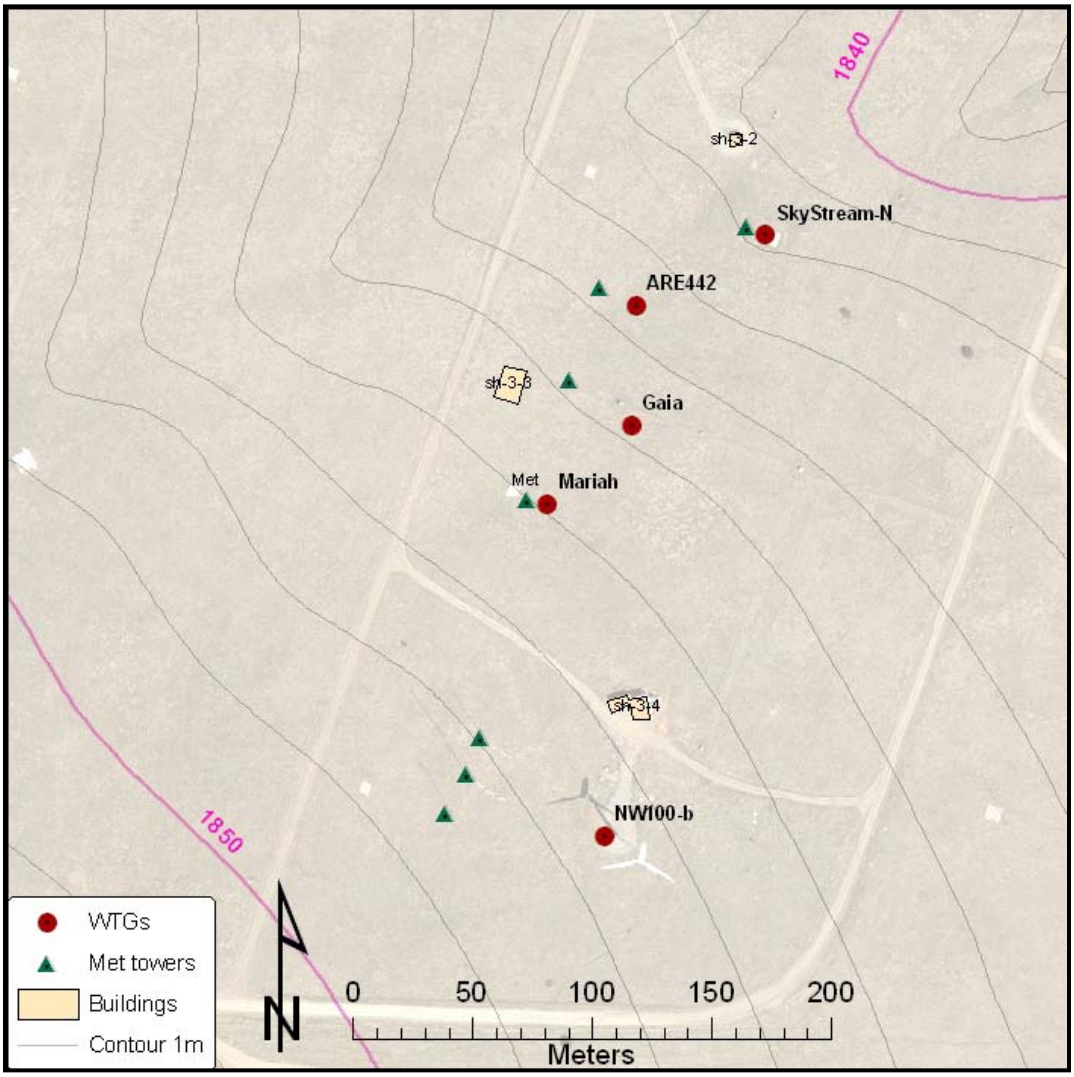

Figure 3. Map of the test site

Table 2. Structures close to test turbine

Designation	Bearing from Test Turbine (degrees T)	Distance from Test Turbine (m)	Obstruction Height (m)	Rotor Diameter or Obstruction Width (m)
Met B	290	107.5	18.2	0.4
Data shed	292	207.5	3.1	7.0
ARE	2	157.6	31.0	7.3
Met A	344	184.9	31.0	0.4
Mariah	227	168.9	6.1	1.2
Met C	236	184.5	4.6	0.4

NREL completed a site assessment to determine if the site fails the requirements of Annex A of the Standard and would therefore require a site calibration. Table 3 shows the results from the site assessment, which confirm that a site calibration was not required.

Table 3. Criteria for test site without site calibration

Description	Distance	Sector (deg)	Test Site Condition	Pass/Fail
Maximum slope of best fit plane <3%	<2 L	360	2.9%	Pass
Maximum variation from best fit plane <0.08 D	<2 L	360	0.01	Pass
Maximum slope of best fit plane <5%	2–4 L	In	1.2%	Pass
Maximum variation from best fit plane <0.15 D	2–4 L	In	0.02	Pass
Steepest slope maximum <10%	2–4 L	Out	2.3%	Pass
Maximum slope of best fit plane <10%	4–8 L	In	1.2%	Pass
Maximum variation from best fit plane <0.15 D	4–8 L	In	0.02	Pass
No neighboring and operating turbines	<2 D_n	360	0	Pass
No obstacles	<2 D_e	360	0	Pass

D = test turbine rotor diameter
L = distance between test turbine and meteorological tower
D_e = equivalent diameter of obstacle
In = inside preliminary measurement sector
Out = outside preliminary measurement sector

The Gaia-Wind 11-kW was connected to the electrical grid at a nominal voltage of 480 VAC at a frequency of 60 Hz. The grid tolerances are 5% for voltage amplitude and 1% for frequency.

5. Description of Test Equipment

All test equipment was calibrated; Appendix B contains the calibration sheets. Table 4 shows the equipment used and calibration due dates. Figure 4 depicts the placement of the meteorological instruments on the tower. The primary anemometer was sent out for recalibration after the test period. The difference between the pre-test and post-test calibrations was within the tolerances allowed by the Standard.

Table 4. Equipment used in the power performance test

Instrument	Make and Model	Serial Number	Calibration Due Date
Power transducer	Ohio Semitronics, DMT 1040E	06091046	February 15, 2010
Current transformers	Ohio Semitronics, 12974	001293045 001235428 001293049	Calibrated with power transducer
Primary anemometer	Thies, First Class	0707890	April 7, 2009
Reference anemometer	NRG, Max 40	179500049023	In situ
Wind vane	Met One, 020C with Aluminum Vane	X4357	April 7, 2009
Pressure sensor (replaced during test)	Vaisala, PTB101B	C1040014 T5030003	October 29, 2008 August, 26 2009
Temperature sensor (replaced during test)	Met One, T200	0890084 0789021	October 29, 2008 October 10, 2009
Precipitation sensor	Campbell Scientific, 237	None	In situ
Data acquisition system	Compact DAQ w/LabView cDAQ backplane NI 9229 NI 9217 NI 9205	 12E4DA3 12CBC7A 12BFEE2 12E9C99	 August 14, 2008 July 20, 2008 October 8, 2008 Modules post-test calibrated on May 5, 2009, were in compliance

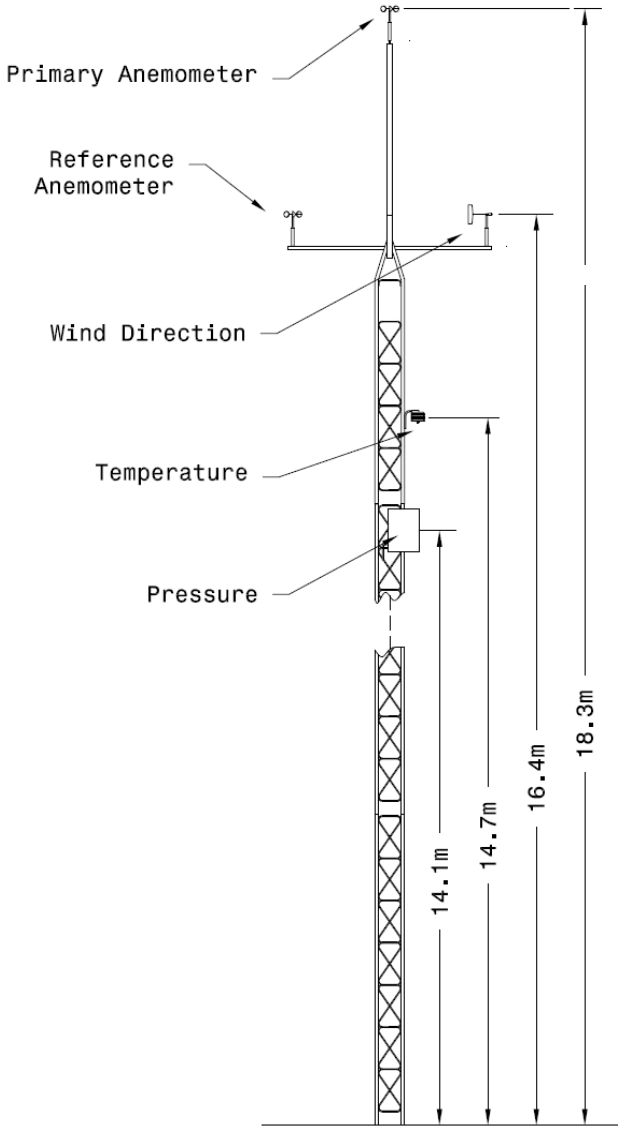

Figure 4. Meteorological tower and instruments

To ensure that only data obtained during normal operation of the turbine are used in the analysis, and to ensure that data are not corrupted, NREL excluded data sets from the database under the following circumstances:

- External conditions other than wind speed are out of the normal range for turbine operation.
- The turbine cannot operate because of a turbine fault condition.
- The turbine is manually shut down or in a test or maintenance operating mode.

Two methods are used to track when any of these conditions occur during the test. In the first method, the logbook will be checked for such events. The turbine controller provides two status signals that indicate when the turbine is available or braked. In the second method, these status signals are checked in the data file during analysis.

6. Description of Test Procedure

NREL conducted the test according to the procedures in the Standard. The sampling rate was 10 kHz, decimated to 40 Hz. The averaging time was 1 minute for the mean values. NREL also collected standard deviation, minimum, and maximum values for each averaging period.

The turbine status signals for the Gaia-Wind 11-kW originate from the turbine controller. The status signals indicated whether the turbine was available or braked.

Only database A is reported because the turbine did not reach cut-out wind speeds during the test period.

Table 5 gives the uncertainty sources and values used in the analysis.

Table 5. Uncertainty values used in the analysis

Component	Uncertainty	Source
Power		
Current sensor/signal conditioner	15.36 W	Specifications
Power transducer	0.09%	Specifications
Data acquisition	56W +0.08%	Specifications
Resistor	0.01%	Specifications
Wind Speed		
Calibration	0.01 m/s	Calibration sheet
Operational characteristics	0.05 m/s +0.52%	IEC equation (I.2)
Mounting effects	1.00%	Assumption
Terrain effects	2.00%	IEC
Data acquisition	< 0.01 m/s	Assumption
Temperature		
Temperature sensor	0.15 °C	Specifications
Radiation shielding	1.15 °C	Assumption
Mounting effects	0.06 °C	IEC method
Data acquisition	0.35 °C	Specifications
Air Pressure		
Pressure sensor	0.20 kPa	Specifications
Mounting effects	< 0.01 kPa	IEC method
Data acquisition	0.06 kPa	Specifications

7. Test Results

7.1. Tabular Results of Power Performance Test

Table 6 through Table 9 list the power performance test results. Table 6 shows the binned power performance results at sea-level normalized air density. Table 7 shows the binned power performance results at the site average air density for the NWTC.

Table 6. Performance at sea-level air density, 1.225 kg/m^3

Measured Power Curve (Database A)							
Reference Air Density: 1.225 kg/m^3					Category A Standard Uncertainty (kW)	Category B Standard Uncertainty (kW)	Combined Standard Uncertainty (kW)
Bin (m/s)	Wind Speed (m/s)	Normalized Power Output (kW)	C_p	Number of 1-Minute Data Sets			
3	3.00	–0.10	–0.05	7347	0.00	0.06	0.06
3.5	3.49	–0.11	–0.03	6270	0.00	0.06	0.06
4	3.99	0.31	0.06	5193	0.01	0.11	0.11
4.5	4.49	1.15	0.16	3951	0.01	0.20	0.20
5	4.99	2.28	0.23	3021	0.02	0.29	0.29
5.5	5.49	3.67	0.27	2381	0.03	0.38	0.38
6	5.99	5.00	0.29	2017	0.03	0.40	0.40
6.5	6.49	6.27	0.28	1706	0.03	0.41	0.41
7	7.00	7.57	0.27	1455	0.03	0.44	0.44
7.5	7.49	8.70	0.25	1358	0.03	0.42	0.42
8	7.99	9.80	0.24	1142	0.03	0.43	0.43
8.5	8.49	10.77	0.22	970	0.03	0.41	0.41
9	9.00	11.67	0.20	873	0.03	0.39	0.39
9.5	9.50	12.36	0.18	713	0.04	0.32	0.32
10	10.00	13.12	0.16	604	0.04	0.37	0.37
10.5	10.49	13.69	0.15	520	0.03	0.30	0.30
11	11.00	14.15	0.13	417	0.04	0.25	0.25
11.5	11.49	14.59	0.12	336	0.04	0.26	0.26
12	12.00	14.80	0.11	317	0.04	0.15	0.15
12.5	12.49	14.90	0.09	280	0.06	0.11	0.13
13	13.00	15.00	0.08	225	0.05	0.11	0.12
13.5	13.49	14.93	0.08	187	0.06	0.10	0.12
14	13.99	14.80	0.07	180	0.07	0.13	0.15
14.5	14.48	14.60	0.06	146	0.08	0.16	0.18
15	15.00	14.40	0.05	117	0.10	0.17	0.19
15.5	15.48	14.49	0.05	100	0.10	0.11	0.15
16	16.03	14.42	0.04	87	0.09	0.10	0.14
16.5	16.50	14.15	0.04	70	0.13	0.24	0.27
17	16.99	14.24	0.04	66	0.10	0.12	0.16
17.5	17.50	14.13	0.03	59	0.10	0.13	0.16
18	17.99	14.08	0.03	53	0.10	0.10	0.14
18.5	18.48	13.91	0.03	31	0.07	0.17	0.18
19	18.99	14.00	0.03	25	0.08	0.12	0.14
19.5	19.45	14.11	0.02	13	0.11	0.14	0.18
20	19.92	13.74	0.02	10	0.10	0.38	0.39

Table 7. Performance at site average density, 0.95 kg/m^3

Measured Power Curve (Database A)							
Reference Air Density: 0.95 kg/m^3					Category A	Category B	Combined
Bin (m/s)	Wind Speed (m/s)	Normalized Power Output (kW)	C_p	Number of 1-Minute Data Sets	Standard Uncertainty (kW)	Standard Uncertainty (kW)	Standard Uncertainty (kW)
3	3.00	–0.08	–0.04	7347	0.00	0.06	0.06
3.5	3.49	–0.08	–0.03	6270	0.00	0.06	0.06
4	3.99	0.24	0.06	5193	0.01	0.09	0.09
4.5	4.49	0.89	0.16	3951	0.01	0.16	0.16
5	4.99	1.77	0.23	3021	0.02	0.23	0.23
5.5	5.49	2.84	0.27	2381	0.02	0.30	0.30
6	5.99	3.88	0.29	2017	0.02	0.31	0.31
6.5	6.49	4.86	0.28	1706	0.03	0.32	0.32
7	7.00	5.87	0.27	1455	0.03	0.34	0.34
7.5	7.49	6.75	0.25	1358	0.02	0.33	0.33
8	7.99	7.60	0.24	1142	0.02	0.33	0.33
8.5	8.49	8.35	0.22	970	0.02	0.32	0.32
9	9.00	9.05	0.20	873	0.03	0.30	0.30
9.5	9.50	9.59	0.18	713	0.03	0.25	0.25
10	10.00	10.17	0.16	604	0.03	0.29	0.29
10.5	10.49	10.62	0.15	520	0.03	0.24	0.24
11	11.00	10.98	0.13	417	0.03	0.20	0.20
11.5	11.49	11.32	0.12	336	0.03	0.20	0.21
12	12.00	11.48	0.11	317	0.03	0.12	0.12
12.5	12.49	11.56	0.09	280	0.05	0.09	0.11
13	13.00	11.63	0.08	225	0.04	0.09	0.10
13.5	13.49	11.58	0.07	187	0.05	0.09	0.10
14	13.99	11.48	0.07	180	0.05	0.11	0.12
14.5	14.48	11.33	0.06	146	0.06	0.13	0.15
15	15.00	11.17	0.05	117	0.08	0.13	0.15
15.5	15.48	11.23	0.05	100	0.08	0.10	0.12
16	16.03	11.18	0.04	87	0.07	0.09	0.11
16.5	16.50	10.97	0.04	70	0.10	0.19	0.21
17	16.99	11.04	0.04	66	0.08	0.10	0.13
17.5	17.50	10.96	0.03	59	0.08	0.10	0.13
18	17.99	10.92	0.03	53	0.08	0.09	0.12
18.5	18.48	10.79	0.03	31	0.05	0.14	0.14
19	18.99	10.86	0.03	25	0.06	0.10	0.12
19.5	19.45	10.94	0.02	13	0.09	0.12	0.15
20	19.92	10.65	0.02	10	0.08	0.30	0.31

Table 8 shows the annual energy production at sea-level normalized air density. Table 9 shows the annual energy production (AEP) at the site average air density at the NWTC.

Table 8. Annual energy production at sea-level density, 1.225 kg/m^3

Estimated annual energy production, database A (all valid data)					
	Reference air density: 1.225 kg/m^3				
	Cut-out wind speed: 25.00 m/s				
Hub height annual average wind speed (Rayleigh) m/s	AEP-measured kWh	Standard Uncertainty in AEP-measured kWh	Standard Uncertainty in AEP-measured %	AEP-extrapolated kWh	Complete if AEP measured is at least 95% of AEP extrapolated
4	17,716	1,693	10%	17,716	Complete
5	32,122	2,093	7%	32,122	Complete
6	46,292	2,284	5%	46,313	Complete
7	58,690	2,328	4%	58,893	Complete
8	68,525	2,286	3%	69,394	Complete
9	75,474	2,199	3%	77,764	Complete
10	79,617	2,089	3%	84,067	Incomplete
11	81,326	1,968	2%	88,411	Incomplete
AEP measured assumes zero power between highest bin and cutout AEP extrapolated assumes power in last bin between last bin and cutout					

Table 9. Annual energy production at site average density, 0.95 kg/m^3

Estimated annual energy production, database A (all valid data)					
	Reference air density: 0.95 kg/m^3				
	Cut-out wind speed: 25.00 m/s				
Hub height annual average wind speed (Rayleigh) m/s	AEP-measured kWh	Standard Uncertainty in AEP-measured kWh	Standard Uncertainty in AEP-measured %	AEP-extrapolated kWh	Complete if AEP measured is at least 95% of AEP extrapolated
4	13,739	1,381	10%	13,739	Complete
5	24,911	1,679	7%	24,911	Complete
6	35,900	1,820	5%	35,916	Complete
7	45,515	1,850	4%	45,672	Complete
8	53,142	1,816	3%	53,816	Complete
9	58,531	1,748	3%	60,307	Complete
10	61,744	1,661	3%	65,195	Incomplete
11	63,069	1,566	2%	68,564	Incomplete
AEP measured assumes zero power between highest bin and cutout AEP extrapolated assumes power in last bin between last bin and cutout					

7.2.Graphical Results Power Performance Test

Figure 5 through Figure 11 show the results of the power performance test. Figure 5 shows a plot of the binned power curve normalized to sea-level air density.

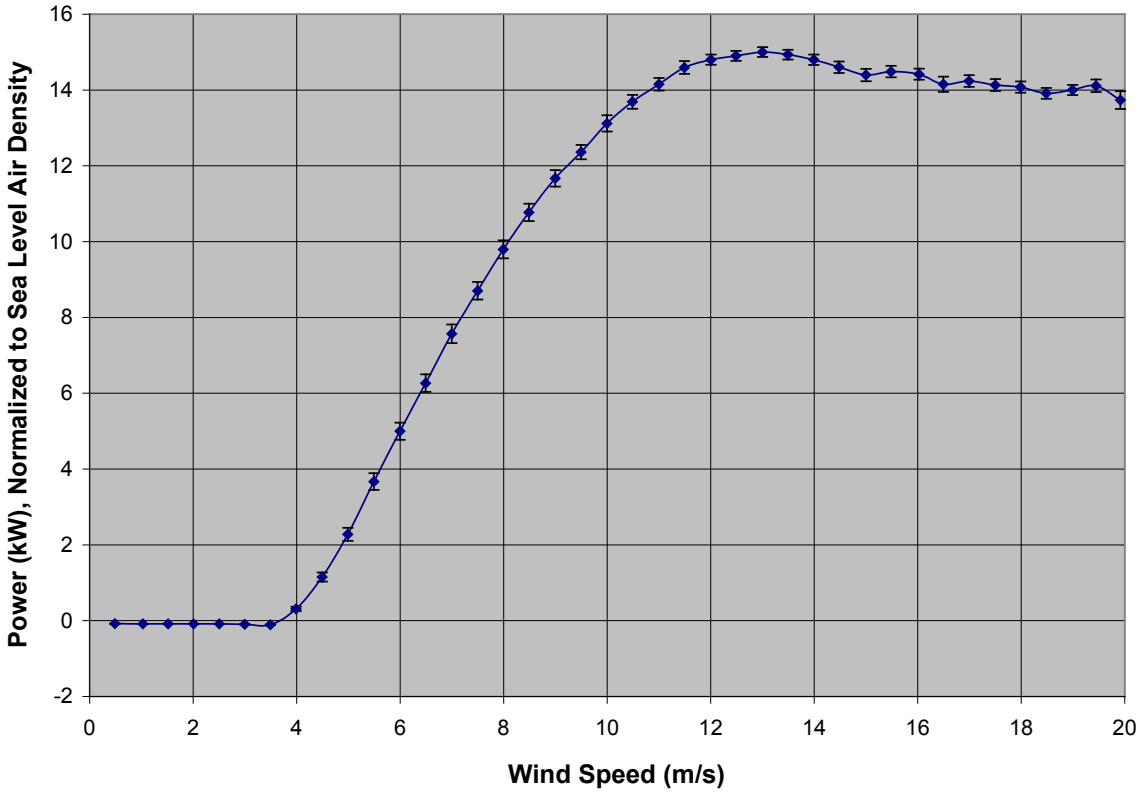

Figure 5. Power curve at sea-level density, 1.225 kg/m^3

Figure 6 shows a plot of the binned power curve at the site average air density during the test period.

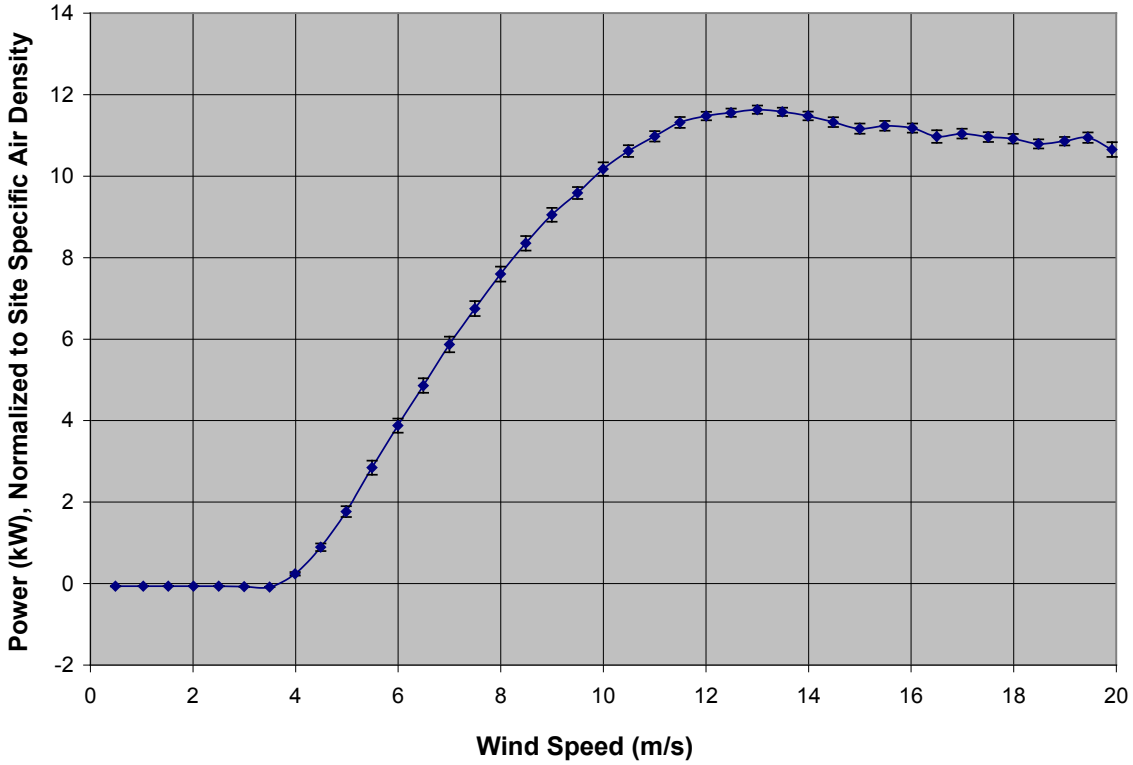

Figure 6. Power curve at site average density, 0.95 kg/m^3

Figure 7 shows a scatter plot of statistics for power for the turbine.

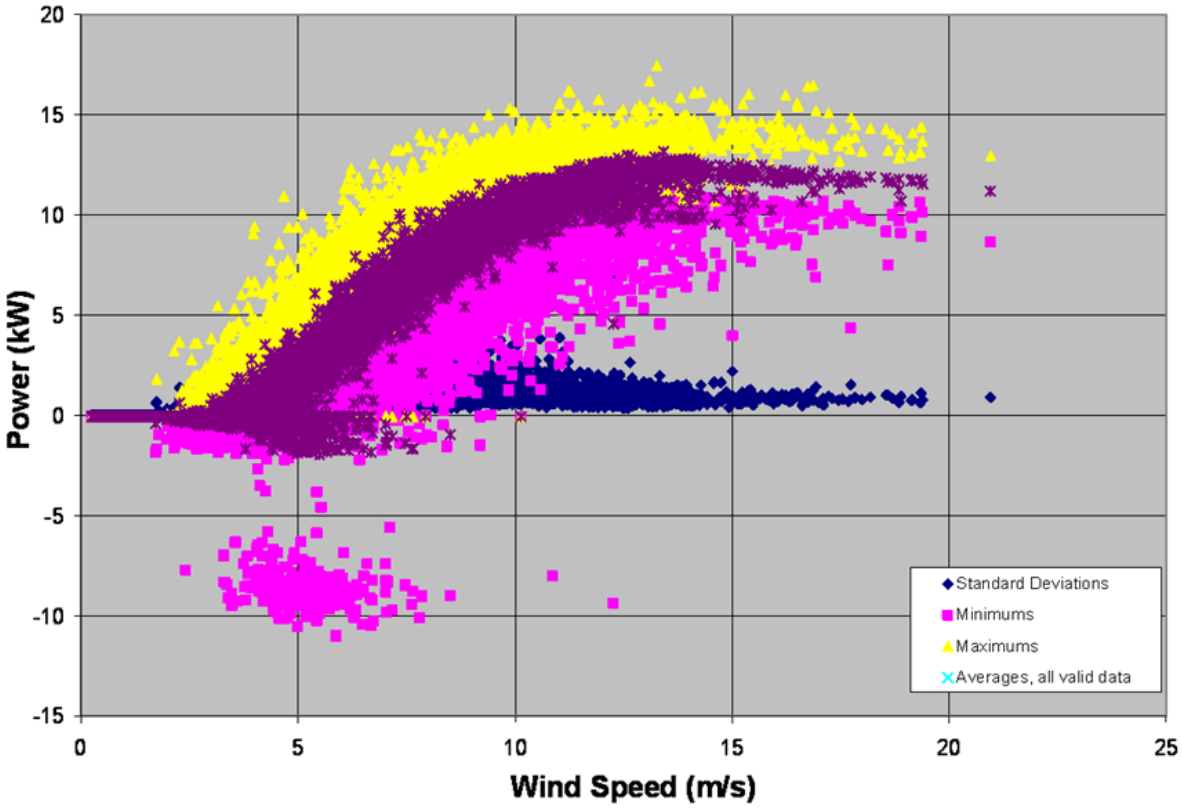

Figure 7. Scatter plot of mean, standard deviation, minimum, and maximum power data

Multiple power curves appear at the higher wind speeds. NREL investigated the cause but did not find it during testing. NREL changed two contactors in the controller during the test, but this did not alter the performance of the turbine. The contactor replacement did not cause the multiple power curves.

Figure 8 shows a plot of the binned coefficient of performance as a function of wind speed at sea-level normalized air density.

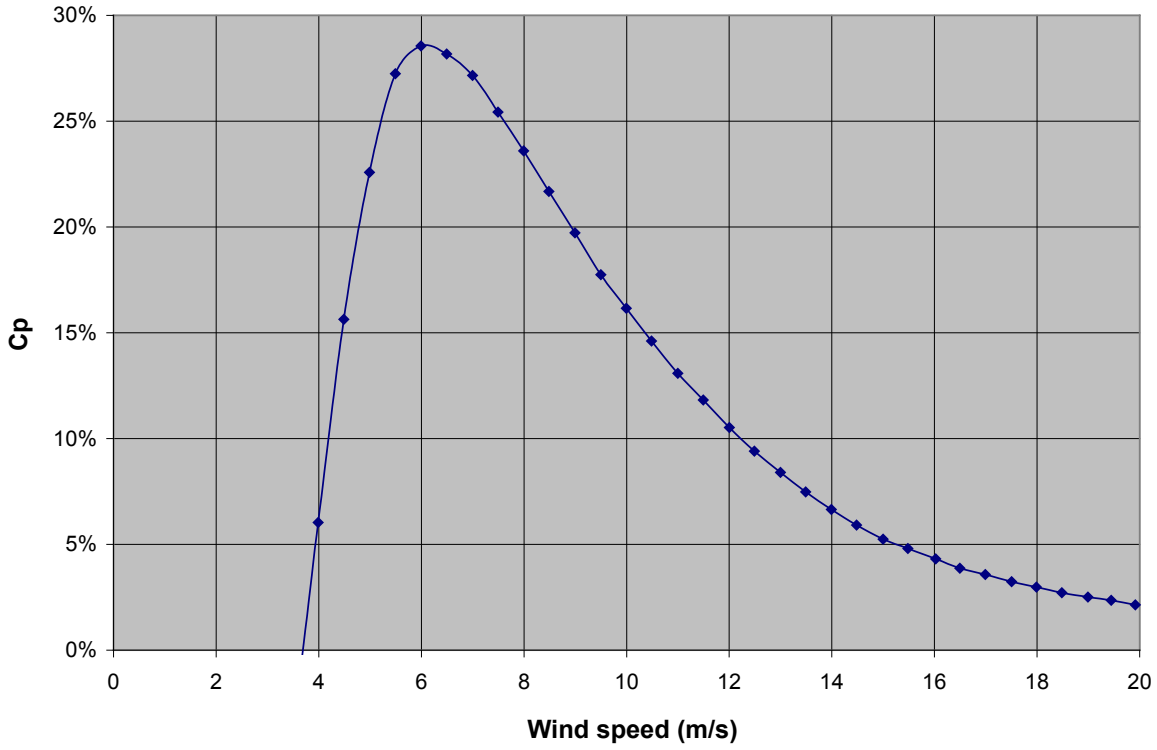

Figure 8. Coefficient of power at sea-level density, 1.225 kg/m^3

Figure 9 shows a scatter plot and binned turbulence intensity as a function of wind speed.

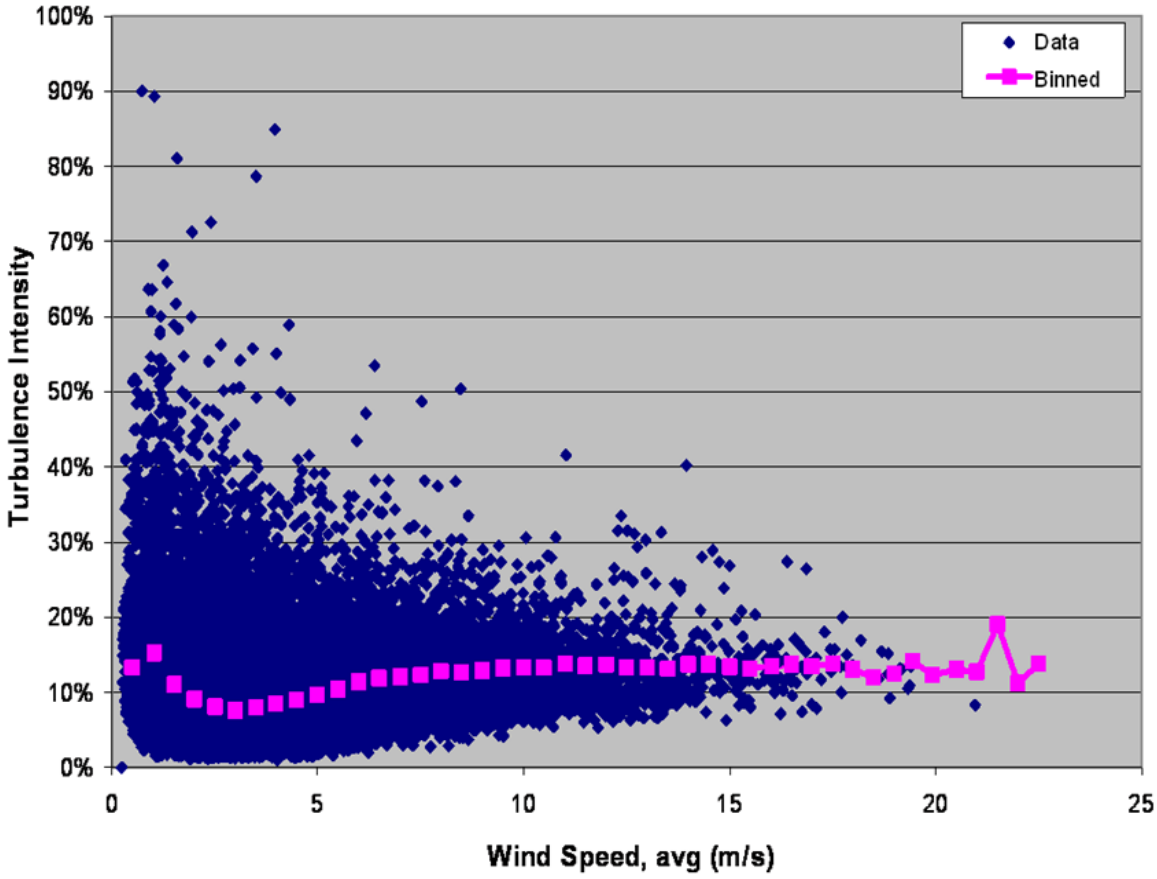

Figure 9. Wind turbulence intensity as a function of wind speed

Figure 10 shows a scatter plot of wind speed and turbulence intensity as a function of wind direction.

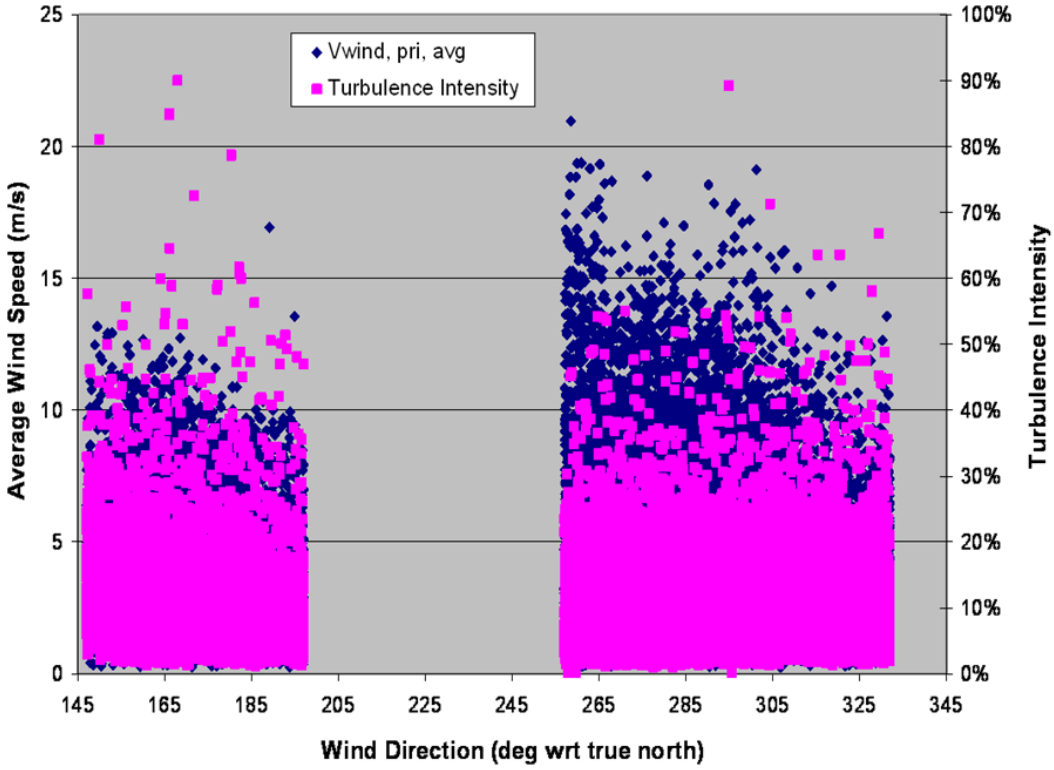

Figure 10. Wind speed and turbulence intensity as a function of wind direction for the measurement sector

Figure 11 shows a scatter plot and binned values of rotor speed as a function of wind speed.

Wind speed	m/s	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7
Rotor speed	rpm	0.3	1.4	3.8	8.5	13.6	20.8	30.7	37.4	45.3	51.9	57.1	59.0	59.4	60.2

Wind speed	m/s	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14
Rotor speed	rpm	60.6	60.7	60.8	60.8	60.8	60.9	61.0	61.0	61.1	61.1	61.0	61.1	61.1	61.1

Wind speed	m/s	14.5	15	15.5	16	16.5	17	17.5	18	18.5	19	19.5	20	20.5	21
Rotor speed	rpm	61.1	61.1	61.1	61.1	61.1	61.0	61.0	61.0	61.0	61.0	61.1	61.0	61.0	61.1

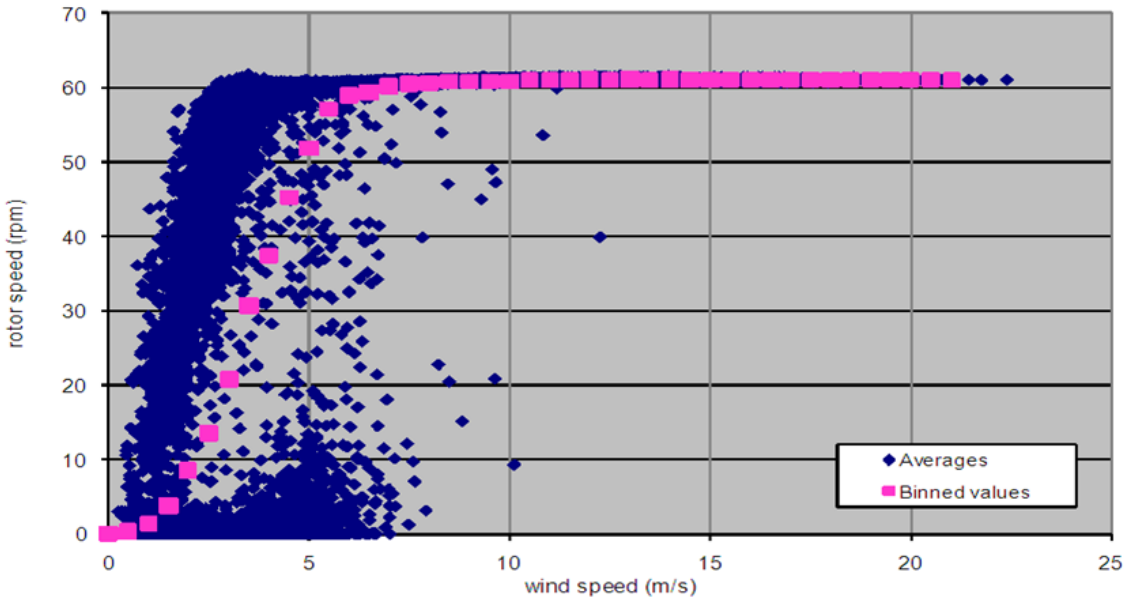

Figure 11. Rotor speed as a function of wind speed (1-minute averages) and binned values

8. Deviations and Exceptions

8.1 Deviations from the Standard

The current transformers are not compliant with IEC 60044-1 but do exceed the minimum accuracy required by the standard.

8.2 Exceptions to NWTC-CT Quality Assurance System

The data acquisition modules were used beyond the calibration due date. The modules were post-test calibrated and found to be in compliance within the specifications. Appendix B includes the post-test calibration sheets.

A. Appendix - Photographs of the Test Site from the Turbine Base

Figure A.1. Southwest

Figure A.2. South–southwest

Figure A.3. South

Figure A.4. Southeast

Figure A.5. East

Figure A.6. East–northeast

Figure A.7. Northeast

Figure 12. North

Figure A.9. Northwest

Figure A.10. West

B. Appendix - Equipment Calibration Sheets

Branch #: 5000

NREL METROLOGY LABORATORY

Test Report

Test Instrument: Multifunction Transducer — DOE #: 03575C

Model # : DMT-1040E — S/N : 06091046

Calibration Date: 02/15/2008 — Due Date: 02/15/2010

A. Set-Up for Total Power Calibration:
A.1. Voltage is applied to Lines 1, 2, & 3 = 277.128 V @ 60 Hz.
A.2. Current is applied to n = 8-TURNS through three current transformers that are connected to Lines 1, 2, & 3 .
A.3. Analog Output-1 is measured across precision resistor = 250 Ω.
A.4. Full Scale setting = -15.796KW to 15.796KW.

Input Current (AAC)	Input Power (KW)	Analog Output-1 (VDC)
18	14.965	4.811
12	9.977	3.209
6	4.988	1.604
0	0	0.002
-6	-4.988	-1.602
-12	-9.977	-3.206
-18	-14.965	-4.807

B. Set-Up for Power Factor Calibration:
B.1. Voltage & Current are applied as A.1 & A.2.
B.2. Analog Output-2 is measured across precision resistor = 250 Ω.

Power (KW)	Power Factor	Analog Output-2 (VDC)
10	1.0	5.001
"	0.8	3.995
"	0.6	2.993
"	0.4	1.991

Page 1 of 2

Figure B.1. Power transducer calibration sheet

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

Deutscher Akkreditierungs Rat
DAR
DKD-K- 36801

Kalibrierschein
Calibration Certificate

Kalibrierzeichen / *Calibration label*: DKD-K-36801 / 07_2415

Gegenstand *Object*	Cup Anemometer
Hersteller *Manufacturer*	Thies Clima D-37083 Göttingen
Typ *Type*	4.3350.00.000
Fabrikat/Serien-Nr. *Serial number*	Body: 0707890 Cup: 0707890
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 *Seal*	Datum *Date*	Leiter des Kalibrierlaboratoriums *Head of the calibration laboratory*	Bearbeiter *Person in charge*
Deutscher DKD-K- 36801 Kalibrierdienst	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

Deutsche WindGuard
Wind Tunnel Services GmbH

Figure B.2. Primary anemometer calibration sheet

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

Deutscher Akkreditierungs Rat
DKD-K-28901

Kalibrierschein
Calibration certificate

Kalibrierzeichen
Calibration label

1294_09
DKD-K-28901
16.06.09

Gegenstand *Object*	Cup Anemometer
Hersteller *Manufacturer*	Thies Clima D-37083 Göttingen
Typ *Type*	4.3350.00.000
Fabrikat/Serien-Nr. *Serial number*	body: 0707890 cup: -
Auftraggeber *Customer*	Thies Clima D-37083 Goettingen,
Auftragsnummer *Order No.*	AB0901617
Anzahl der Seiten des Kalibrierscheines *Number of pages of the certificate*	3+3
Datum der Kalibrierung *Date of calibration*	16.06.09

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 *Seal*	Datum *Date*	Stellv. Leiter des Kalibrierlaboratoriums *Deputy head of the calibration laboratory*	Bearbeiter *Person in charge*
Deutscher DKD-K-28901 Kalibrierdienst	16.06.09	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

Figure B.3. Primary anemometer calibration sheet II

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

Page: 1 of 1

Procedure:
NWTC-CT: GI24-000613, Wind Vane Calibration

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

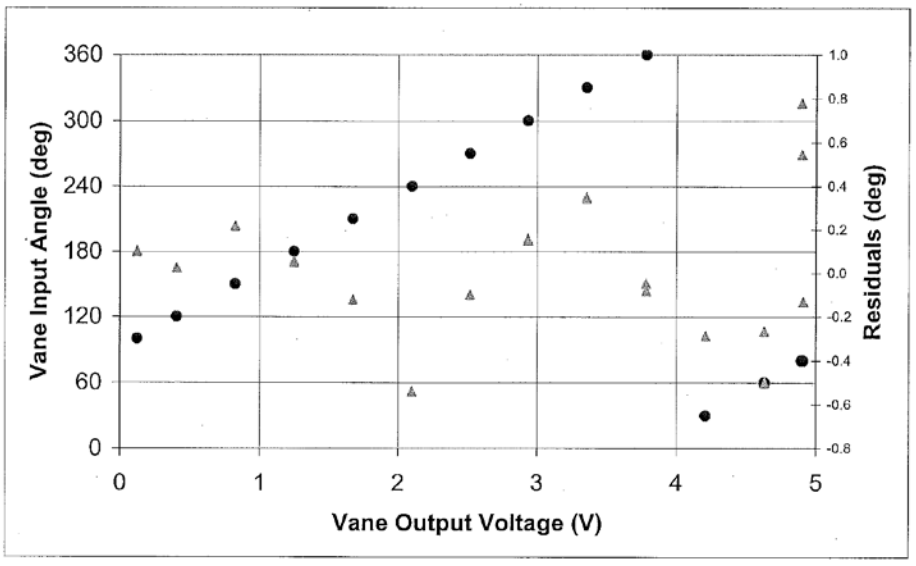

Figure B.4. Wind vane calibration sheet

Branch #: 5000 sheet: 1 of: 1

NREL METROLOGY LABORATORY

Test Report

Test Instrument: RTD Probe DOE #: 02885C

Model # : 78N01N00N S/N : 0890084

Calibration Date: 10/29/2007 Due Date: 10/29/2008

No	Nominal Values		Measured Values		
	Nominal Resistance /	Equivalent Temperature /	Measured Resistance /	Equivalent Temperature /	Temperature Error /
1	96.09 Ω	-10 °C	96.078 Ω	-10.03 °C	0.03 °C
2	100.00 Ω	0 °C	99.996 Ω	-0.01 °C	0.01 °C
3	103.90 Ω	10 °C	103.903 Ω	10.01 °C	-0.01 °C
4	107.79 Ω	20 °C	107.796 Ω	20.02 °C	-0.02 °C
5	111.67 Ω	30 °C	111.677 Ω	30.02 °C	-0.02 °C
6	115.54 Ω	40 °C	115.546 Ω	40.02 °C	-0.02 °C

Notes:

1. Total Uncertainty of Nominal Values = ±0.02 °C
2. Calibration was performed at 23 °C and 37% RH
3. Resistance is measured using 4-wire technique

Calibrated by: Reda QA by: Bev

Date : 10/29/2007 Date : 10/29/2007

Figure B.5. RTD probe calibration sheet I

Branch #: 5000 sheet: 1 of: 1

NREL METROLOGY LABORATORY

Test Report

Test Instrument: RTD-Probe DOE #: 02883C

Model # : 78N01N00N S/N : 0789021

Calibration Date: 10/10/2008 Due Date: 10/10/2009

No	Function Tested	Nominal Value (°C)	Measured Values (Ω)		( )Mfr. Specs. OR (X)Data only
			AS Found	AS Left	
*	Temperature:	0	99.96	Same	
		25	109.41	"	
		50	118.95	"	
	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 = 38. - Uncertainty of Nominal Values = ± 0.03 °C, k = 2.				

Tested By: Reda

Date : 10/10/2008

Figure B.6. RTD probe calibration sheet II

Branch #: 5000 sheet: 1 of: 1

NREL METROLOGY LABORATORY

Test Report

Test Instrument: Pressure Transmitter DOE #: 03510C

Model # : PTB101B S/N : C1040014

Calibration Date: 10/29/2007 Due Date: 10/29/2008

No	Function Tested	Nominal Value (kPa)	Measured Output Voltage (VDC)		( )Mfr. Specs. OR (X)Data only (mb)
			As Found	As Left	
*	Absolute Pressure				
		65	0.275		
		70	0.548		
		75	0.820		
		80	1.092		
		85	1.364		
		90	1.635		
		95	1.907		
		100	2.178		
		105	2.451		
	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: 10/29/2007

QA By: Bev
Date: 10/29/2007

Figure B.7. Pressure transmitter calibration sheet

NATIONAL INSTRUMENTS

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.

Figure B.8. NI 9229 data acquisition module calibration sheet I

NATIONAL INSTRUMENTS

Certificate of Calibration

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.

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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.

Figure B.9. NI 9217 data acquisition module calibration sheet I

NATIONAL INSTRUMENTS

Certificate of Calibration

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.

Figure B.10. NI 9205 data acquisition module calibration sheet I

Davis Calibration

ACCREDITED CALIBRATION

Certificate of Calibration

3214337

Instrument Identification

Company ID: 229037
NATIONAL INSTRUMENTS

PO Number: 337683

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

Instrument ID: **12CBC7A**
Manufacturer: NATIONAL INSTRUMENTS
Description: 4-CHANNEL, ±60 V, 24-BIT SIMULTANEOUS ANALOG INPUT

Model Number: NI 9229
Serial Number: 12CBC7A

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/NCSL Z540-1-1994, 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. 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.

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

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

Figure B.11. NI 9229 data acquisition module calibration sheet II

Davis Calibration

ACCREDITED CALIBRATION

Certificate of Calibration

3214181

Instrument Identification

Company ID: 229037
NATIONAL INSTRUMENTS

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

PO Number: 337683

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

Remarks: *Reference attached Data.*

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

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/NCSL Z540-1-1994, 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.
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.

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
3004176	15-0060	DIGITAL MULTIMETER (GOLDEN CAL)	3458A OPT 002	17Feb2009	17May2009

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Figure B.12. NI 9217 data acquisition module calibration sheet II

Davis Calibration

ACCREDITED CALIBRATION

Certificate of Calibration

3214135

Instrument Identification

Company ID: 229037
NATIONAL INSTRUMENTS

PO Number: 337683

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

Instrument ID: **12E9C99**
Manufacturer: NATIONAL INSTRUMENTS
Description: 32-CH ±200 MV TO ±10 V, 16-BIT, 250 KS/S ANALOG INPUT MODULE

Model Number: NI 9205
Serial Number: 12E9C99

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: 47.0 %

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/NCSL Z540-1-1994, 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.
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.

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

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Figure B.13. NI 9205 data acquisition module calibration sheet II

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This test is being conducted as part of the U.S. Department of Energy's (DOE) Independent Testing project. It is a power performance test that the National Renewable Energy Laboratory (NREL) conducted on the Gaia-Wind 11-kW small wind turbine.

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