WIND DATA REPORT

Mt. Tom

December 1, 2004 – February 28, 2005

Prepared for

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April 6, 2005

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NOTICE AND ACKNOWLEDGEMENTS

This report was prepared by the Renewable Energy Research Laboratory (RERL) at the University of Massachusetts, Amherst in the course of performing work sponsored by the Renewable Energy Trust (RET), as administered by the Massachusetts Technology Collaborative (MTC), pursuant to work order number 05-1. The opinions expressed in this report do not necessarily reflect those of MTC or the Commonwealth of Massachusetts, and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it.

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EXECUTIVE SUMMARY

All the work presented in this Wind Data Report including installation and decommissioning of the meteorological tower and instrumentation, and the data analysis and reporting was preformed by the Renewable Energy Research Laboratory (RERL) at the University of Massachusetts, Amherst.

This wind measurement station is installed on the FAA tower at Mt. Tom in Holyoke, MA. Installed in December of 1999, the station is in continuous operation to this day. Two sets of two anemometers and one wind vane are mounted at 24 m (78.7 ft) and 37 m (121.4 ft), respectively.

During the period covered by this report, December 2004 – February 2005, the mean recorded wind speed for this quarter was 6.47 m/s (14.49 mph)* and the prevailing wind direction was west-northwest. The gross data recovery percentage (the actual percentage of expected data received) was 99.77 % and the net data recovery percentage (the percentage of expected data which passed all of the quality assurance tests) was 94.24 %. The high gross data recovery percentage indicates that the logger is performing well. The low net data recovery percent is the result of several icing events during this quarter.

Additional information about interpreting the data presented in this report can be found in the Fact Sheet, "Interpreting Your Wind Resource Data," produced by RERL and the Massachusetts Technology Collaborative (MTC). This document is found through the RERL website:

http://www.ceere.org/rerl/about_wind/RERL_Fact_Sheet_6_Wind_resource_interpretation.pdf.

* 1m/s = 2.24 mph

SECTION 1 - Station Location

The Mt. Tom site is located at an existing FAA tower on top of Mt. Tom in Holyoke, MA. Some trees are located in the vicinity, as is an ESI-80 wind turbine. The location of the tower base is at 42°-14'-59.2" N, 72°-38'-42.2" W (NAD 27).

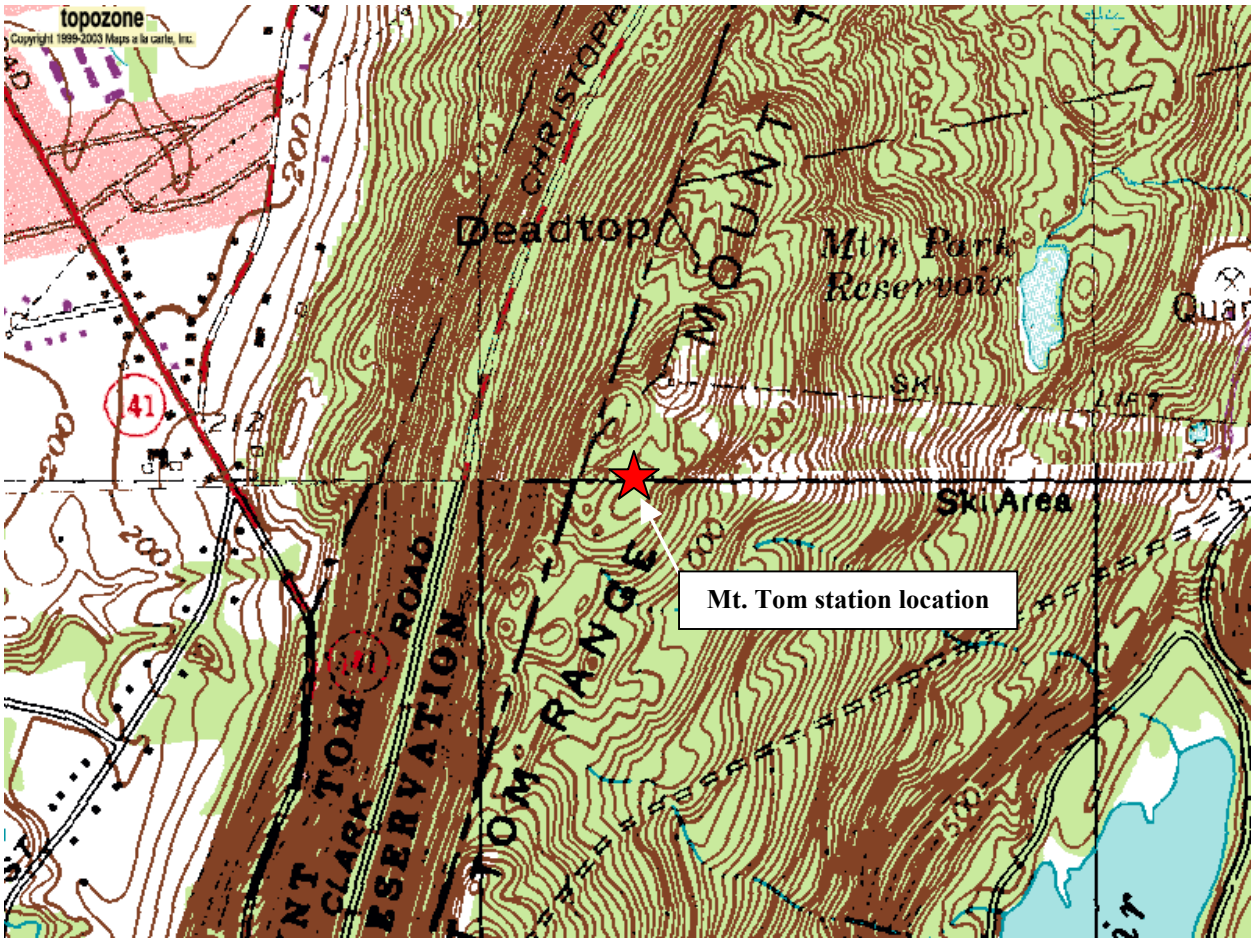

Figure 1 – Station location of Mt. Tom.

www.topozone.com

SECTION 2 - Instrumentation and Equipment

The wind monitoring equipment is mounted on a 160 ft lattice tower. All the remaining monitoring equipment comes from NRG Systems, and consists of the following items:

- Model 9302 Cellogger®, serial # 0656
- Electrical enclosure box
- Yagi directional antenna and mount
- 4 – #40 Anemometers, standard calibration (Slope - 0.765 m/s, Offset – 0.350 m/s). Two anemometers are located at both 37 m (121.4 ft) and 24 m (78.7 ft).
- 2 - #200P Wind direction vanes. They are located at 37 m (121.4 ft) and 24 m (78.7 ft).
- 4 – Sensor booms, 43" length
- Lightning rod and grounding cable
- Shielded sensor wire

The NRG 9302 system logger is equipped with a built-in cell phone so that the data can be transmitted weekly to a PC, located at the University of Massachusetts, Amherst. The logger samples the wind speed and direction 1 Hz. These samples are then combined into 10-minute averages and, along with the standard deviation for those 10-minute periods, are put into a binary file. These binary files are converted to ASCII text files using the NRG software BaseStation®. These text files are then imported into a database software program where they are subjected to quality assurance (QA) tests prior to using the data.

SECTION 3 - Data Collection and Maintenance

The following maintenance/equipment problems occurred during the reporting period, and the following corrective actions were taken:

- On 2/02/2005, the data transmission was not successful when the logger cell phone made its weekly call to the RERL. The data card was manually swapped on 2/09/2005. The data transmission was again unsuccessful on 3/02/2005 and so the data card was manually swapped on 3/07/2005.
- In order to remedy the data transmission problems, the two 9-volt batteries that power the logger were replaced. The cell phone's 12-volt battery and 12-power supply were also replaced. The data were successfully transmitted on the next scheduled logger cell phone call.

No measurement of wind speed can be perfectly accurate. Errors occur due to anemometer manufacturing variability, anemometer calibration errors, the response of anemometers to turbulence and vertical air flow and due to air flows caused by the anemometer mounting system. Every effort is made to reduce the sources of these errors. Nevertheless, the values reported in this report have an expected uncertainty of about ± 2% or ± 0.2 m/s.

Data Statistics Summary

Date	Mean Wind Speed	Max Wind Speed	Turbulence Intensity	Prevailing Wind Direction	Mean Wind Speed	Max Wind Speed	Turbulence Intensity	Prevailing Wind Direction
Heights, units	**37 m, [m/s]**	**37 m, [m/s]**	**37 m, [ ]**	**37 m, [ ]**	**24 m, [m/s]**	**24 m, [m/s]**	**24 m, [ ]**	**24 m, [ ]**
Dec 2004	6.87	23.90	0.18	WNW	5.91	21.80	0.23	WNW
Jan 2005	6.15	19.38	0.19	NW	5.28	16.09	0.24	WNW
Feb 2005	6.36	18.67	0.18	WNW	5.57	16.93	0.23	WNW
Dec 2004 -- Feb 2005	**6.47**	**23.9**	**0.18**	**WNW**	**5.59**	**21.8**	**0.23**	**WNW**

SECTION 4- Data Recovery and Validation

All raw wind data are subjected to a series of tests and filters to weed out data that are faulty or corrupted. Definitions of these quality assurance (QA) controls are given below under Test Definitions and Sensor Statistics. These control filters were designed to automate the quality control process and used many of the previous hand-worked data sets made at UMass to affect a suitable emulation. The gross percentage of data recovered (ratio of the number of raw data points received to data points expected) and net percentage (ratio of raw data points which passed all QA control tests to data points expected) are shown below.

Gross Data Recovered [%]	99.77
Net Data Recovered [%]	94.24

The high gross data recovery percentage indicates that the logger is performing well. The low net data recovery is the result of several icing events during this quarter. The dates and times of these icing events are listed below:

- December 6, 2004 at 21:40 – December 8, 2004 at 6:50
- January 6, 2004 at 12:20 – January 10, 2005 at 7:40
- February 10, 2005 at 8:50 – February 11, 2005 at 00:10
- February 21, 2005 at 15:30 – February 23, 2005 at 3:30

Test Definitions

All raw data were subjected to a series of validation tests, as described below. The sensors tested and the parameters specific to each sensor are given in the Sensor Performance Report that is included in APPENDIX A. Data that were flagged as invalid were not included in the statistics presented in this report.

MinMax Test: All sensors are expected to report data values within a range specified by the sensor and logger manufacturers. If a value falls outside this range, it is flagged as invalid. A data value from the sensor listed in Test Field 1 (TF1) is flagged if it is less than Factor 1 (F1) or greater than Factor 2. This test has been applied to the following sensors (as applicable): wind speed, wind speed standard deviation, wind direction, temperature, and solar insolation.

$$F1 > TF1 > F2$$

MinMaxT Test: This is a MinMax test for wind direction standard deviation with different ranges applied for high and low wind speeds. A wind direction standard deviation data value (TF1) is flagged either if it is less than Factor 1, if the wind speed (TF2) is less than Factor 4 and the wind direction standard deviation is greater than Factor 2, or if the wind speed is greater than or equal to Factor 4 and the wind direction standard deviation is greater than Factor 3.

$$(TF1 < F1)$$
$$\text{or } (TF2 < F4 \text{ and } TF1 > F2)$$
$$\text{or } (TF2 \geq F4 \text{ and } TF1 > F3)$$

Icing Test: An icing event occurs when ice collects on a sensor and degrades its performance. Icing events are characterized by the simultaneous measurements of near-zero standard deviation of wind direction, non-zero wind speed, and near- or below-freezing temperatures. Wind speed, wind speed standard deviation, wind direction, and wind direction standard deviation data values are flagged if the wind direction standard deviation (CF1) is less than or equal to Factor 1 (F1), the wind speed (TF1) is greater than Factor 2 (F2), and the temperature (CF2) is less than Factor 3 (F3). To exit an icing event, the wind direction standard deviation must be greater than Factor 4.

$$CF1 \leq F1 \text{ and } TF1 > F2 \text{ and } CF2 < F3$$

CompareSensors Test: Where primary and redundant sensors are used, it is possible to determine when one of the sensors is not performing properly. For anemometers, poor performance is characterized by low data values. Therefore, if one sensor of the pair reports values significantly below the other, the low values are flagged. At low wind speeds (Test Fields 1 and 2 less than or equal to Factor 3) wind speed data are flagged if the absolute difference between the two wind speeds is greater than Factor 1. At high wind speeds (Test Fields 1 or 2 greater than Factor 3) wind speed data are flagged if the absolute value of the ratio of the two wind speeds is greater is greater than Factor 2.

$$[\ TF1 \leq F3 \text{ and } TF2 \leq F3 \text{ and } \text{abs}(TF1 - TF2) > F1\ ]$$
$$\text{or } [\ (TF1 > F3 \text{ or } TF2 > F3) \text{ and } (\text{abs}(1 - TF1 / TF2) > F2 \text{ or } \text{abs}(1 - TF2 / TF1) > F2)\ ]$$

Sensor Statistics

Expected Data Points: the total number of sample intervals between the start and end dates (inclusive).

Actual Data Points: the total number of data points recorded between the start and end dates.

% Data Recovered: the ratio of actual and expected data points (this is the *gross data recovered percentage*).

Hours Out of Range: total number of hours for which data were flagged according to MinMax and MinMaxT tests. These tests flag data that fall outside of an expected range.

Hours of Icing: total number of hours for which data were flagged according to Icing tests. This test uses the standard deviation of wind direction, air temperature, and wind speed to determine when sensor icing has occurred.

Hours of Fault: total number of hours for which data were flagged according to CompareSensors tests. These tests compare two sensors (e.g. primary and redundant anemometers installed at the same height) and flag data points where one sensor differs significantly from the other.

% Data Good: the filter results are subtracted from the gross data recovery percentage to yield the *net data recovered percentage*.

SECTION 5 - Data Summary

This report contains several types of wind data graphs. Unless otherwise noted, each graph represents data at a height of 37 m (121.4 ft) for the fall quarter comprising of December 2005 and January and February 2005. The following graphs are included:

- Time Series – In Figure 2, 10-minute average wind speeds are plotted against time for all data starting on December 1, 2004 at midnight through February 28, 2004 at 11:50 P.M. The time series shows the high winter wind speeds.

- Wind Speed Distribution – A histogram plot giving the percentage of time that the wind is at a given wind speed is shown in Figure 3. This plot shows that the wind speeds ranged between 5 and 6 (11.2 and 13.4 mph) 11.34 % of the time.

- Wind Rose – Figure 7 is a plot, by compass direction, showing the percentage of time that the wind comes from a given direction and the average wind speed in that direction. This wind rose shows that the prevailing wind direction is west-northwest. Wind blew from this direction 15.71 % of the time with a mean wind speed of 9.39 m/s (21.03 mph).

SECTION 6 - Graphs

Data for the wind speed histograms, monthly and diurnal average plots, and wind roses are included in APPENDIX B.

Wind Speed Time Series

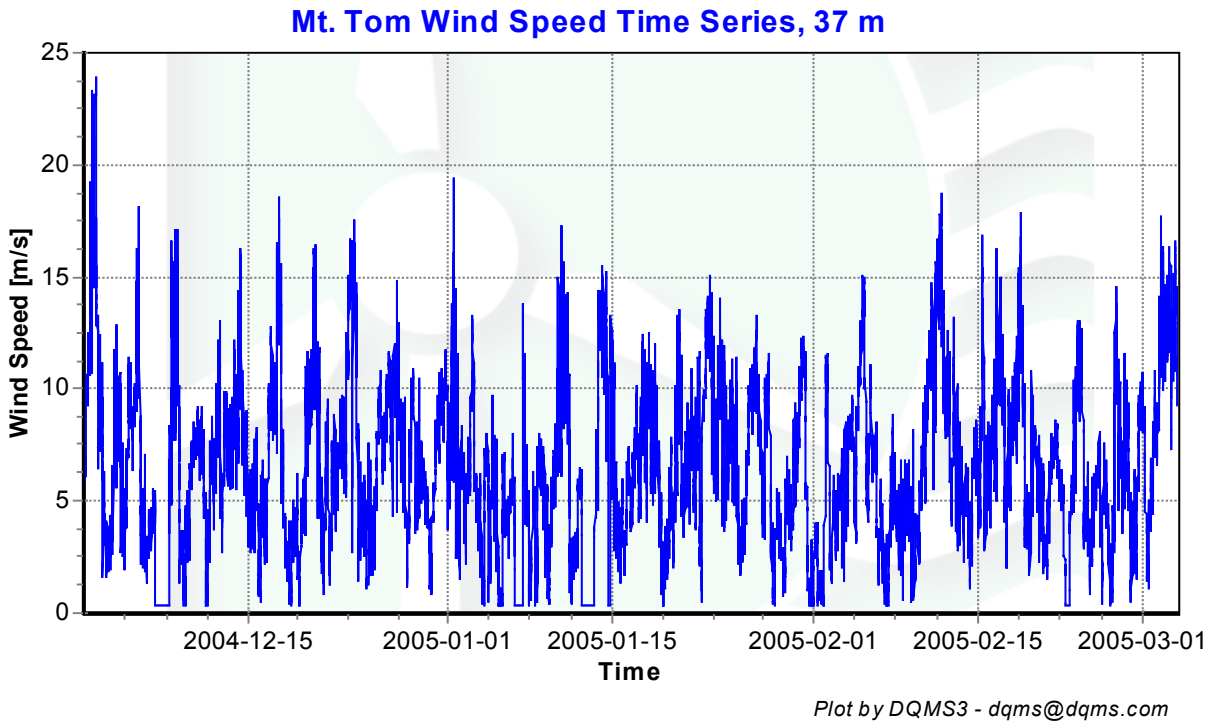

Figure 2 - Wind Speed Time Series, December 2004 – February 2005

Wind Speed Distribution

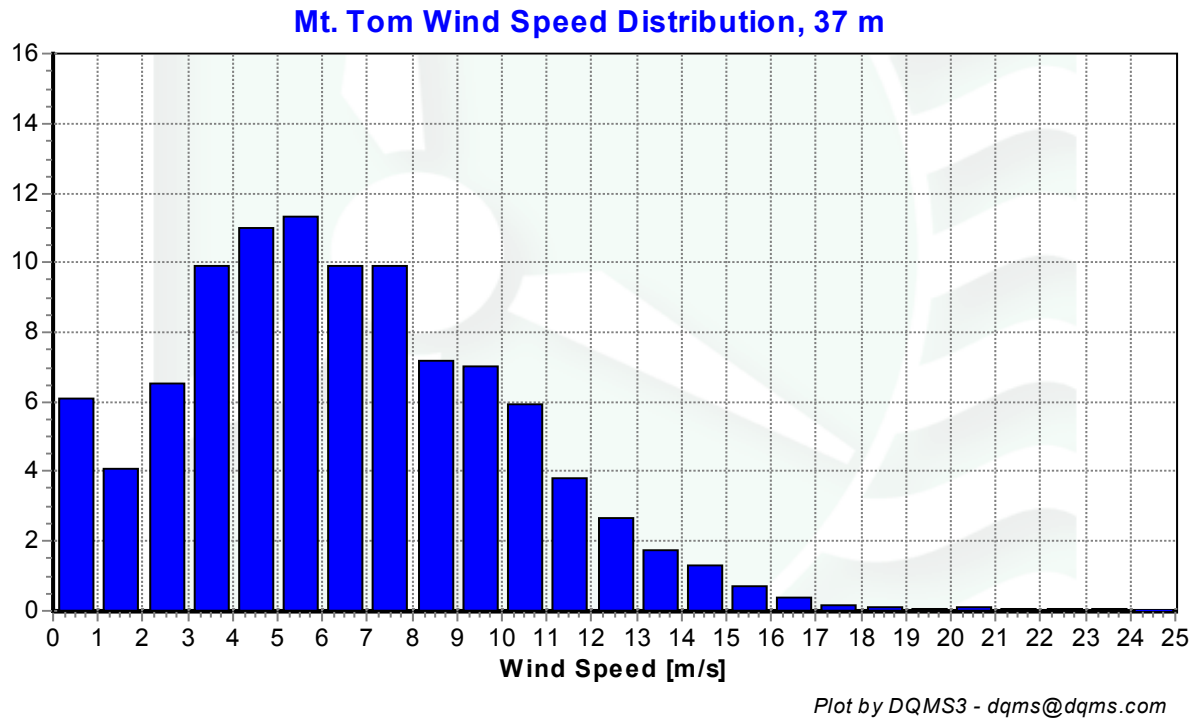

Figure 3 – Wind Speed Distributions, December 2004 – February 2005

Wind Rose

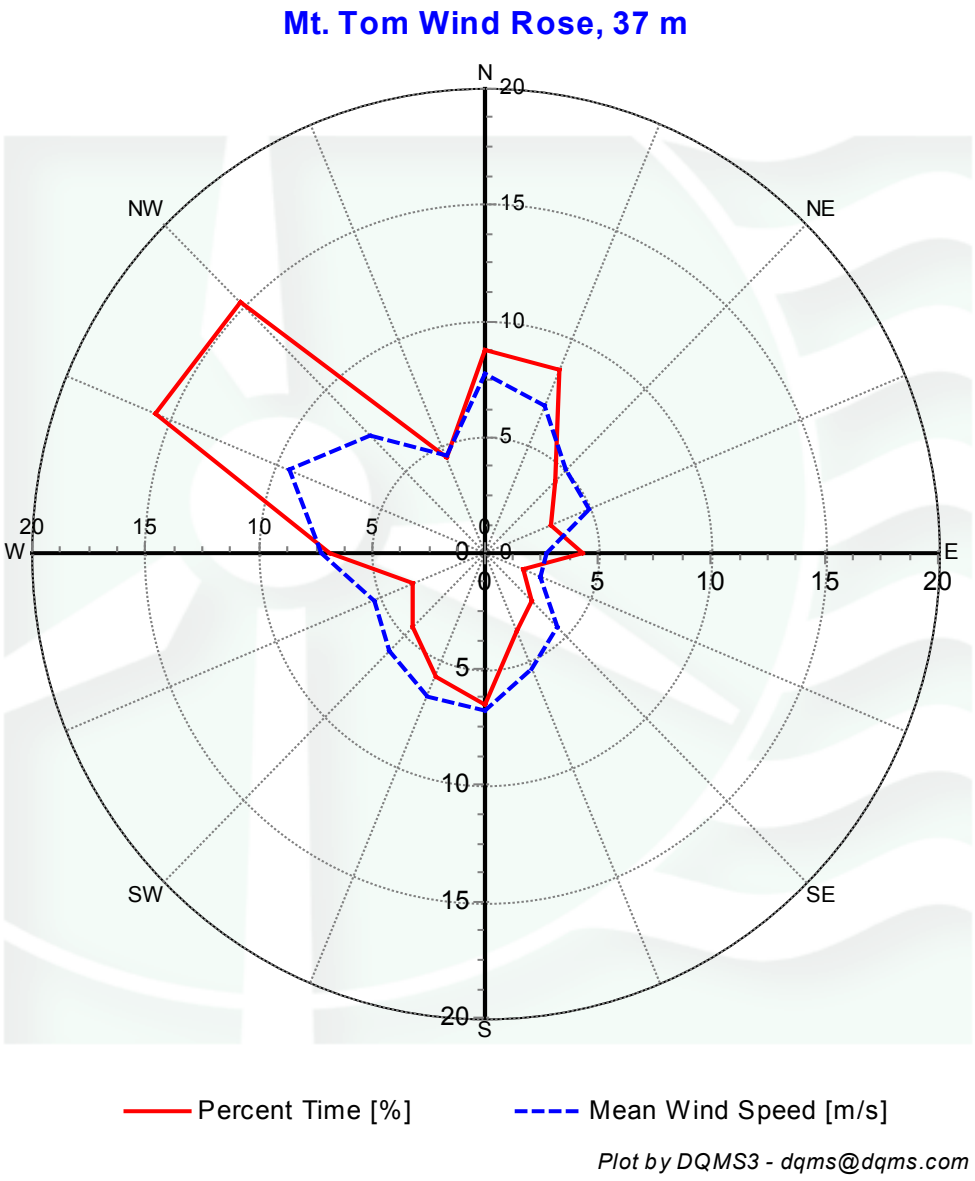

Figure 4 - Wind Rose, December 2004 – February 2005

APPENDIX A - Sensor Performance Report

Test Definitions

Test Order	TestField1	TestField2	TestField3	CalcField1	CalcField2	TestType	Factor1	Factor2	Factor3	Factor4
1						TimeTest Insert				
2	Itmp3aDEGC					MinMax	-30	60		
3	Batt3aVDC					MinMax	10.5	15		
4	Etmp3aDEGC					MinMax	-30	60		
5	EtmpSD3aDEGC					MinMax	0	4		
10	Anem24yMS					MinMax	0	90		
11	Anem37yMS					MinMax	0	90		
12	Anem24aMS					MinMax	0	90		
13	Anem24bMS					MinMax	0	90		
14	Anem37aMS					MinMax	0	90		
15	Anem37bMS					MinMax	0	90		
16	Anem18bMS					MinMax	0	90		
17	Anem21aMS					MinMax	0	90		
20	AnemSD24aMS					MinMax	0	7		
21	AnemSD24bMS					MinMax	0	7		
22	AnemSD37aMS					MinMax	0	7		
23	AnemSD37bMS					MinMax	0	7		
24	AnemSD18bMS					MinMax	0	7		
25	AnemSD21aMS					MinMax	0	7		
26	AnemSD24yMS					MinMax	0	7		
27	AnemSD37yMS					MinMax	0	7		
40	Pyro6aWMS					MinMax	0	1500		
41	PyroSD6aWMS					MinMax	0	1000		
50	Turb24zNONE					MinMax	0	2		
51	Turb37zNONE					MinMax	0	2		
60	Wshr0zNONE					MinMax	-100	100		
70	Pwrd24zWMC					MinMax	0	10000		
71	Pwrd37zWMC					MinMax	0	10000		
200	VaneSD24aDEG	Anem24yMS				MinMaxT	0	100	100	10
201	VaneSD37aDEG	Anem37yMS				MinMaxT	0	100	100	10
250	Vane24aDEG					MinMax	0	359.9		
251	Vane37aDEG					MinMax	0	359.9		
252	Vane19aDEG					MinMax	0	359.9		
300	Anem24aMS	AnemSD24aMS	Vane24aDEG	VaneSD24aDEG	Etmp3aDEGC	Icing	0.5	1	2	10
301	Anem24bMS	AnemSD24bMS	Vane24aDEG	VaneSD24aDEG	Etmp3aDEGC	Icing	0.5	1	2	10
302	Anem37aMS	AnemSD37aMS	Vane37aDEG	VaneSD37aDEG	Etmp3aDEGC	Icing	0.5	1	2	10
303	Anem37bMS	AnemSD37bMS	Vane37aDEG	VaneSD37aDEG	Etmp3aDEGC	Icing	0.5	1	2	10
400	Anem24aMS	Anem24bMS				CompareSensors	1	0.25	3	0
401	Anem37aMS	Anem37bMS				CompareSensors	1	0.25	3	0

Sensor Statistics

Sensor	Expected Data Points	Actual Data Points	% Data Recovered	Hours Out of Range	Hours of Icing	Hours of Fault	% Data Good
Itmp3aDEGC	12960	12754	98.41	0	0	0	98.41
Batt3aVDC	12960	12754	98.41	0	0	0	98.41
Anem24aMS	12960	12952	99.938	0	153.333	8.5	92.446
AnemSD24aMS	12960	12952	99.938	0	153.333	8.5	92.446
Anem24bMS	12960	12952	99.938	0	153.333	25.5	91.659
AnemSD24bMS	12960	12952	99.938	0	153.333	25.5	91.659
Anem37aMS	12960	12952	99.938	0	176.5	2.667	91.644
AnemSD37aMS	12960	12952	99.938	0	176.5	2.667	91.644
Anem37bMS	12960	12952	99.938	0	176.5	48.5	89.522
AnemSD37bMS	12960	12952	99.938	0	176.5	48.5	89.522
Vane24aDEG	12960	12952	99.938	1	153.333	0	92.793
VaneSD24aDEG	12960	12952	99.938	1	153.333	0	92.793
Vane37aDEG	12960	12952	99.938	0	176.5	0	91.767
VaneSD37aDEG	12960	12952	99.938	0	176.5	0	91.767
Etmp3aDEGC	12960	12952	99.938	0	0	0	99.938
EtmpSD3aDEGC	12960	12952	99.938	0	0	0	99.938
Pyro6aWMS	12960	12952	99.938	0	0	0	99.938
PyroSD6aWMS	12960	12952	99.938	0	0	0	99.938
Total	**233280**	**232740**	**99.769**	**2**	**1979**	**170.333**	**94.235**

APPENDIX B - Plot Data

Wind Speed Distribution Data

Bin Center Wind Speed [m/s]	Percent of Time [%]
0.5	6.11
1.5	4.08
2.5	6.55
3.5	9.89
4.5	10.99
5.5	11.34
6.5	9.88
7.5	9.91
8.5	7.17
9.5	7.02
10.5	5.93
11.5	3.78
12.5	2.67
13.5	1.75
14.5	1.3
15.5	0.72
16.5	0.36
17.5	0.16
18.5	0.09
19.5	0.05
20.5	0.08
21.5	0.08
22.5	0.05
23.5	0.03
24.5	0

Table 1: Wind Speed Distribution

Wind Rose Data

Direction	Percent Time [%]	Mean Wind Speed [m/s]
N	8.73	7.73
NNE	8.58	6.89
NE	4.36	5.09
ENE	3.13	4.94
E	4.28	2.73
ESE	1.81	2.63
SE	2.93	4.46
SSE	3.64	5.43
S	6.57	6.76
SSW	5.72	6.66
SW	4.49	5.97
WSW	3.46	5.3
W	6.84	7.25
WNW	15.71	9.39
NW	15.27	7.21
NNW	4.48	4.51

Table 2: Wind Rose, Time Percentage and Mean Wind Speed by Direction