WIND DATA REPORT

Mt. Tom

June 1, 2004 – August 31, 2004

Prepared for

Massachusetts Technology Collaborative
75 North Drive
Westborough, MA 01581

by

Melissa L. Ray
James F. Manwell
Anthony L. Rogers
Anthony F. Ellis
Ashwin Gambhir

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Renewable **E**nergy **R**esearch **L**aboratory
University of Massachusetts, Amherst
160 Governors Drive, Amherst, MA 01003
www.ceere.org/rerl • (413) 545-4359 • rerl@ecs.umass.edu

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, June 2004 – August 2004, no mean recorded quarterly wind speed is available because data is missing from July 1, 2004 – August 4, 2004 due to logger failure. For June 2004, the mean recorded wind speed at 37 m (121.4 ft) was 5.55 m/s (12.42 mph)* with a prevailing wind from west-northwest. For August 2004, using only the 27 days of available data, the mean recorded wind speed at 37 m (121.4 ft) was 5.01 m/s (11.21 mph) with a prevailing wind from the south. The gross data recovery percentage (the actual percentage of expected data received) for the quarter was 53.76 %. The low gross data recovery is the consequence of three factors:

1. The NRG 9302 Cellogger failed on July 1, 2004. Data is missing from July 1 to August 4, when a Symphonie logger was installed as a temporary replacement.

2. When the broken logger was replaced with the Symphonie logger on August 4, six logger channels were mistakenly left unplugged until August 21.

3. Unlike the NRG 9302 logger, the Symphonie logger does not collect logger internal temperature and battery voltage. While these missing data are not directly used in quarterly wind data reports, they still contributed to the low gross data recovery percentage.

The net data recovery percentage (the percentage of expected data which passed all of the quality assurance tests) was 53.625%. The closeness of the net data recovery value to the gross data recovery value suggests that all of the sensors are working well.

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.

* 1 m/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).

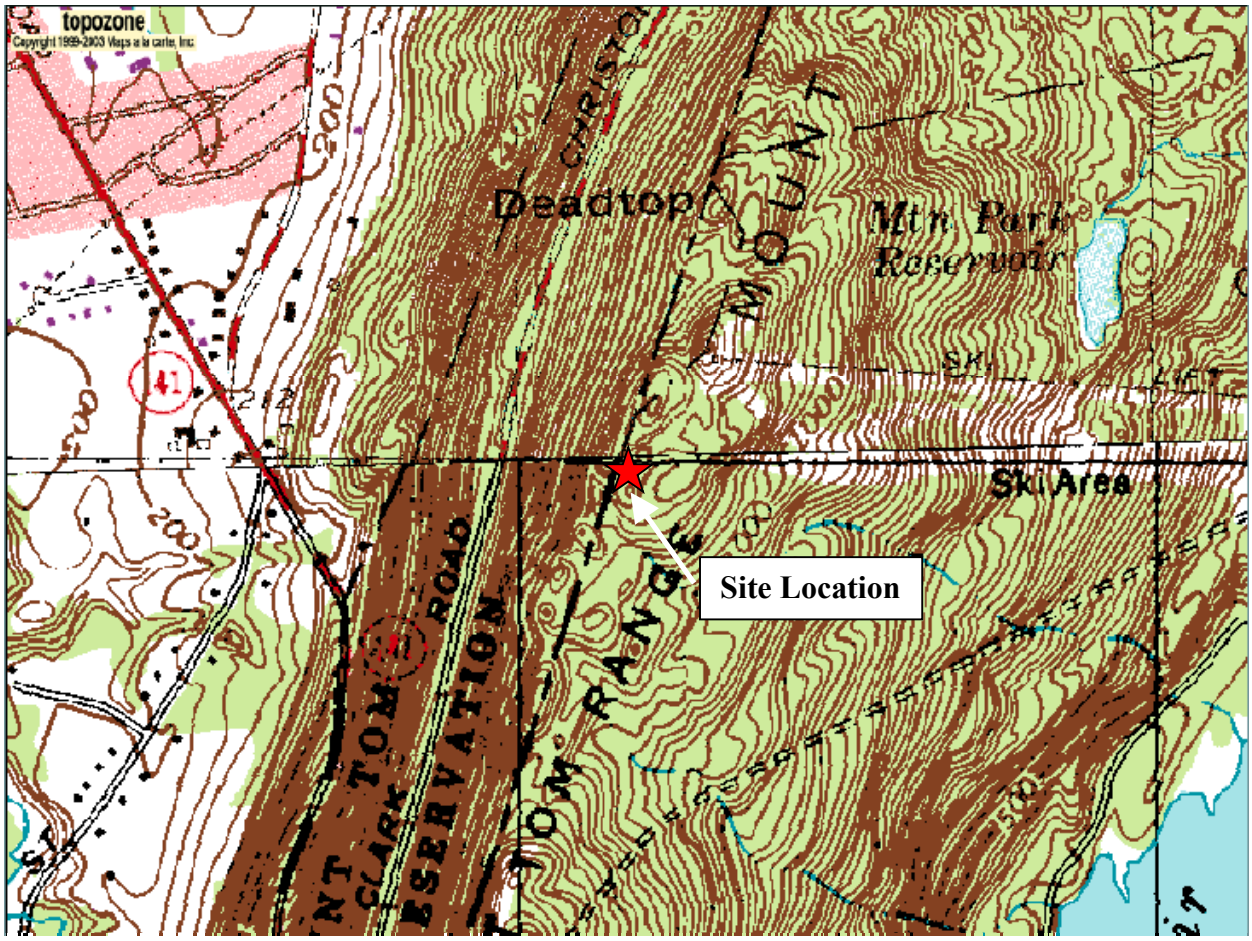

Figure 1: Station location of Mt. Tom.

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 & Symphonie Data Logger (from 8/04/2004)
- 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 data from the Symphonie logger was retrieved about once per month. The NRG 9302 and Symphonie loggers sample wind speed and direction at 1 and 2 Hz, respectively. 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 July 1, 2004 at 2:40 p.m., the NRG 9302 Cellogger failed. When this problem was identified, a Symphonie Data Logger was available as a replacement. The Symphonie logger was installed and started collecting data on August 4, 2004 at 2:40 p.m.
- During the installation of the Symphonie logger, six logger channels were mistakenly left unplugged. Of these channels, data from only two were used in this quarterly report. However, all of the missing data contributed to the low gross data recovery. The relevant missing data for this quarterly report are the external temperature and the redundant anemometer at 37 m (121.4 ft). All of the channels were plugged in on August 21, 2004 at 11:00 a.m.
- The Symphonie Data Logger does not collect the exact same type of data as the NRG 9302 Cellogger that it replaced. Therefore, for the time period that the Symphonie was installed, August 4, 2004 to December 2, 2004, there are no available logger internal temperature or battery voltage data. These missing data do not affect the results in this report, but they do contribute to lower gross data recovery percentages.

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.

Given that the logger was down from July 1 through August 4, only June has a full month of data for this quarter consisting of June, July, and August of 2004. For that reason, June is the only full month for which data statistics are summarized in the table below. The August data statistics only represent data from August 4, 2004 at 2:40 p.m – August 31, 2004 at 11:50 p.m. With less than a day of July data, no July data statistics are presented. Furthermore, without complete July or August data, the quarterly averaged statistics are not applicable, so they have also been omitted from the summary table.

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, [ ]**
June 2004	.55	17.66	0.2	WNW	4.62	14.03	0.26	WNW
July 2004	--	--	--	--	--	--	--	--
Aug 2004	5.01	15.6	0.19	S	4.2	12.5	0.25	S
June – Aug 2004	--	--	--	--	--	--	--	--

SECTION 4 - Significant Meteorological Events

The summer of 2004 had close to average wind conditions. There are no major wind events shown in the wind speed time series. The summer of 2004 was cooler and wetter than an average summer, but this did not cause abnormal wind conditions.

Source: http://www.erh.noaa.gov/box/MonthlyClimate2.shtml.

SECTION 5 - 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 [%]	53.76
Net Data Recovered [%]	53.625

The low Gross Data Recovered Percentage is the result of three circumstances:

1. The NRG 9302 Cellogger failed on July 1, 2004. Data is missing from July 1 to August 4, when a Symphonie logger was installed as a temporary replacement.

2. When the broken logger was replaced with the Symphonie logger on August 4, six logger channels were mistakenly left unplugged until August 21.

3. Unlike the NRG 9302 logger, the Symphonie logger does not collect logger internal temperature and battery voltage. While these missing data are not directly used in quarterly wind data reports, they still contributed to the low gross data recovery percentage.

The very small difference between the Gross Data Recovered Percentage and the Net Data Recovery Percentage indicates that the sensors were functioning properly.

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.

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

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 which 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 6 - 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 summer quarter comprising of June, July, and August of 2004. Due to the missing data from July and August, most of the quarterly graphs were not generated and are therefore not included. These are denoted by "Data Not Available."

The following graphs are included:

- Time Series – In Figure 2, 10-minute average wind speeds are plotted against time for all data starting on June 1, 2004 at midnight through August 31, 2004 at 11:50 p.m. The gap in the data is due to the down logger from July 1, 2004 at 11:10 p.m. through August 4, 2004 at 2:40 p.m.

- Wind Speed Distribution – There were not enough data to calculate the quarterly values for this plot. The wind speed distribution is shown in Figure 3.

- Monthly Average – A plot of the average monthly wind speed over a 12-month period is shown in Figure 4. The monthly average for November 2003 is unavailable due to sensor failure and the averages for July and August 2004 were not calculated because more than 10% of the data was missing due to the aforementioned equipment problems. This graph demonstrates the trend that average wind speeds are generally higher in the winter months, with a maximum average wind speed of 7.65 m/s (17.11 mph) in January 2003.

- Diurnal Averages– There were not enough data to calculate the quarterly values for this plot. The diurnal averages are shown in Figure 5.

- Turbulence Intensity – There were not enough data to calculate the quarterly values for this plot. The turbulence intensity is shown in Figure 6.

- Wind Rose – There were not enough data to calculate the quarterly values for this plot. The wind rose is shown in Figure 7.

SECTION 7 - Graphs

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

Wind Speed Time Series

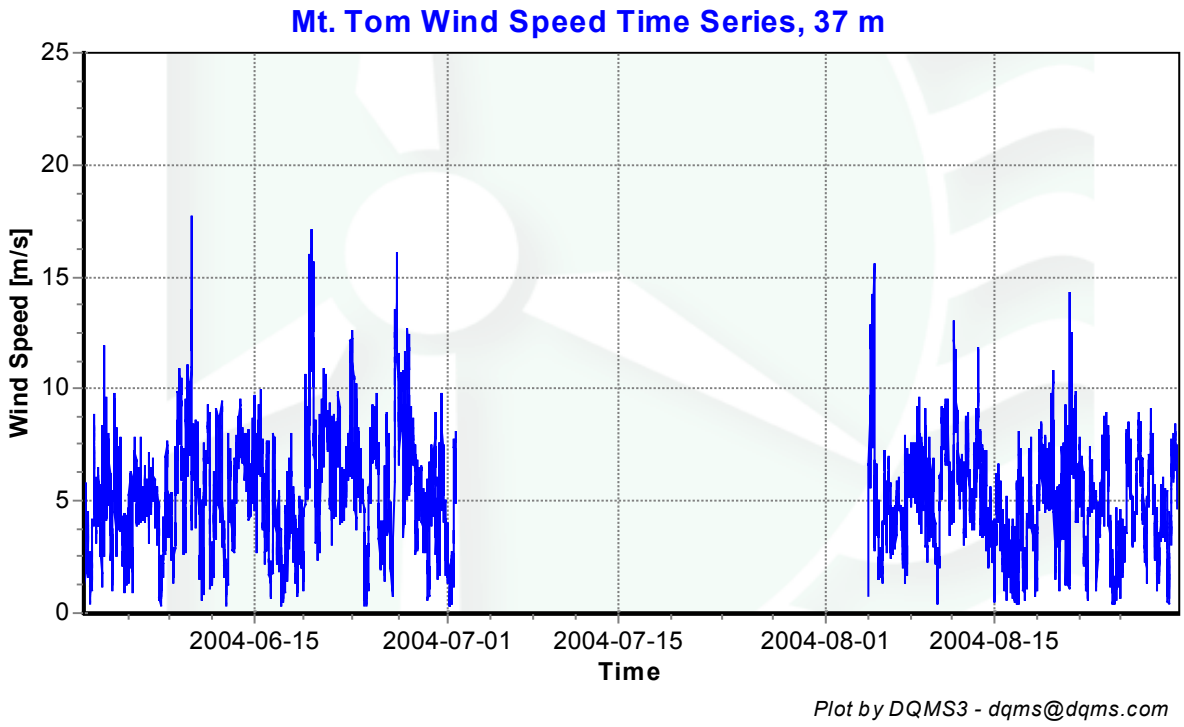

Figure 2 - Wind Speed Time Series, June 2004 – August 2004

Wind Speed Distribution

Data Not Available

Figure 3 – Wind Speed Distributions, June 2004 – August 2004

Monthly Average Wind Speeds

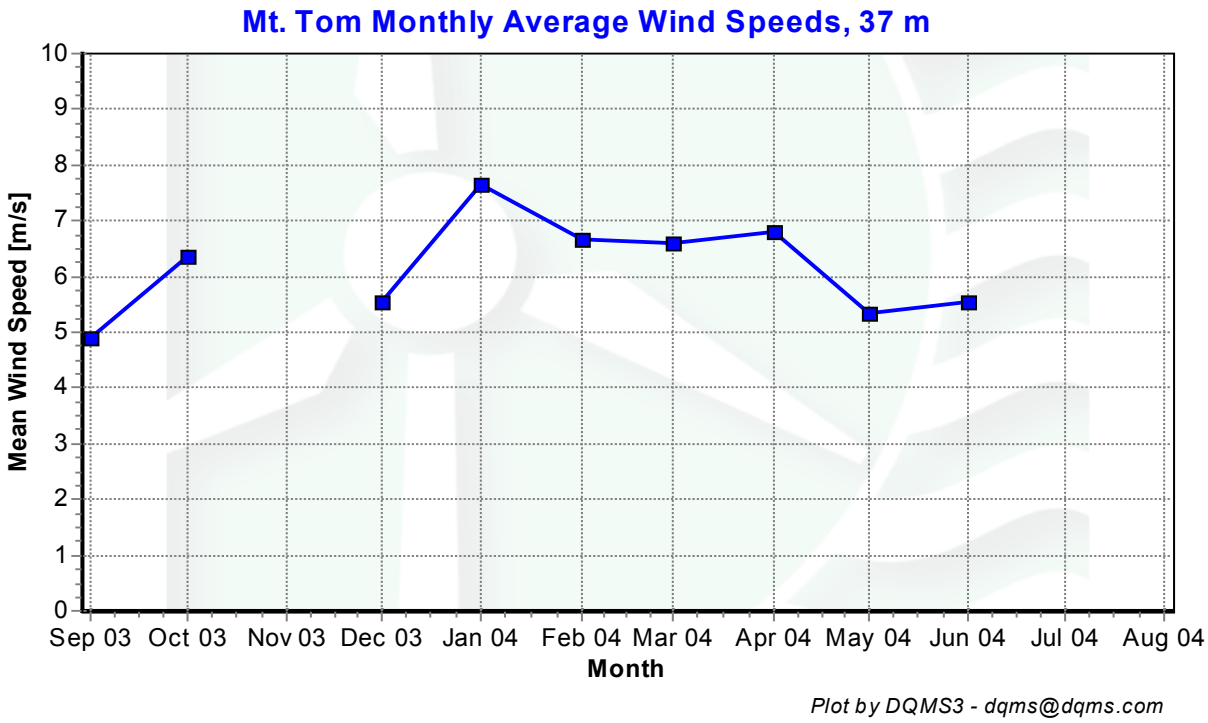

Figure 4 - Monthly Averages, September 2003 – August 2004

Diurnal Average Wind Speeds

Data Not Available

Figure 5 - Diurnal Average Wind Speed, June 2004 – August 2004

Turbulence Intensities

Data Not Available

Figure 6 - Turbulence Intensity vs. Wind Speed, June 2004 – August 2004

Wind Rose

Figure 7 - Wind Rose, June 2004 – August 2004

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	13248	4406	33.258	0	0	0	33.258
Batt3aVDC	13248	4406	33.258	0	0	0	33.258
Anem24aMS	13248	8350	63.028	0	0	2.167	62.93
AnemSD24aMS	13248	8350	63.028	0	0	2.167	62.93
Anem24bMS	13248	8350	63.028	0	0	7.667	62.681
AnemSD24bMS	13248	8350	63.028	0	0	7.667	62.681
Anem37aMS	13248	8350	63.028	0	0	0.667	62.998
AnemSD37aMS	13248	8350	63.028	0	0	0.667	62.998
Anem37bMS	13248	5981	45.146	0	0	14.667	44.482
AnemSD37bMS	13248	5981	45.146	0	0	14.667	44.482
Vane24aDEG	13248	8350	63.028	0.833	0	0	62.991
VaneSD24aDEG	13248	8350	63.028	0.833	0	0	62.991
Vane37aDEG	13248	8350	63.028	0.833	0	0	62.991
VaneSD37aDEG	13248	8350	63.028	0.833	0	0	62.991
Etmp3aDEGC	13248	5981	45.146	0	0	0	45.146
EtmpSD3aDEGC	13248	5981	45.146	0	0	0	45.146
Pyro6aWMS	13248	5981	45.146	0	0	0	45.146
PyroSD6aWMS	13248	5981	45.146	0	0	0	45.146
Total	**238464**	**128198**	**53.76**	**3.333**	**0**	**50.333**	**53.625**

APPENDIX B - Plot Data

Wind Speed Distribution Data

Bin Center Wind Speed [m/s]	Percent of Time [%]
0.5	NA
1.5	NA
2.5	NA
3.5	NA
4.5	NA
5.5	NA
6.5	NA
7.5	NA
8.5	NA
9.5	NA
10.5	NA
11.5	NA
12.5	NA
13.5	NA
14.5	NA
15.5	NA
16.5	NA
17.5	NA
18.5	NA
19.5	NA
20.5	NA
21.5	NA
22.5	NA
23.5	NA
24.5	NA

Table 1: Wind Speed Distribution

Monthly Average Wind Speed Data

Date	10 min Mean [m/s]
Sept 2003	4.9
Oct	6.35
Nov	----
Dec	5.53
Jan 2004	7.65
Feb	6.65
Mar	6.59
Apr	6.79
May	5.36
Jun	5.55
July	-----
Aug	-----

Table 2 - Wind Speed Averages

Diurnal Average Wind Speed Data

Hour of Day	Average Wind Speed [m/s]
0	NA
1	NA
2	NA
3	NA
4	NA
5	NA
6	NA
7	NA
8	NA
9	NA
10	NA
11	NA
12	NA
13	NA
14	NA
15	NA
16	NA
17	NA
18	NA
19	NA
20	NA
21	NA
22	NA
23	NA

Table 3 - Diurnal Average Wind Speeds

Wind Rose Data

Direction	Percent Time [%]	Mean Wind Speed [m/s]
N	NA	NA
NNE	NA	NA
NE	NA	NA
ENE	NA	NA
E	NA	NA
ESE	NA	NA
SE	NA	NA
SSE	NA	NA
S	NA	NA
SSW	NA	NA
SW	NA	NA
WSW	NA	NA
W	NA	NA
WNW	NA	NA
NW	NA	NA
NNW	NA	NA

Table 4: Wind Rose, Time Percentage and Mean Wind Speed by Direction