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Wind Turbine Generator System Power Performance Test Report for the Mariah Windspire 1-kW Wind Turbine

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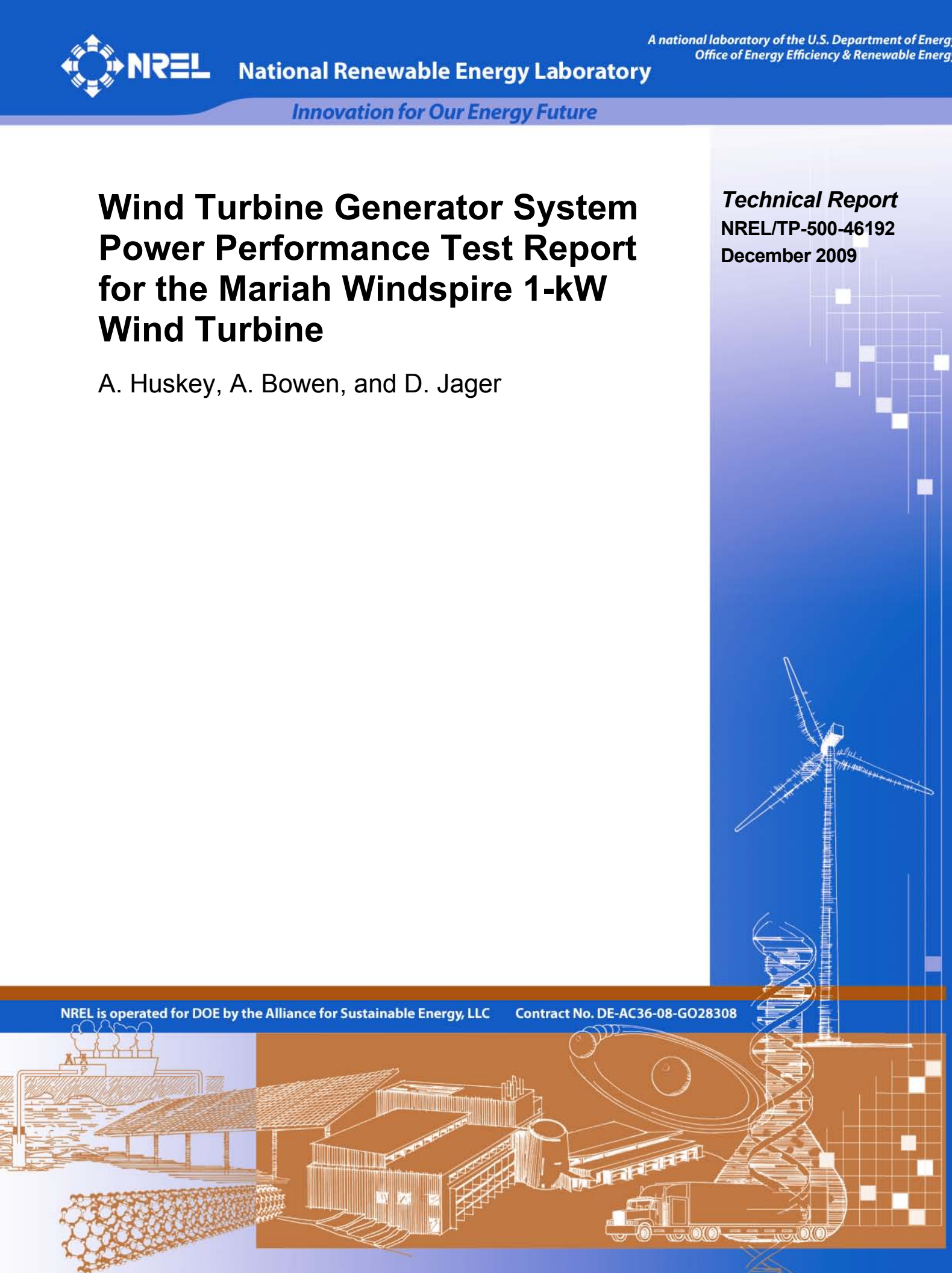

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Wind Turbine Generator System Power Performance Test Report for the Mariah Windspire 1-kW Wind Turbine

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10 June 2009

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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 NREL conducted on the Mariah Windspire 1-kW wind turbine. In this test, the Windspire turbine was installed at the NWTC, close to Boulder, Colorado. This test was conducted in accordance with the International Electrotechnical Commission's (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. However, because the Windspire is a small turbine as defined by IEC, NREL also followed Annex H that applies to small wind turbines. This test report refers to these procedures as the Standard.

During this test, two configurations were tested on the same turbine. In the first configuration, the turbine inverter was optimized for power production. Data collection was not completed with the last required wind speed bin (14 m/s) not filled. In the second configuration, the turbine inverter was set for normal power production. Again, data collection was not completed with the last wind speed bin (14 m/s) not filled. In both configurations, the inverter experienced failures and the tests were not finished.

In Figure 1, the first summary result, the normal configuration results are shown. Power is normalized to sea-level air density. Additional results are given in Section 7.1. This test was begun on October 7, 2008, and was ended on November 19, 2009. 291.57 hours of valid data were collected during that time. The highest wind speed bin filled was the 13.5 m/s bin. The amount of test data is not sufficient to meet the requirements of the Standard, Annex H.

In Figure 2, the second summary result, the optimized power configuration results are shown. Power is normalized to sea-level air density. Additional results are given in Section 7.2**.** This test was begun on June 12, 2008, and was ended on September 13, 2009. 1023.5 hours of valid data were collected during that time. The highest wind speed bin filled was the 13.5 m/s bin. The amount of test data is not sufficient to meet the requirements of the Standard, Annex H.

National Renewable Energy Laboratory

Power Performance Test
Mariah Power Windspire

Sea-Level Density Power Curve

Report Created: January 23, 2009

Turbine Specifications:

Serial Number:	800021	
Rated Power:	1	kW
Cut-in Wind Speed:	4.00	m/s
Cut-out Wind Speed:	N/A	
Rated Wind Speed:	11	m/s
Rotor Diameter:	3.076	m
Control Type:	Stall	
Pitch Setting:	Fixed	

Site Conditions:

Location	NWTC, Boulder, CO	
Average Air Density:	1.00	kg/m^3
Measurement Sectors:	132 - 323	degrees true

Test Statistics:

Start Date:	October 7, 2008	
End Date:	November 19, 2008	
Amount of Data Collected:	291.57	hours
Highest Bin Filled:	13.50	m/s
Test Completed?	No	

Bin Wind Speed (m/s)	Bin Power (kW)	Number Data Points	Cp
0.54	-0.01	477	-10.70
1.03	-0.01	905	-1.56
1.52	-0.01	1,595	-0.48
2.01	-0.01	2,228	-0.21
2.50	-0.01	2,343	-0.11
2.99	-0.01	2,084	-0.06
3.48	0.00	1,335	-0.02
3.98	0.01	910	0.02
4.50	0.03	670	0.07
4.99	0.05	599	0.10
5.49	0.09	567	0.11
6.00	0.13	573	0.13
6.50	0.18	510	0.14
7.01	0.25	472	0.16
7.49	0.32	409	0.17
7.98	0.41	351	0.18
8.50	0.52	291	0.19
8.99	0.64	307	0.19
9.49	0.76	253	0.20
9.98	0.88	189	0.19
10.48	0.96	132	0.18
10.99	1.02	114	0.17
11.48	1.06	65	0.15
11.99	1.09	42	0.14
12.49	0.99	38	0.11
13.02	0.96	21	0.10
13.47	0.99	14	0.09

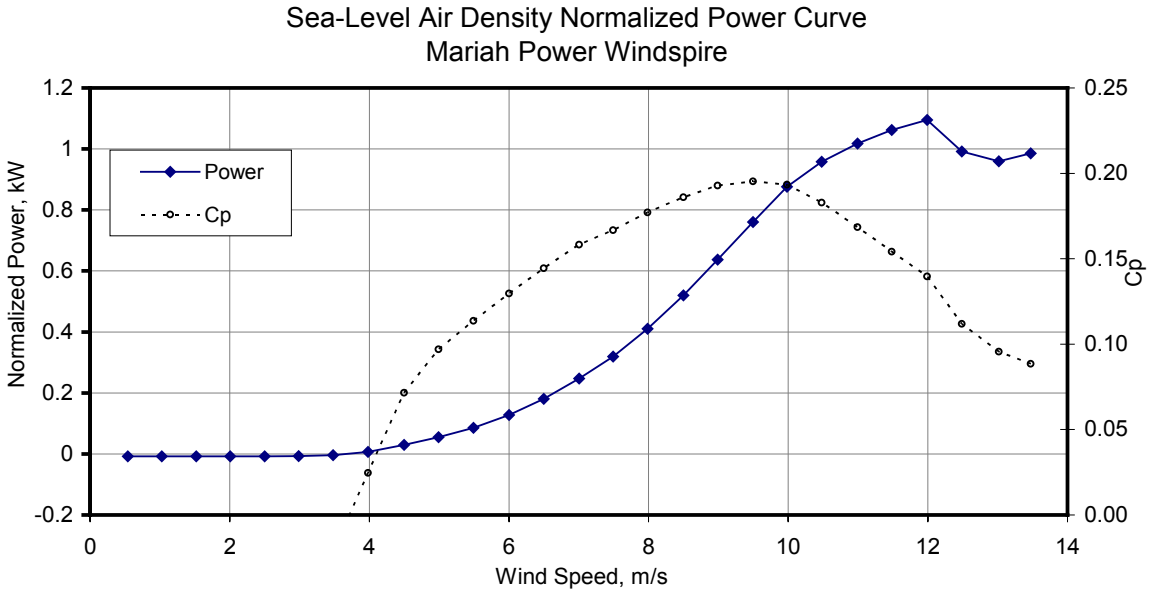

Figure 1. Power curve summary for the normal configuration

NREL National Renewable Energy Laboratory

Power Performance Test
Mariah Power Windspire
Optimized inverter
Sea-Level Density Power Curve

Report Created: January 26, 2009

Turbine Specifications:

Serial Number:	800021	
Rated Power:	1	kW
Cut-in Wind Speed:	4.00	m/s
Cut-out Wind Speed:	N/A	
Rated Wind Speed:	11	m/s
Rotor Diameter:	3.076	m
Control Type:	Stall	
Pitch Setting:	Fixed	

Site Conditions:

Location	NWTC, Boulder, CO	
Average Air Density:	0.97	kg/m^3
Measurement Sectors:	132 - 323	degrees true

Test Statistics:

Start Date:	June 12, 2008	
End Date:	September 13, 2008	
Amount of Data Collected:	1023.50	hours
Highest Bin Filled:	13.50	m/s
Test Completed?	No	

Bin Wind Speed (m/s)	Bin Power (kW)	Number Data Points	Cp
0.55	-0.01	1,548	-10.60
1.02	-0.01	3,520	-1.68
1.52	-0.01	6,102	-0.51
2.01	-0.01	9,108	-0.22
2.50	-0.01	9,709	-0.11
2.99	-0.01	8,497	-0.06
3.48	-0.01	6,251	-0.03
3.98	0.01	3,977	0.02
4.48	0.02	2,690	0.06
4.99	0.05	2,031	0.09
5.49	0.08	1,576	0.11
6.00	0.12	1,391	0.12
6.48	0.16	1,124	0.13
6.99	0.22	953	0.14
7.49	0.29	741	0.15
7.99	0.37	559	0.16
8.47	0.48	411	0.17
8.98	0.60	331	0.18
9.48	0.72	206	0.19
10.00	0.86	181	0.19
10.50	0.96	146	0.18
10.99	1.08	121	0.18
11.47	1.15	80	0.17
12.02	1.24	71	0.16
12.50	1.29	43	0.14
13.02	1.32	29	0.13
13.56	1.37	14	0.12

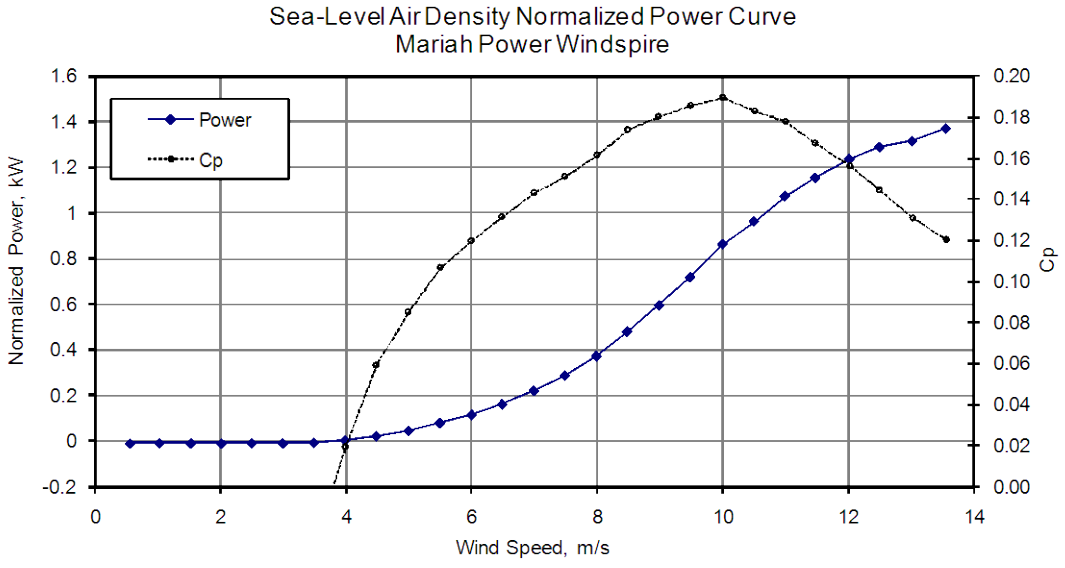

Figure 2. Power curve summary for the power optimized configuration

3. Test Turbine Configuration

Table 1 lists the configuration of the Windspire that was tested at the NWTC.

Table 1. Test Turbine Configuration

Turbine make, model, serial number, production year	Mariah Power, Windspire, 800021, 2008
Horizontal or vertical axis turbine	Vertical
Rotor diameter (m)	3.05
Rotor height (m)	6.10
Rotor center height (m)	6.10
Tower type	Tubular
Rated electrical power (kW)	1
Rated wind speed (m/s)	11.0
Rotor speed range (rpm)	0 – 500
Fixed or variable pitch	Fixed
Number of blades/airfoils	3
Blade pitch angle (deg)	0
Blade make, type, serial number	Mariah Power, Airfoil
Description of control system (device & software version)	Windspire 1.2G

The rotor diameter was verified by measurements.

Figure 3. Mariah Power Windspire 1-kW test turbine at the NWTC

4. Test Site Description

The test turbine is located at site 3.3C at the NWTC, located 8 miles south of Boulder, Colorado. The terrain primarily consists of mostly flat terrain with short vegetation. The test site has prevailing wind bearing at 292 degrees relative to true north. For measurements where it is important to accurately measure wind speed, NREL used data obtained when wind direction is between 132° and 323° degrees true. In this measurement sector, the influence of terrain and obstructions on the anemometer is small. Figure 4 shows the turbine and meteorological tower locations. This figure also shows nearby obstructions and topographical features of the site. Sizes and distances of nearby obstructions are provided in Table 2.

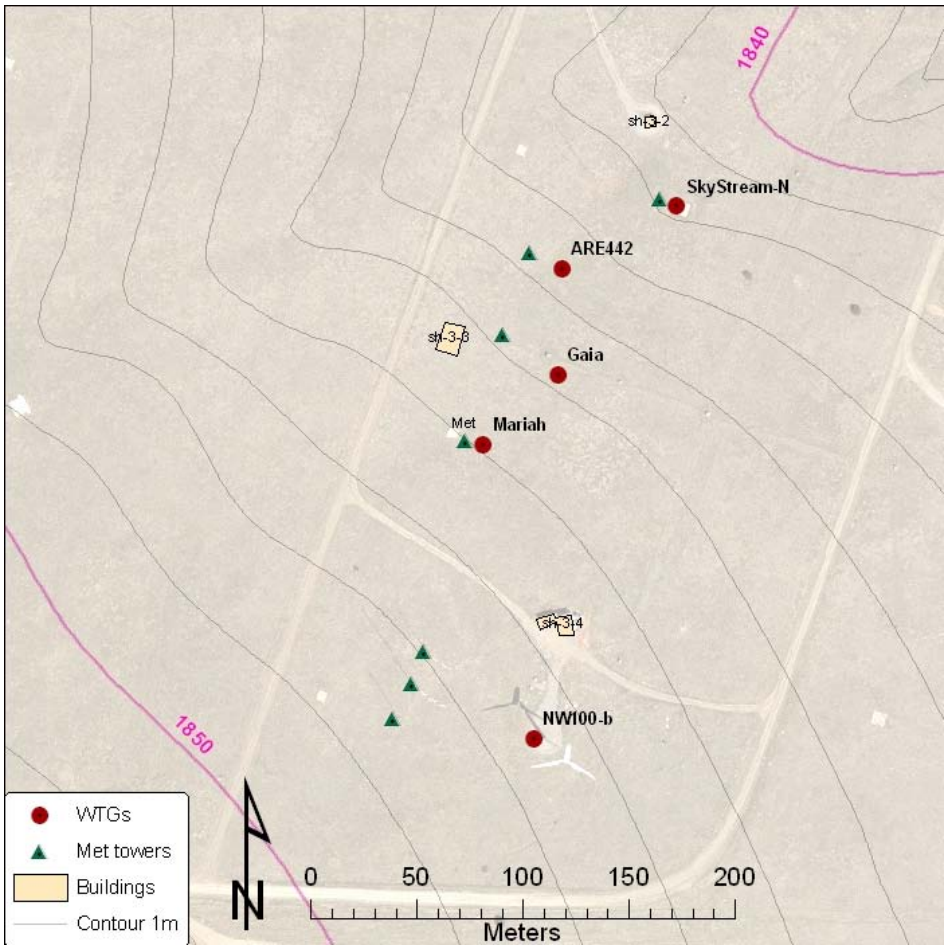

Figure 4. Map of the test site

Table 2. Structures close to the test turbine

Designation	Bearing from Test Turbine (deg. T)	Distance from Test Turbine (m)	Obstruction Height (m)	Rotor Diameter or Obstruction Width (m)
Windspire met	293	7.0	4.6	0.3
Data shed	341	60.0	3.1	7.0
ARE 442	26	303.4	31.0	7.3
ARE 442 met	13	299.3	31.0	0.4
Gaia	47	168.9	18.2	13.0
Gaia met	9	153.3	8.2	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. Based on the site assessment results, a site calibration is 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%	<2L	360	2.6%	Pass
Maximum variation from best fit plane < 0.08 D	<2L	360	0.04	Pass
Maximum slope of best fit plane < 5%	2-4L	In	1.7%	Pass
Maximum variation from best fit plane < 0.15 D	2-4L	In	0.04	Pass
Steepest slope maximum < 10%	2-4L	Out	3.4%	Pass
Maximum slope of best fit plane < 10%	4-8L	In	2.0%	Pass
Maximum variation from best fit plane < 0.15 D	4-8L	In	0.04	Pass
No neighboring and operating turbines	$<2D_n$	360	0	Pass
No obstacles	$<2D_e$	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 Mariah Windspire was connected to the electrical grid at a nominal voltage of 120 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 and the calibration sheets are included in Appendix B. Table 4 shows the equipment used and calibration due dates. Figure 5 shows placement of the meteorological instruments on the tower. The primary anemometer was sent out for re-calibration 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	Second Wind, Phaser 5FM-4A20	02061	8 Feb 2009
Voltage transformers	Ohio Semitronics, VT7-010E-11	08010700	Calibrated with power transducer
Primary anemometer	Thies, First Class	0707894	27 Feb 2009
Reference anemometer	NRG, Max 40	179500049701 179500049703	In situ
Wind vane	Met One, 020C with aluminum vane	W5515	27 Feb 2009
Pressure sensor (replaced during test)	Vaisala, PTB101B	C1040008 Y3350027	29 Oct 2008 29 Nov 2009
Temperature sensor (replaced during test)	Met One, T200	0673553 0602948	29 Oct 2008 10 Oct 2009
Precipitation sensor	Campbell Scientific, 237	None	In situ
Data acquisition system	Compact DAQ w/LabVIEW cDAQ backplane NI 9229 NI 9217 NI 9205	 12E4D23 12B6DD2 12BD192 12E9C3E	 28 Jun 2008 06 Jul 2008 08 Oct 2008 Modules post-test calibrated on 6 May 2009 and found in compliance

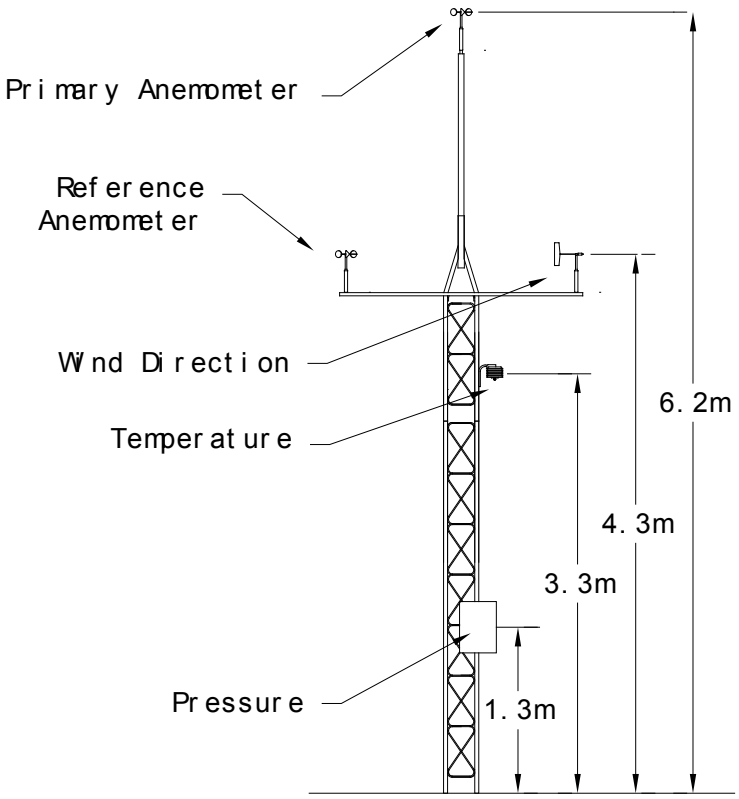

Figure 5. Meteorological tower and instruments

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

- external conditions other than wind speed are out of the normal range for turbine operation,
- turbine cannot operate because of a turbine fault condition, and,
- 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. The first method, the logbook will be checked for such events. The other method is a signal from the turbine that indicates when the turbine is braked.

6. Description of Test Procedure

The test was conducted 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. Standard deviation, minimum, and maximum values for each averaging period were also collected.

The turbine status signal for the Windspire was obtained by checking the release of the brake. The status signal indicated if the turbine was braked or not.

Only database A is reported since the Windspire does not have a cut-out wind speed.

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	6.00 W	Specifications (specs)
Power transducer	0.12%	Specs
Data acquisition	40.50 W +0.08%	Specs
Resistor	0.01%	Specs
Wind Speed		
Calibration	0.02 m/s	Calibration sheet
Operational characteristics	0.05 m/s +0.52%	IEC
Mounting effects	1.00%	Assumption
Terrain effects	2.00%	IEC
Data acquisition	< 0.01 m/s	Assumption
Temperature		
Temperature sensor	0.15 °C	Specs
Radiation shielding	1.15 °C	Assumption
Mounting effects	0.09 °C	IEC method
Data acquisition	0.35 °C	Specs
Air Pressure		
Pressure sensor	0.20 kPa	Instrument specs.
Mounting effects	< 0.01 kPa	IEC method
Data acquisition	0.06 kPa	Specs

7. Test Results

Test results are given for two turbine configurations. The first section is for the normal configuration. The second section is for the power optimized configuration.

7.1. Results of Power Performance Test for the Normal Configuration

7.1.1. Tabular Results for Normal Power Production

Table 6 through Table 9 provide the power performance test results for the normal configuration in tabular format. Table 6 shows the binned power performance results at sea-level normalized air density for normal power production. Table 7 shows the binned power performance results for the site average air density at the NWTC for normal power production.

Table 6. Performance at Sea-level air density; 1.225 kg/m^3 for normal power production

Measured power curve (database A)							
Reference air density: 1.225 kg/m^3					Category A Standard Uncertainty	Category B Standard Uncertainty	Combined Standard Uncertainty
Bin (m/s)	Wind Speed (m/s)	Normalized Power Output (kW)	C_p	Number of 1-Minute Data Sets	(kW)	(kW)	(kW)
2.5	2.50	-0.01	-0.11	2343	0.00	0.04	0.04
3	2.99	-0.01	-0.06	2084	0.00	0.04	0.04
3.5	3.48	0.00	-0.02	1335	0.00	0.04	0.04
4	3.98	0.01	0.02	910	0.00	0.04	0.04
4.5	4.50	0.03	0.07	670	0.00	0.04	0.04
5	4.99	0.05	0.10	599	0.00	0.04	0.04
5.5	5.49	0.09	0.11	567	0.00	0.04	0.04
6	6.00	0.13	0.13	573	0.00	0.04	0.04
6.5	6.50	0.18	0.14	510	0.00	0.04	0.04
7	7.01	0.25	0.16	472	0.00	0.05	0.05
7.5	7.49	0.32	0.17	409	0.00	0.05	0.05
8	7.98	0.41	0.18	351	0.00	0.05	0.05
8.5	8.50	0.52	0.19	291	0.00	0.06	0.06
9	8.99	0.64	0.19	307	0.00	0.07	0.07
9.5	9.49	0.76	0.20	253	0.00	0.07	0.07
10	9.98	0.88	0.19	189	0.00	0.07	0.07
10.5	10.48	0.96	0.18	132	0.01	0.06	0.06
11	10.99	1.02	0.17	114	0.01	0.05	0.05
11.5	11.48	1.06	0.15	65	0.02	0.05	0.05
12	11.99	1.09	0.14	42	0.03	0.04	0.05
12.5	12.49	0.99	0.11	38	0.03	0.07	0.08
13	13.02	0.96	0.10	21	0.04	0.04	0.06
13.5	13.47	0.99	0.09	14	0.06	0.04	0.07

Table 7. Performance at site average density; 1.00 kg/m^3 for normal power production

Measured power curve (database A)							
Reference air density: 1.00 kg/m^3					Category A Standard Uncertainty	Category B Standard Uncertainty	Combined Standard Uncertainty
Bin (m/s)	Wind Speed (m/s)	Normalized Power Output (kW)	C_p	Number of 1-Minute Data Sets	(kW)	(kW)	(kW)
2.5	2.50	-0.01	-0.11	2343	0.00	0.04	0.04
3	2.99	-0.01	-0.06	2084	0.00	0.04	0.04
3.5	3.48	0.00	-0.02	1335	0.00	0.04	0.04
4	3.98	0.01	0.02	910	0.00	0.04	0.04
4.5	4.50	0.02	0.07	670	0.00	0.04	0.04
5	4.99	0.04	0.10	599	0.00	0.04	0.04
5.5	5.49	0.07	0.11	567	0.00	0.04	0.04
6	6.00	0.10	0.13	573	0.00	0.04	0.04
6.5	6.50	0.15	0.14	510	0.00	0.04	0.04
7	7.01	0.20	0.16	472	0.00	0.04	0.04
7.5	7.49	0.26	0.17	409	0.00	0.05	0.05
8	7.98	0.33	0.18	351	0.00	0.05	0.05
8.5	8.50	0.42	0.19	291	0.00	0.05	0.05
9	8.99	0.52	0.19	307	0.00	0.06	0.06
9.5	9.49	0.62	0.20	253	0.00	0.06	0.06
10	9.98	0.72	0.19	189	0.00	0.06	0.06
10.5	10.48	0.78	0.18	132	0.01	0.05	0.05
11	10.99	0.83	0.17	114	0.01	0.05	0.05
11.5	11.48	0.87	0.15	65	0.01	0.05	0.05
12	11.99	0.89	0.14	42	0.02	0.04	0.05
12.5	12.49	0.81	0.11	38	0.02	0.06	0.07
13	13.02	0.78	0.10	21	0.03	0.04	0.05
13.5	13.47	0.80	0.09	14	0.05	0.04	0.06

Table 8 shows the annual energy production at sea-level normalized air density for normal power production. Table 9 shows the annual energy production at the site average air density for the NWTC for normal power production. A cut-out wind speed of 25 m/s is assumed for analysis purposes, though the turbine does not have a cut out wind speed.

Table 8. Annual energy production (AEP) at sea-level density; 1.225 kg/m^3 for normal power production

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	615	372	61%	617	Complete
5	1,354	391	29%	1,383	Complete
6	2,120	402	19%	2,283	Incomplete
7	2,700	400	15%	3,156	Incomplete
8	3,032	385	13%	3,898	Incomplete
9	3,152	362	11%	4,459	Incomplete
10	3,126	336	11%	4,827	Incomplete
11	3,010	308	10%	5,024	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; 1.00 kg/m^3 for normal power production

Estimated annual energy production, database A (all valid data)					
Reference air density:	1.00	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	502	367	73%	503	Complete
5	1,106	380	34%	1,129	Complete
6	1,731	386	22%	1,864	Incomplete
7	2,204	381	17%	2,577	Incomplete
8	2,475	365	15%	3,182	Incomplete
9	2,573	342	13%	3,640	Incomplete
10	2,552	316	12%	3,941	Incomplete
11	2,457	290	12%	4,101	Incomplete
AEP measured assumes zero power between highest bin and cutout AEP extrapolated assumes power in last bin between last bin and cutout					

7.1.2. Graphical Results for Normal Power Production

Figure 6 through Figure 12 show the results of the power performance test for normal power production in graphical format. Figure 6 shows a plot of the binned power curve normalized to sea level air density for normal power production.

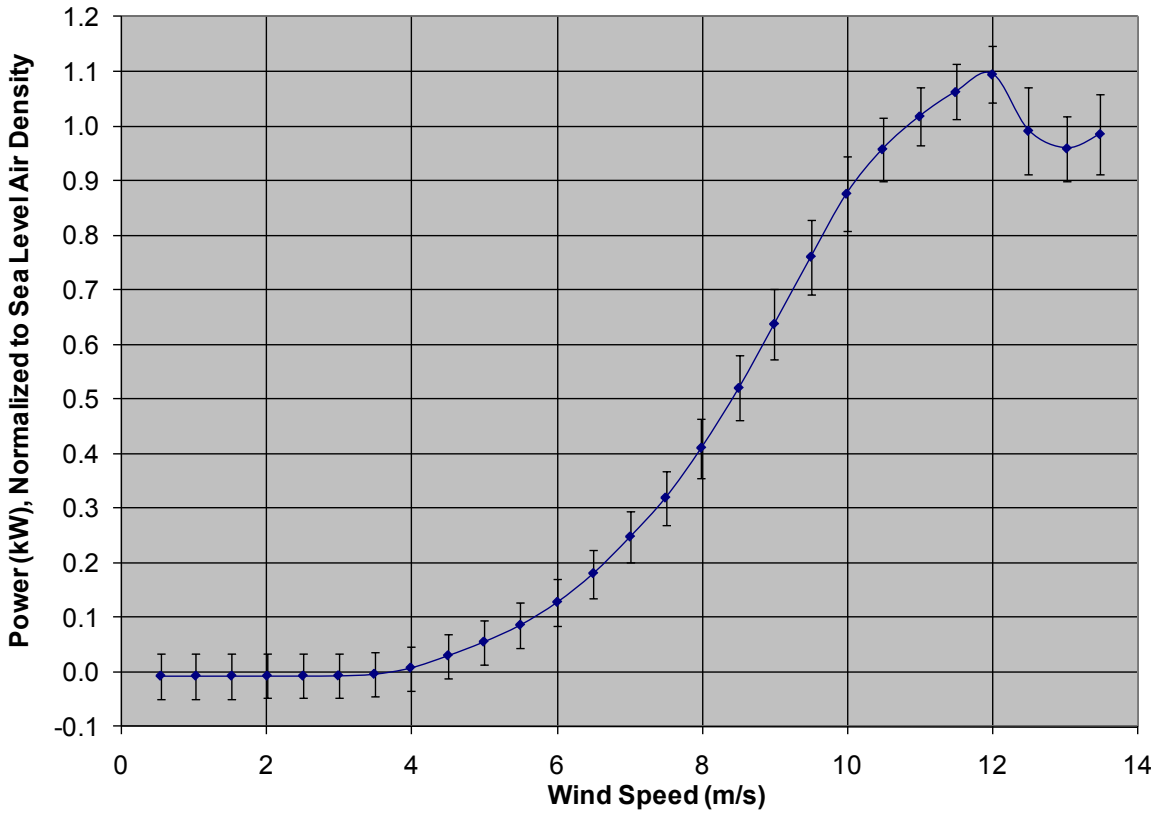

Figure 6. Power curve at sea-level density; 1.225 kg/m^3 for normal power production

Figure 7 shows a plot of the binned power curve at the site average air density during the test period for normal power production.

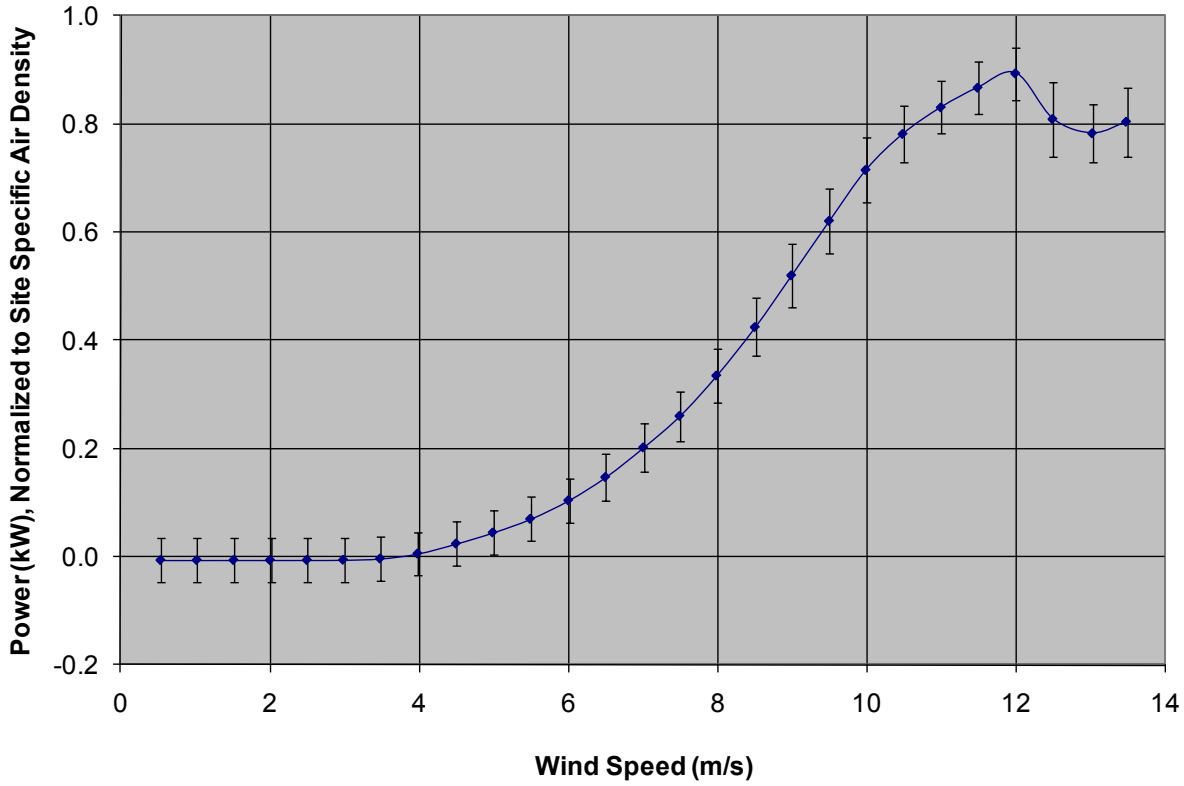

Figure 7. Power curve at site average density; 1.00 kg/m^3 for normal power production

Figure 8 shows a scatter plot of statistics for normal power production.

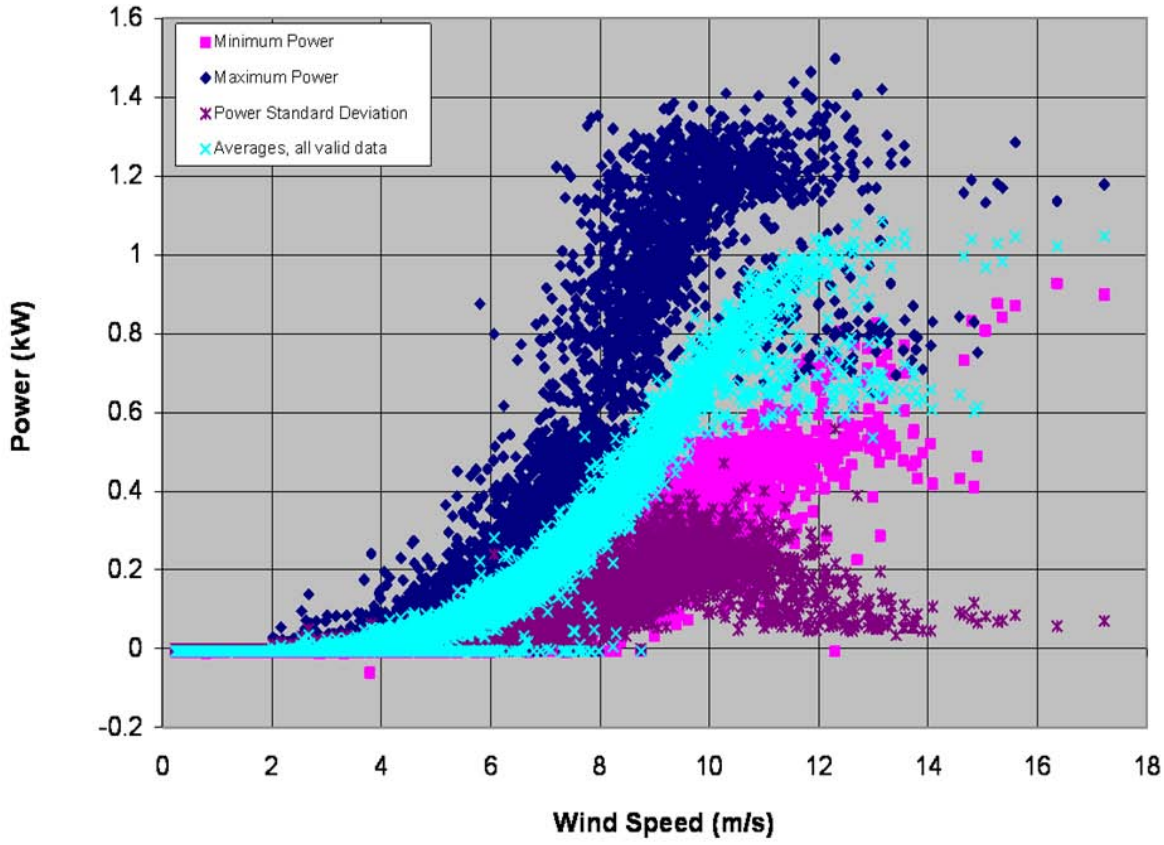

Figure 8. Scatter plot of mean, standard deviation, minimum, and maximum power data for normal power production

Multiple power curves appear at the higher wind speeds. NREL did not find the cause during testing.

Figure 9 shows a plot of the binned coefficient of power as a function of wind speed at sea-level normalized air density for normal power production.

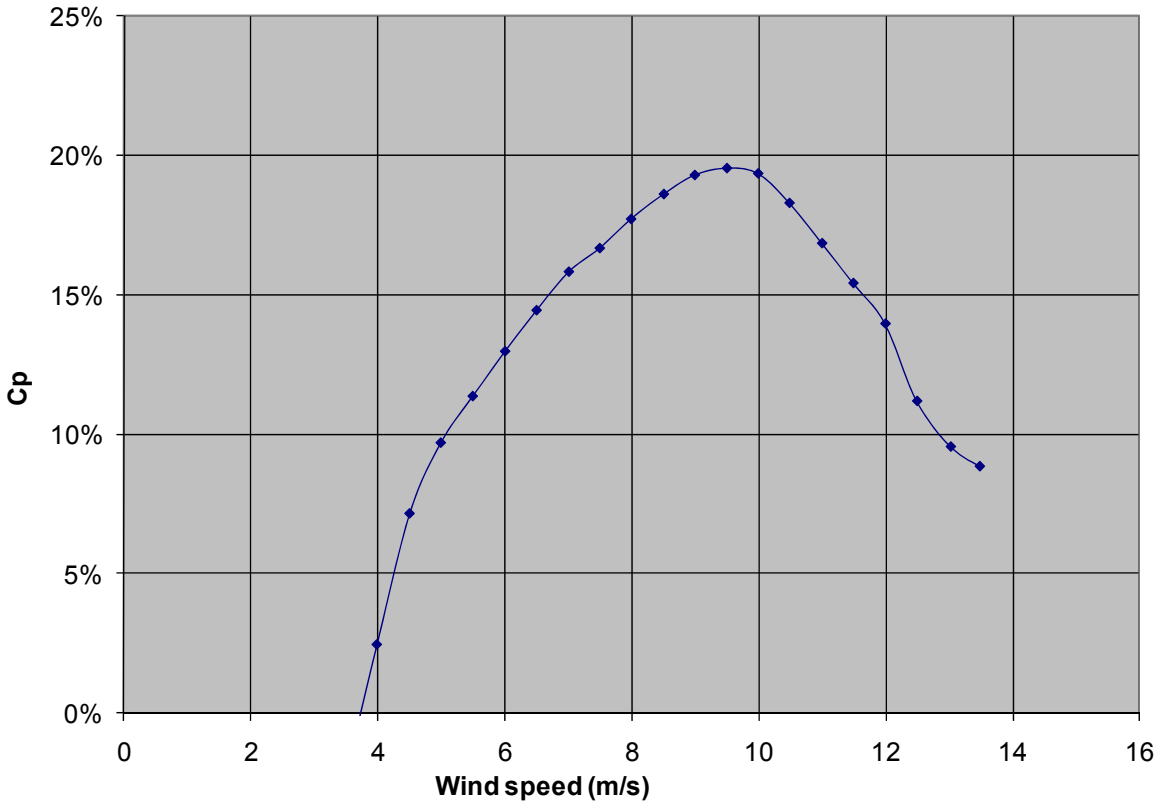

Figure 9. Coefficient of power at sea-level density; 1.225 kg/m^3 for normal power production

Figure 10 shows a scatter plot and binned turbulence intensity as a function of wind speed for normal power production.

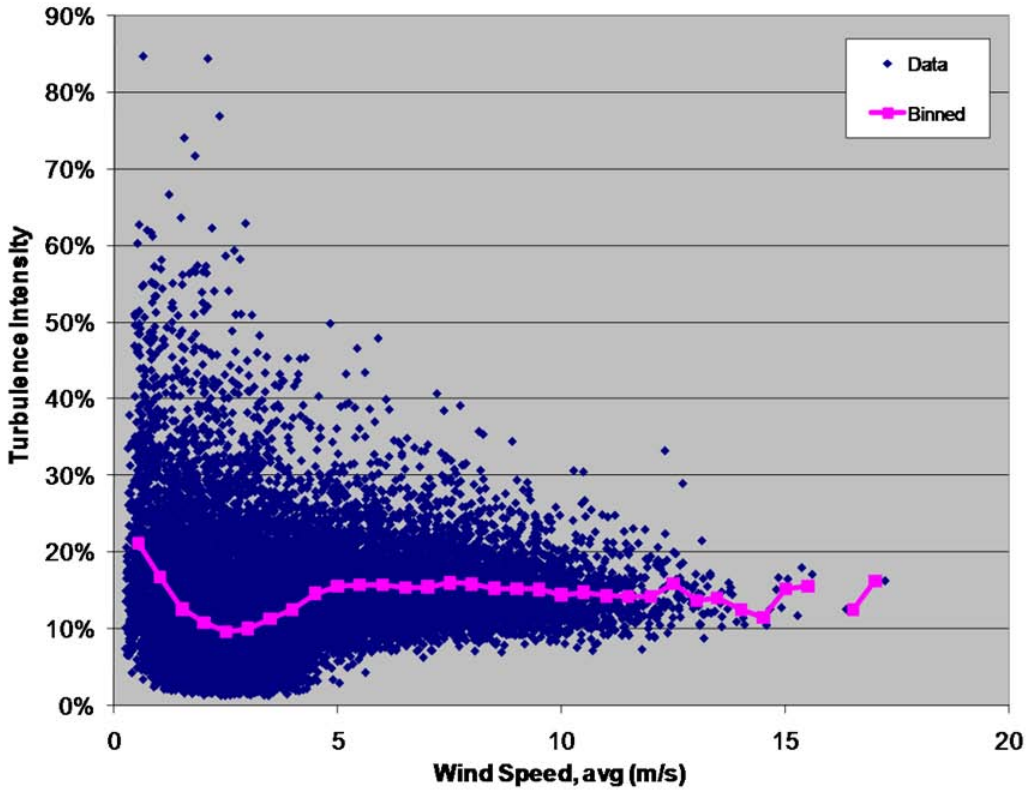

Figure 10. Wind turbulence intensity as a function of wind speed during for normal power production

Figure 11 shows a scatter plot of wind speed and turbulence intensity as a function of wind direction for normal power production.

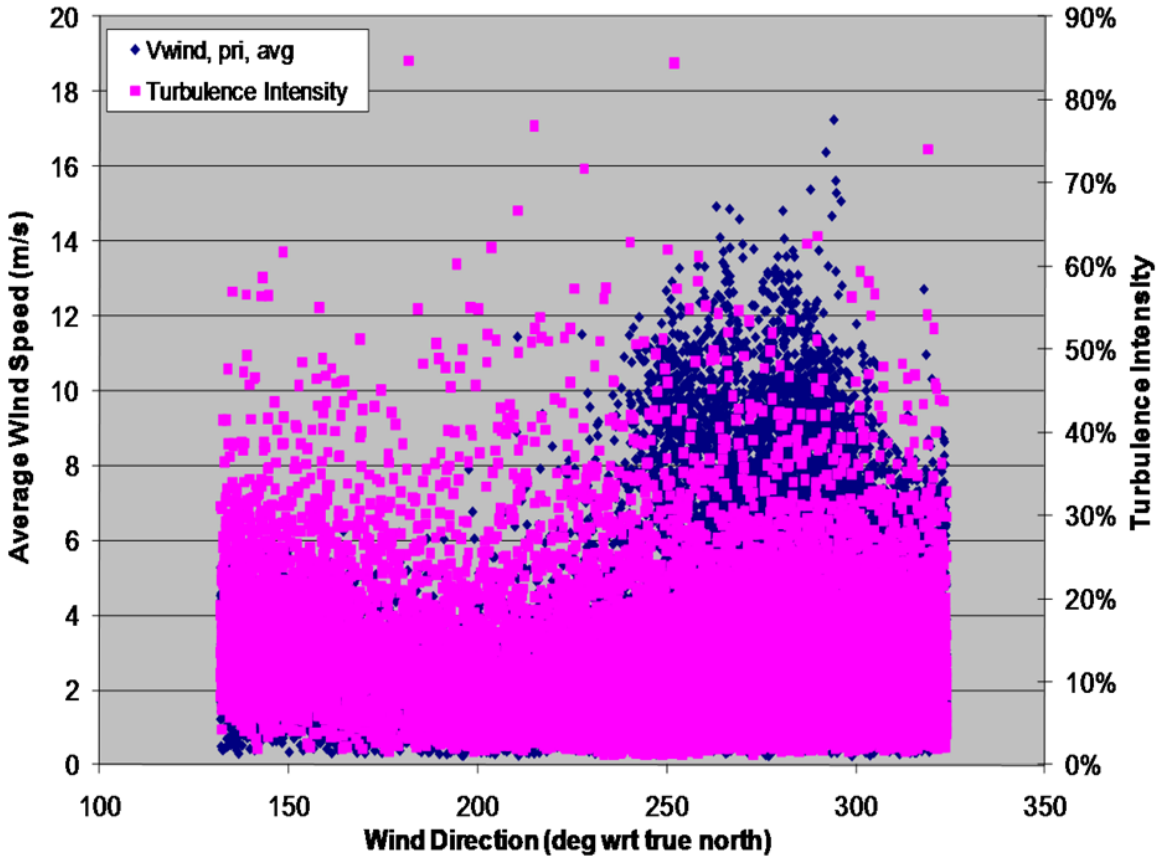

Figure 11. Wind speed and turbulence intensity as a function of wind direction during test for normal power production

Figure 12 shows a scatter plot of binned values of rotor speed as a function of wind speed for normal power production.

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	0	1	3	9	20	42	80	137	177	204	228	255	276

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	291	312	331	344	353	359	355	352	348	346	326	318	321	299

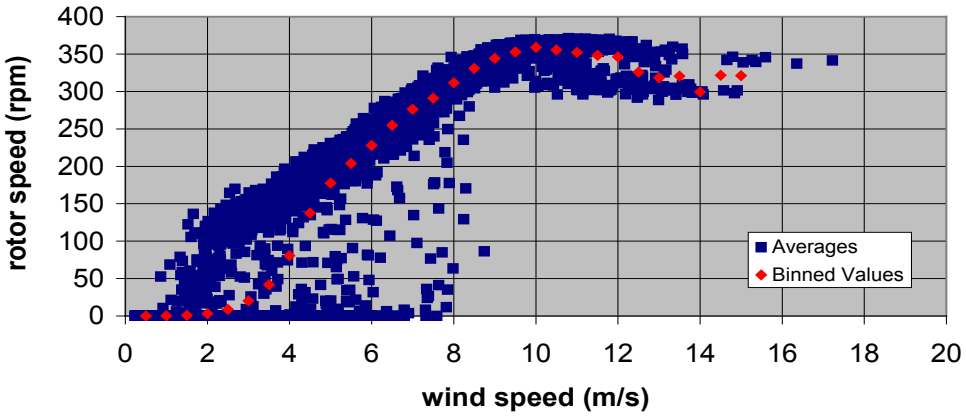

Figure 12. Rotor speed as a function of wind speed (1-minute averages) and binned values for normal power production

7.2 Results of Power Performance Test for Optimized Power Production

7.2.1 Tabular Results for Optimized Power Production

Table 10 through Table 13 provide the power performance test results for the optimized power production in tabular format.

Table 10 shows the binned power performance results at sea-level normalized air density for optimized power production.

Table 10. Performance at sea-level air density; 1.225 kg/m^3 for optimized power production

Measured power curve (database A)							
Reference air density: 1.225 kg/m^3					Category A Standard Uncertainty	Category B Standard Uncertainty	Combined Standard Uncertainty
Bin (m/s)	Wind Speed (m/s)	Normalized Power Output (kW)	C_p	Number of 1-Minute Data Sets	(kW)	(kW)	(kW)
3	2.99	-0.01	-0.06	8497	0.00	0.01	0.01
3.5	3.48	-0.01	-0.03	6251	0.00	0.01	0.01
4	3.98	0.01	0.02	3977	0.00	0.01	0.01
4.5	4.48	0.02	0.06	2690	0.00	0.02	0.02
5	4.99	0.05	0.09	2031	0.00	0.02	0.02
5.5	5.49	0.08	0.11	1576	0.00	0.03	0.03
6	6.00	0.12	0.12	1391	0.00	0.03	0.03
6.5	6.48	0.16	0.13	1124	0.00	0.04	0.04
7	6.99	0.22	0.14	953	0.00	0.05	0.05
7.5	7.49	0.29	0.15	741	0.00	0.06	0.06
8	7.99	0.37	0.16	559	0.00	0.08	0.08
8.5	8.47	0.48	0.17	411	0.01	0.11	0.11
9	8.98	0.60	0.18	331	0.01	0.11	0.11
9.5	9.48	0.72	0.19	206	0.01	0.13	0.13
10	10.00	0.86	0.19	181	0.01	0.14	0.14
10.5	10.50	0.96	0.18	146	0.01	0.11	0.11
11	10.99	1.08	0.18	121	0.01	0.12	0.12
11.5	11.47	1.15	0.17	80	0.01	0.09	0.09
12	12.02	1.24	0.16	71	0.02	0.09	0.09
12.5	12.50	1.29	0.14	43	0.01	0.07	0.07
13	13.02	1.32	0.13	29	0.01	0.04	0.04
13.5	13.56	1.37	0.12	14	0.01	0.06	0.06

Table 11 shows the binned power performance results at the site average air density for the NWTC for optimized power production.

Table 11. Performance at site average density; 0.95 kg/m^3 for optimized power production

Measured power curve (database A)							
Reference air density: 0.95 kg/m^3					Category A Standard Uncertainty	Category B Standard Uncertainty	Combined Standard Uncertainty
Bin (m/s)	Wind Speed (m/s)	Normalized Power Output (kW)	C_p	Number of 1-Minute Data Sets	(kW)	(kW)	(kW)
3	2.99	-0.01	-0.06	8497	0.00	0.01	0.01
3.5	3.48	0.00	-0.03	6251	0.00	0.01	0.01
4	3.98	0.00	0.02	3977	0.00	0.01	0.01
4.5	4.48	0.02	0.06	2690	0.00	0.02	0.02
5	4.99	0.04	0.09	2031	0.00	0.02	0.02
5.5	5.49	0.06	0.11	1576	0.00	0.02	0.02
6	6.00	0.09	0.12	1391	0.00	0.03	0.03
6.5	6.48	0.13	0.13	1124	0.00	0.03	0.03
7	6.99	0.17	0.14	953	0.00	0.04	0.04
7.5	7.49	0.22	0.15	741	0.00	0.05	0.05
8	7.99	0.29	0.16	559	0.00	0.06	0.06
8.5	8.47	0.37	0.17	411	0.00	0.08	0.08
9	8.98	0.46	0.18	331	0.00	0.09	0.09
9.5	9.48	0.56	0.19	206	0.01	0.10	0.10
10	10.00	0.67	0.19	181	0.01	0.11	0.11
10.5	10.50	0.75	0.18	146	0.01	0.08	0.08
11	10.99	0.83	0.18	121	0.01	0.10	0.10
11.5	11.47	0.90	0.17	80	0.01	0.07	0.07
12	12.02	0.96	0.16	71	0.01	0.07	0.07
12.5	12.50	1.00	0.14	43	0.01	0.05	0.05
13	13.02	1.02	0.13	29	0.01	0.03	0.03
13.5	13.56	1.06	0.12	14	0.01	0.05	0.05

Table 12 shows the annual energy production at sea-level normalized air density for optimized power production. Table 13 shows the annual energy production at the site average air density at the NWTC for optimized power production.

Table 12. Annual energy production (AEP) at sea-level density; 1.225 kg/m^3 for optimized power production

Estimated annual energy production, database A (all valid data)					
Reference air density:	1.225	kg/m^3			
Cut-out wind speed:	20.00	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	569	229	40%	571	Complete
5	1,309	332	25%	1,347	Complete
6	2,127	416	20%	2,343	Incomplete
7	2,786	463	17%	3,397	Incomplete
8	3,192	476	15%	4,361	Incomplete
9	3,367	467	14%	5,139	Incomplete
10	3,376	444	13%	5,690	Incomplete
11	3,277	414	13%	6,023	Incomplete
AEP measured assumes zero power between highest bin and cutout AEP extrapolated assumes power in last bin between last bin and cutout					

Table 13. Annual energy production at site average density; 0.95 kg/m^3 for optimized power production

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 MWh	Standard Uncertainty in AEP-measured MWh	Standard Uncertainty in AEP-measured %	AEP-extrapolated MWh	Complete if AEP measured is at least 95% of AEP extrapolated
4	442	194	44%	443	Complete
5	1,015	271	27%	1,044	Complete
6	1,650	334	20%	1,817	Incomplete
7	2,160	368	17%	2,634	Incomplete
8	2,475	377	15%	3,382	Incomplete
9	2,612	369	14%	3,985	Incomplete
10	2,618	350	13%	4,413	Incomplete
11	2,542	327	13%	4,671	Incomplete
AEP measured assumes zero power between highest bin and cutout AEP extrapolated assumes power in last bin between last bin and cutout					

7.2.2 Graphical Results for Power-Optimized Configuration

Figure 13 through Figure 19 show the results of the power performance test for optimized power production in graphical format. Figure 13 shows a plot of the binned power curve normalized to sea-level air density of optimized power production.

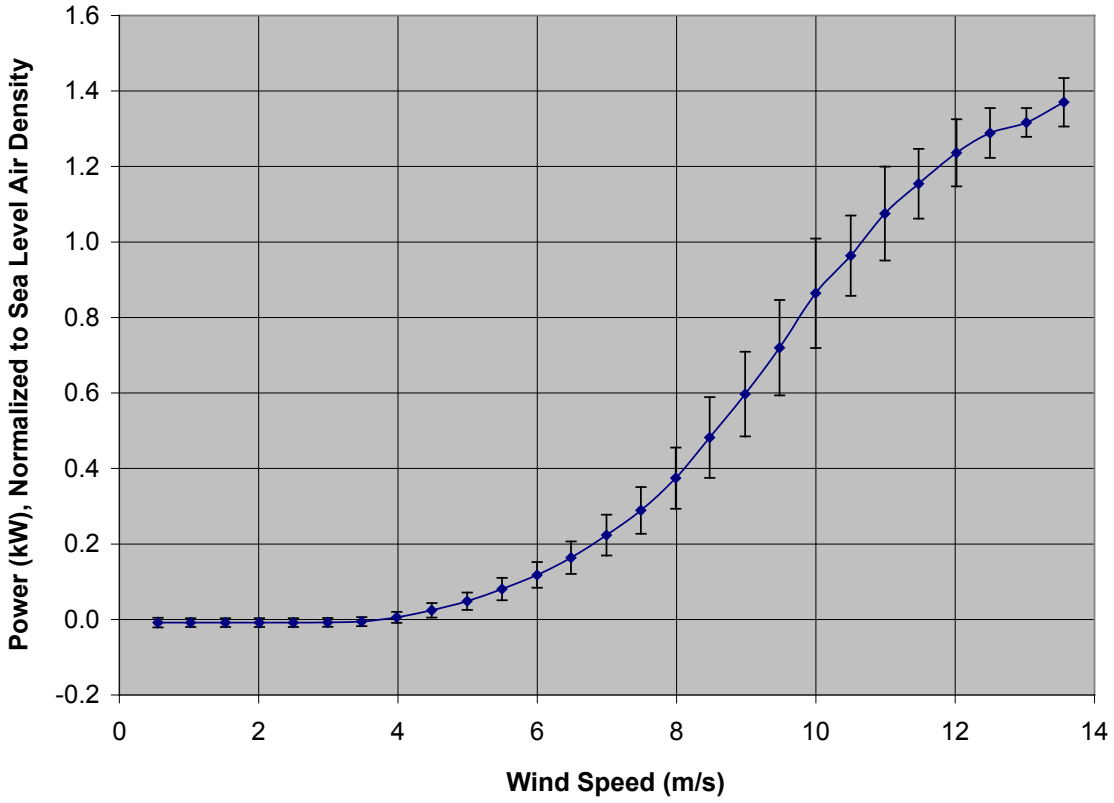

Figure 13. Power curve at sea-level density; 1.225 kg/m^3 for optimized power production

Figure 14 shows a plot of the binned power curve at the site average air density for the NWTC for optimized power production.

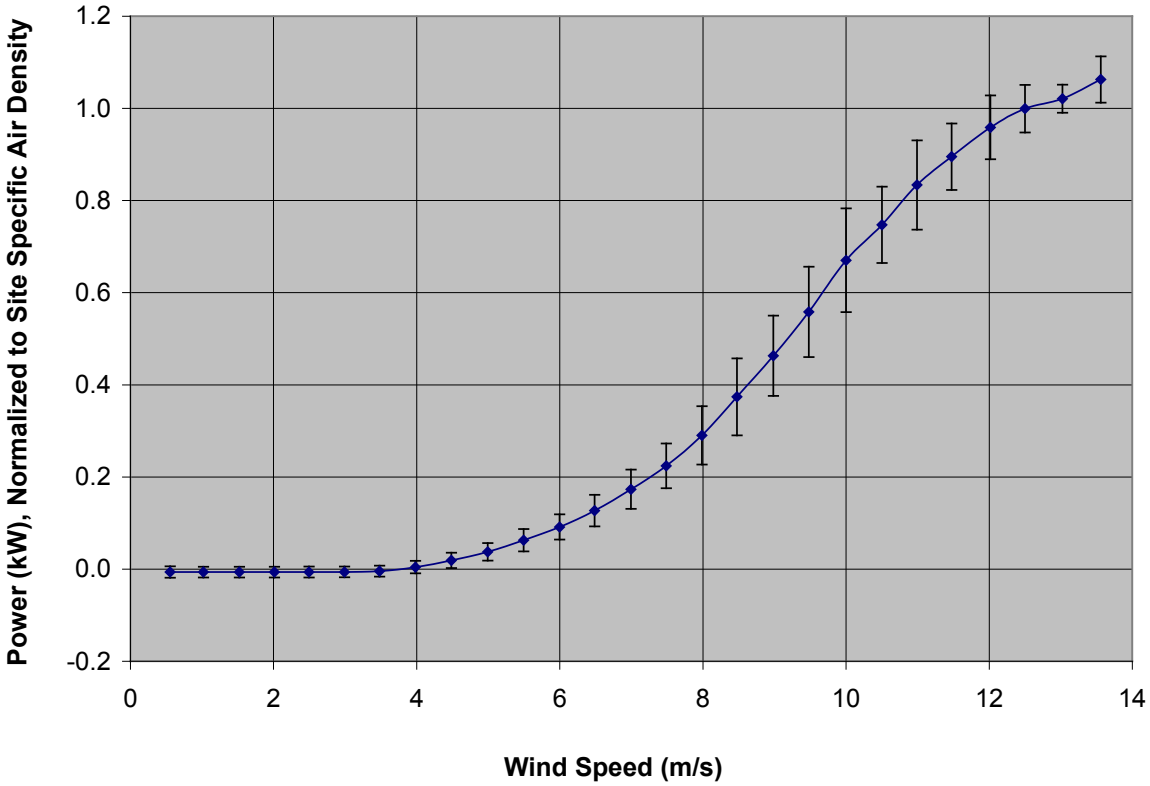

Figure 14. Power curve at site average density; 0.95 kg/m^3 for optimized power production

Figure 15 shows a scatter plot of statistics for optimized power production.

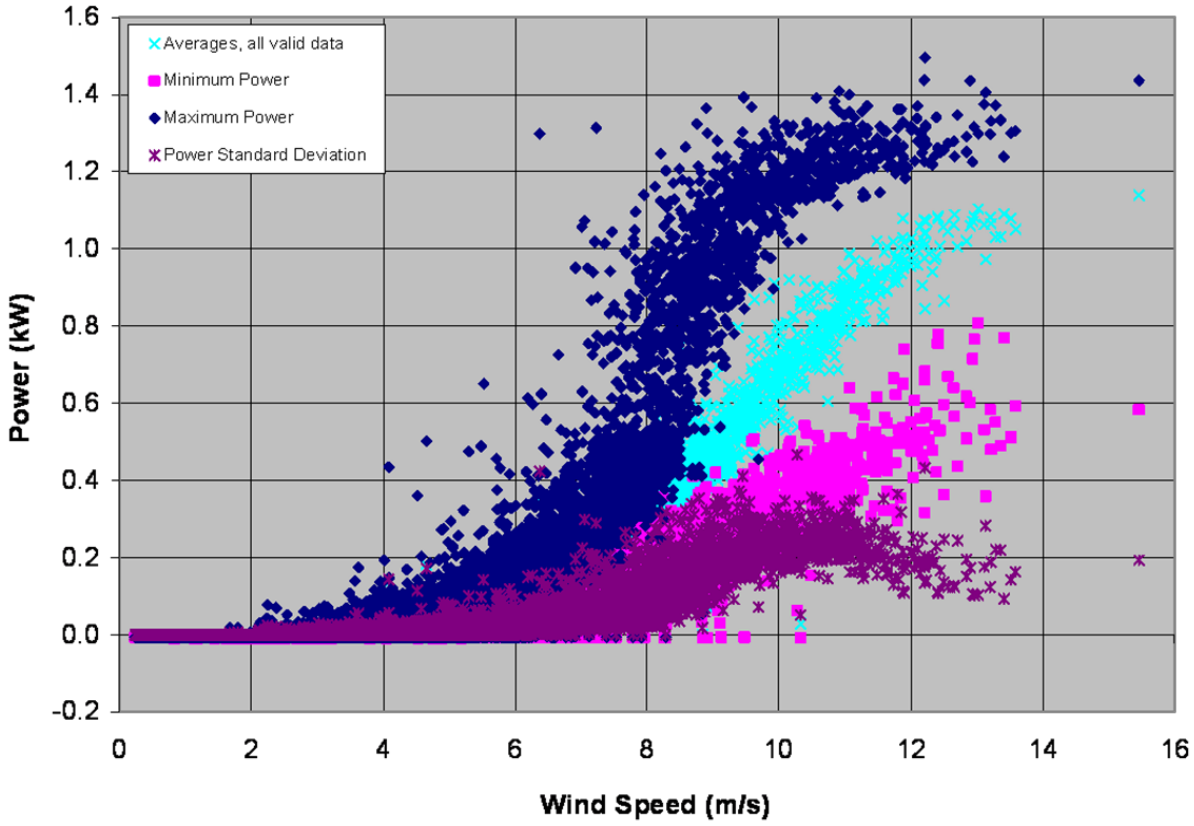

Figure 15. Scatter plot of mean, standard deviation, minimum, and maximum power data for optimized power production

Figure 16 shows a plot of the binned coefficient of power as a function of wind speed at sea-level normalized air density for optimized power production.

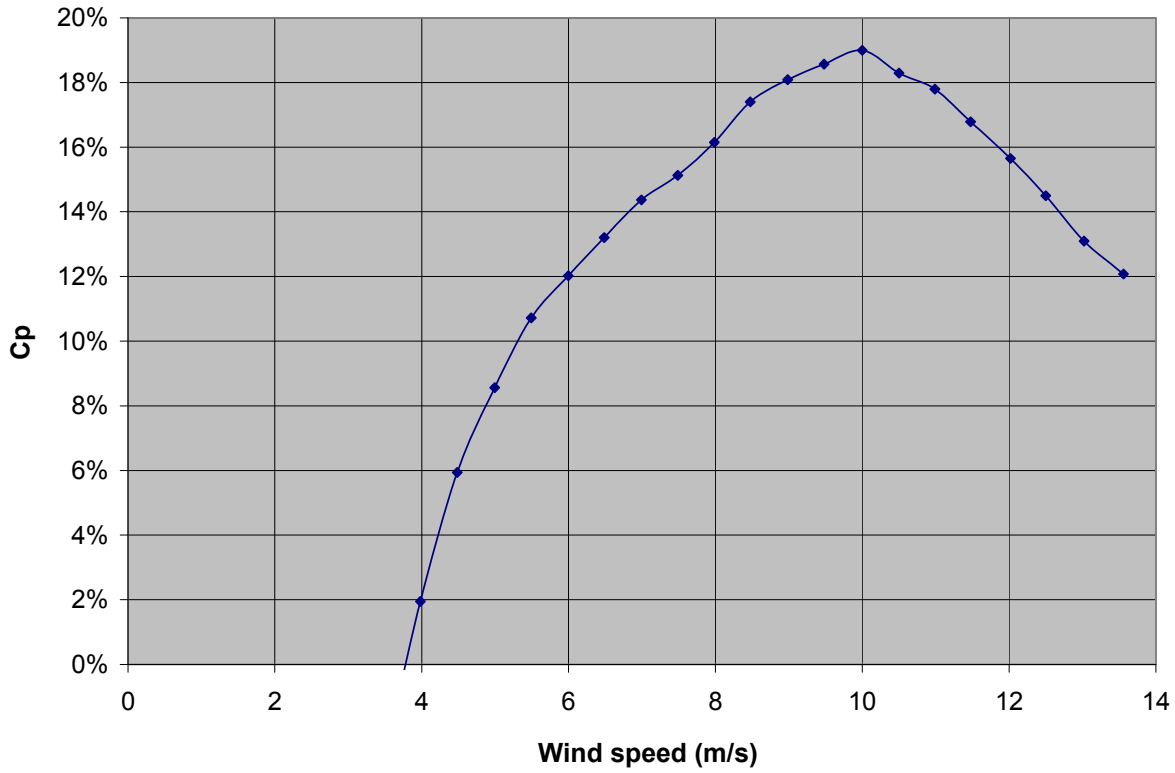

Figure 16. Coefficient of power at sea level density; 1.225 kg/m^3 for optimized power production

Figure 17 shows a scatter plot and binned turbulence intensity as a function of wind speed for optimized power production.

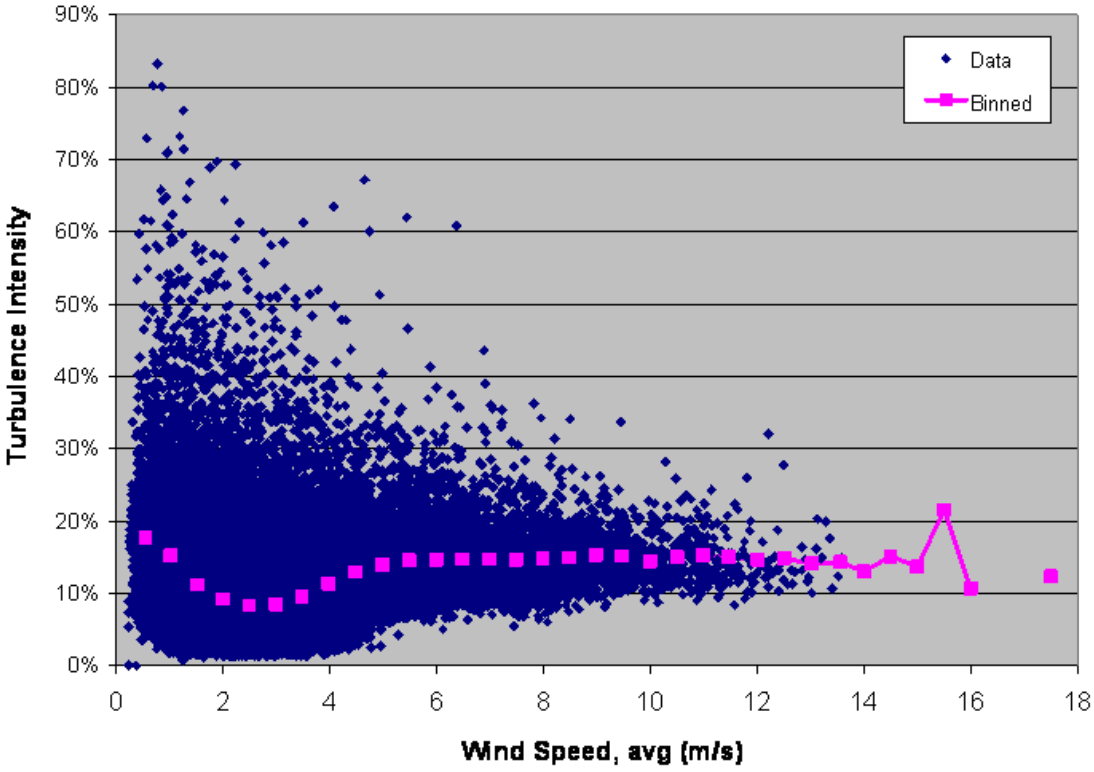

Figure 17. Wind turbulence intensity as a function of wind speed during the test for optimized power production

Figure 18 shows a scatter plot of wind speed and turbulence intensity as a function of wind direction for optimized power production.

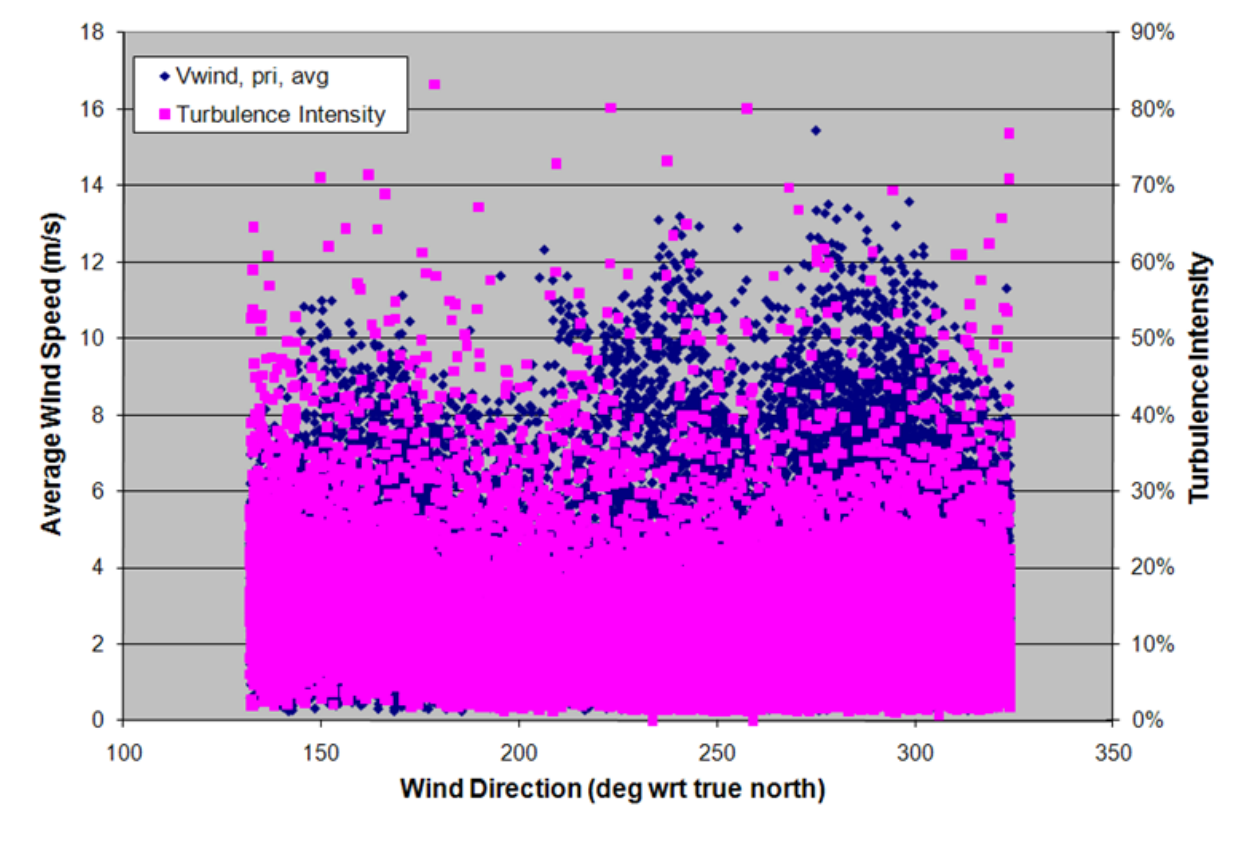

Figure 18. Wind speed and turbulence intensity as a function of wind direction during the test for optimized power production

Figure 19 shows a scatter plot and binned values of rotor speed as a function of wind speed for optimized power production.

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	0	1	2	8	21	43	80	125	164	199	227	253	279

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	299	320	337	350	360	367	369	373	374	371	373	369	370	371

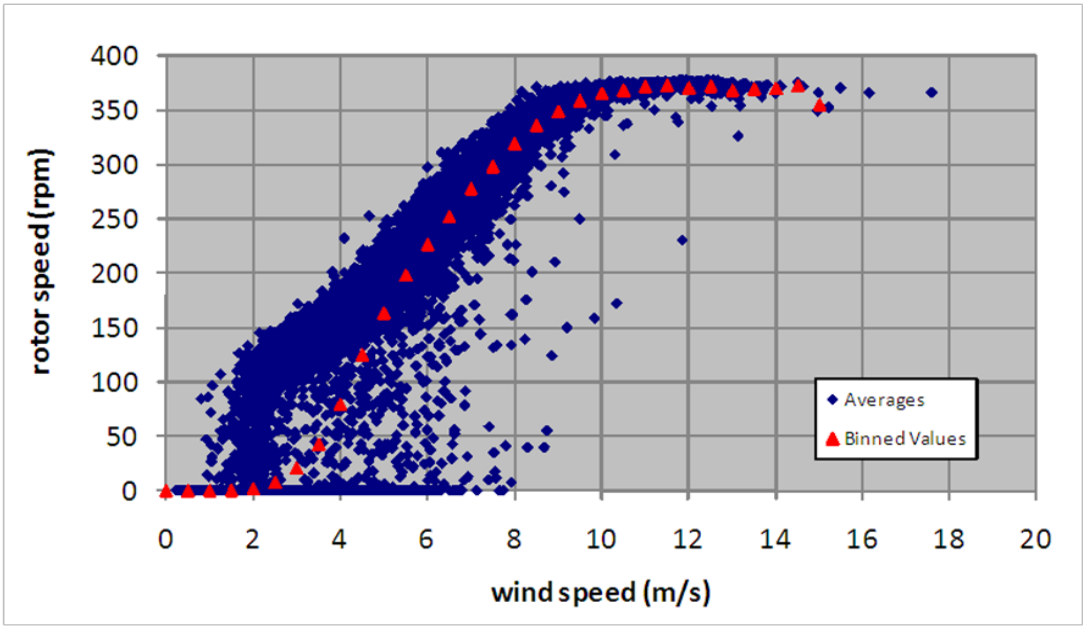

Figure 19. Rotor speed as a function of wind speed (1-minute averages) and binned values for optimized power production

8. Deviations and Exceptions

8.1. Deviations from the Standard

1. The current transformers are not complaint with IEC 60044-1, but do exceed the minimum accuracy required by the Standard.

2. For both turbine configurations, the 14 m/s wind speed bin was not filled as required in Annex H.

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 in compliance with the specifications. The post-test calibration sheets are included in Appendix B.

A. Appendix – Pictures of the Test Site from the Turbine Base

Figure A.1. South-southwest

Figure A.2. South-southeast

Figure A.3. East-southeast

Figure A.4. East-northeast

Figure A.5. North-northeast

Figure A.6. Northwest

Figure A.7. West-northwest

Figure A.8. West

B. Appendix – Equipment Calibration Sheets

Branch #: 5000

NREL METROLOGY LABORATORY

Test Report

Test Instrument: Phaser Power Transducer & 1-CT DOE #: 02825C

Model # : Phaser-5-4A 20 S/N : 02061

Calibration Date: 02/08/2008 Due Date: 02/08/2010

A. Set-Up for Total Real Power Calibration:
A.1. Voltage is applied to phases A&N = 100 V @ 60 Hz.
A.2. Current is applied to n = 10-TURNS through the current transformer that is connected to phases A.
A.3. Analog Output-1 is measured across precision resistor = 250 Ω.
A.4. Phaser Full Scale setting = -1.5KW to 1.5KW.

Input Current (AAC)	Input Power (KW)	Analog Output-1 (VDC)
15	1.5	4.991
10	1.0	4.328
5	0.5	3.662
0	0	2.995
-5	-0.5	2.329
-10	-1.0	1.663
-15	-1.5	0.999

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)
1.5	1.0	4.988
"	0.8	4.182
"	0.6	3.382
"	0.4	2.582

Page 1 of 2

Figure B.1. Power transducer calibration sheet

Branch #: 5000 sheet: 1 of: 1

NREL METROLOGY LABORATORY

Test Report

Test Instrument: RTD Probe DOE #: 03506C

Model # : 78N01N00N04 S/N : 0673553

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	96.070 Ω	-10.05 °C	0.05 °C
2	100.00 Ω	0 °C	99.984 Ω	-0.04 °C	0.04 °C
3	103.90 Ω	10 °C	103.886 Ω	9.96 °C	0.04 °C
4	107.79 Ω	20 °C	107.777 Ω	19.97 °C	0.03 °C
5	111.67 Ω	30 °C	111.653 Ω	29.96 °C	0.04 °C
6	115.54 Ω	40 °C	115.520 Ω	39.95 °C	0.05 °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.2. RTD probe calibration sheet I

Branch #: 5000 sheet: 1 of: 1

NREL METROLOGY LABORATORY

Test Report

Test Instrument: RTD-Probe DOE #: 02746C

Model # : 78N01N00 S/N : 0602948

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	99.94	Same	
		25	109.69	"	
		50	119.35	"	
	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.3. RTD probe calibration sheet II

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_2407

Gegenstand *Object*	Cup Anemometer
Hersteller *Manufacturer*	Thies Clima D-37083 Göttingen
Typ *Type*	4.3350.00.000
Fabrikat/Serien-Nr. *Serial number*	Body: 0707894 Cup: 0707894
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.

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

Figure B.4. Primary anemometer calibration sheet I

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
DAR
DKD-K-28901

Kalibrierschein
Calibration certificate

Kalibrierzeichen
Calibration label

1293_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: 0707894 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.5. 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: **28-Sep-06**

Report Number: W5515-060928

Page: 1 of 1

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

Deviations from procedure: None

Item Calibrated:

Manufacturer	Met One Instruments, Inc
Model	020C
Serial Number	**W5515**
Vane Material	Aluminum
Condition	Refurbished

Results:

Slope:	**0.14242**	**deg/mv**
Offset to boom:	**89.563**	**deg**
Max error:	0.77	deg

Estimated Uncertainty:

Inclinometer Uncertainty (deg)	Total Uncertainty (deg)
0.10	0.44

Traceability:

	Mfg & Model	Serial Number	Cal Date
Inclinometer:	Spi-Tronic	31-038-3	9-Nov-05
Voltmeter:	Fluke743B	6965608	5-May-06

Calibration by: Mark Meadors for

28-Sep-06
Date

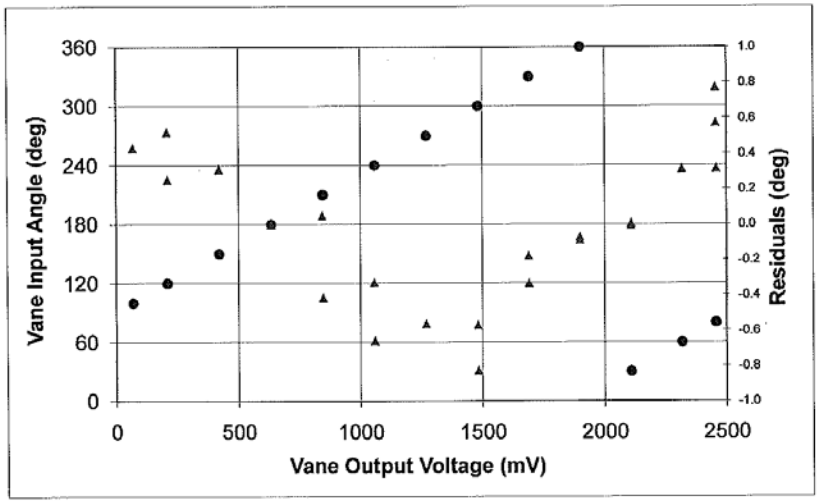

Figure B.6. Wind vane calibration sheet

Branch #: 5000 sheet: 1 of: 1

NREL METROLOGY LABORATORY

Test Report

Test Instrument: Pressure Transmitter DOE #: 03511C

Model # : PTB101B S/N : C1040008

Calibration Date: 09/09/2008 Due Date: 09/09/2009

No	Function Tested	Nominal Value (kPa)	Measured Output Voltage (VDC)		( )Mfr. Specs. OR (X)Data only (mb)
			As Found	As Left	
*	Absolute Pressure				
		65	0.284		
		70	0.558		
		75	0.829		
		80	1.102		
		85	1.376		
		90	1.647		
		95	1.919		
		100	2.192		
		105	2.465		
	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: 02727C, and 02301C.				

Calibrated By: Reda
Date: 09/09/2008

QA By: Bev
Date: 09/09/2008

Figure B.7. Pressure transmitter calibration sheet

Branch #: 5000 sheet: 1 of: 1

NREL METROLOGY LABORATORY

Test Report

Test Instrument: Pressure Transmitter DOE #: 03681C

Model # : PTB101B S/N : Y3350027

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	0.285	Same	
		70	0.558	"	
		75	0.831	"	
		80	1.103	"	
		85	1.375	"	
		90	1.647	"	
		95	1.919	"	
		100	2.193	"	
		105	2.466	"	
	Notes: 1. Uncertainty of the nominal value is ± 0.2 kPa, 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

QA By: Bev
Date: 08/26/2008

Figure B.8. Pressure transmitter calibration sheet II

NATIONAL INSTRUMENTS

Certificate of Calibration

Board Information:
Serial Number: 12B6DD2
NI Part Number: 192580D-02
Description: NI 9229

Certificate Information:
Certificate Number: 756395
Date Printed: 02-JUN-09

Calibration Date: 28-JUN-07
Recommended Calibration Due Date: 28-JUN-08*

Ambient Temperature: 24 °C
Relative Humidity: 39 %

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.

Figure B.9. NI 9229 data acquisition module calibration sheet I

NATIONAL INSTRUMENTS

Certificate of Calibration

Board Information:
Serial Number: 12BD192
NI Part Number: 192547D-01
Description: NI 9217

Certificate Information:
Certificate Number: 762337
Date Printed: 02-JUN-09

Calibration Date: 06-JUL-07
Recommended Calibration Due Date: 06-JUL-08*

Ambient Temperature: 23 °C
Relative Humidity: 43 %

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.

Figure B.10. NI 9217 data acquisition module calibration sheet I

NATIONAL INSTRUMENTS

Certificate of Calibration

Board Information:
Serial Number: 12E9C3E
NI Part Number: 193299F-01
Description: NI-9205

Certificate Information:
Certificate Number: 834976
Date Printed: 02-JUN-09

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

Ambient Temperature: 22 °C
Relative Humidity: 39 %

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.

Figure B.11. NI 9205 data acquisition module calibration sheet I

Davis Calibration

ACCREDITED CALIBRATION

Certificate of Calibration

3214335

Instrument Identification

Company ID: 229037
NATIONAL INSTRUMENTS

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

PO Number: 337683

Instrument ID: 12B6DD2
Manufacturer: NATIONAL INSTRUMENTS
Description: 4-CHANNEL, ±60 V, 24-BIT SIMULTANEOUS ANALOG INPUT

Model Number: NI 9229
Serial Number: 12B6DD2

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

Figure B.12. NI 9229 data acquisition module calibration sheet II

Davis Calibration

ACCREDITED CALIBRATION

Certificate of Calibration

3214168

Instrument Identification

Company ID: 229037
NATIONAL INSTRUMENTS

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

PO Number: 337683

Instrument ID: 12BD192
Manufacturer: NATIONAL INSTRUMENTS
Description: 4-CH 100 OHM 24-BIT RTD ANALOG INPUT

Model Number: NI 9217
Serial Number: 12BD192

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
3078962	15-0011	DECADE RESISTOR	DB52	24Mar2009	24Mar2010
3004176	15-0060	DIGITAL MULTIMETER (GOLDEN CAL)	3458A OPT 002	17Feb2009	17May2009

Figure B.13. NI 9217 data acquisition module calibration sheet II

Davis Calibration

ACCREDITED CALIBRATION

Certificate of Calibration

3214141

Instrument Identification

Company ID: 229037
NATIONAL INSTRUMENTS

PO Number: 337683

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

Instrument ID: 12E9C3E
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: 12E9C3E

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 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.

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

Figure B.14. NI 9205 data acquisition module calibration sheet II

REPORT DOCUMENTATION PAGE

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1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
December 2009	Technical Report	

4. TITLE AND SUBTITLE
Wind Turbine Generator System Power Performance Test Report for the Mariah Windspire 1-kW Wind Turbine

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DE-AC36-08-GO28308

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
A. Huskey, A. Bowen, and D. Jager

5d. PROJECT NUMBER
NREL/TP-500-46192

5e. TASK NUMBER
WE102211

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National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

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13. SUPPLEMENTARY NOTES

14. ABSTRACT *(Maximum 200 Words)*

This report summarizes the results of a power performance test that NREL conducted on the Mariah Windspire 1-kW wind turbine. During this test, two configurations were tested on the same turbine. In the first configuration, the turbine inverter was optimized for power production. In the second configuration, the turbine inverter was set for normal power production. In both configurations, the inverter experienced failures and the tests were not finished.

15. SUBJECT TERMS
wind energy; Mariah; Mariah Windspire 1-kW wind turbine; 1-kW wind turbine; power performance

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (*Include area code*)
Unclassified	Unclassified	Unclassified	UL		

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