WIND DATA REPORT

Mt. Tom

June 1, 2003 – August 31, 2003

Prepared for

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by

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EXECUTIVE SUMMARY

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. The 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 2003 – August 2003, the mean recorded wind speed was 4.96 m/s (11.1 mph) and the prevailing wind direction was from the west-north-west. The gross data recovery percentage (the actual percentage of expected data received) was 100% and the net data recovery percentage (the percentage of expected data which passed all of the quality assurance tests) was 99.777%. Both of these percentages are very high, indicating that the sensors and data logger were performing well.

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' North, 72°-38-42.2' West.

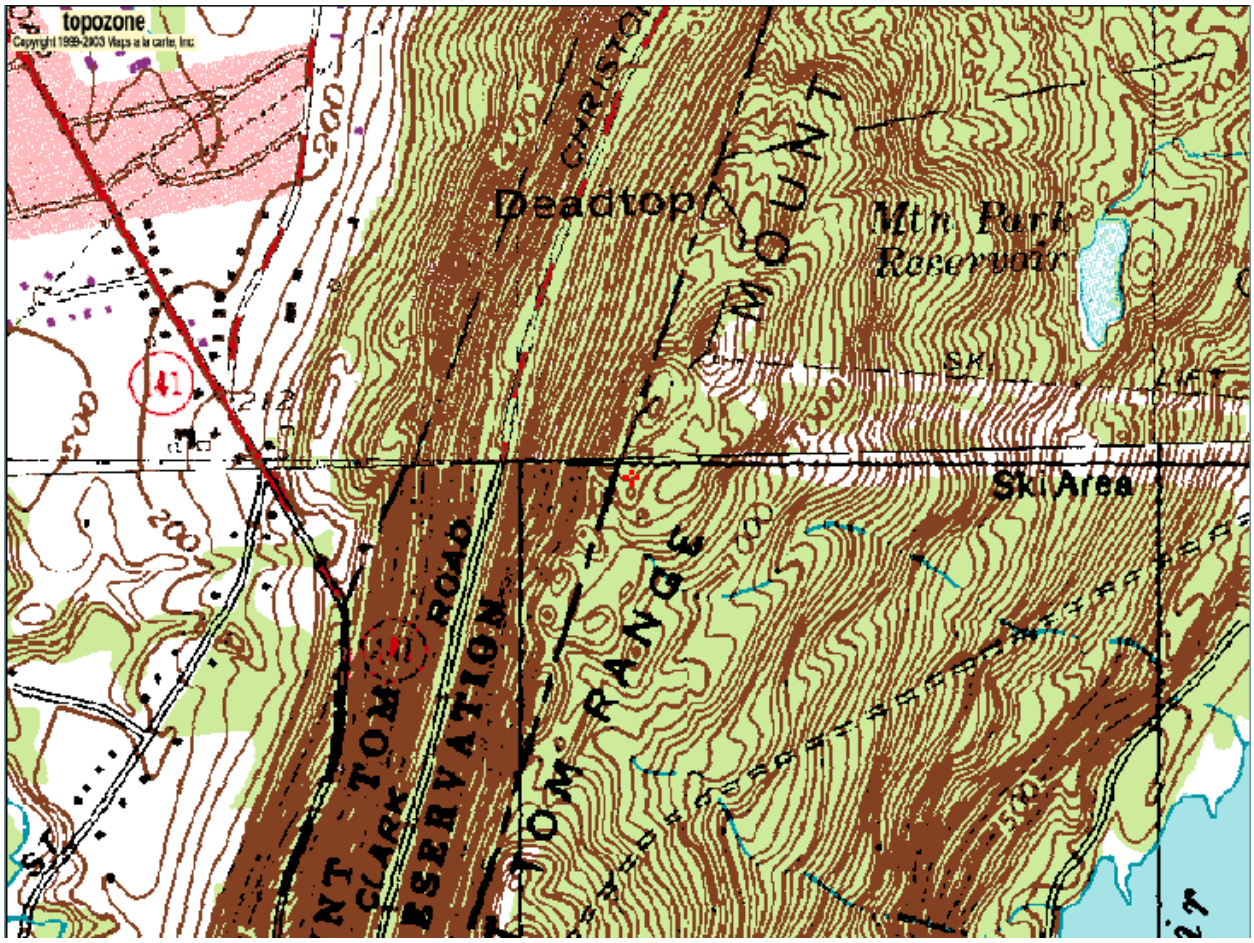

Figure 1 - Site location at Mt. Tom site. Red cross marks location of tower base.

Source: 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)
- 2 - #200P Wind direction vanes
- 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 wind speed and direction once every second. These 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 QA tests prior to using the data.

SECTION 3 - Data Collection and Maintenance

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

- June 26: The logger required 3 call attempts to transmit data. Indicative of poor cell phone reception, possibly due to inclement weather.
- July 24: The logger required 2 call attempts to transmit data. Indicative of poor cell phone reception, possibly due to inclement weather.
- Aug 21: The logger required 3 call attempts to transmit data. Indicative of poor cell phone reception, possibly due to inclement weather.

All other data transmission calls were successful on the first attempts.

Data Statistics Summary

Date	Mean Wind Speed [m/s]	Max Wind Speed [m/s]	Turbulence Intensity [ ]	Prevailing Wind Direction [ ]
June 2003	4.86	16.61	0.23	WNW
July 2003	5.05	14.44	0.2	S
August 2003	4.97	14.03	0.21	S
Jun 03 – Aug 03	**4.96**	**16.61**	**0.22**	**WNW**

SECTION 4 - Significant Meteorological Events

The northeast region as a whole experienced a cool and wet early summer followed by a warm and wet late summer. According to the National Weather Service, Boston, MA experienced greater than average precipitation (9.67 in, 0.11 in above average) and about average temperatures (71.3°F) during the summer of 2003. Providence, RI recorded 4.29 inches of precipitation above normal. The season began with a nor'easter-like storm in early June bringing strong winds and heavy rain. By August, the weather had turned warm and humid; in Boston, August 2003 was the 8th warmest August on record and in Providence, it was the 4th warmest (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 [%]	100.0
Net Data Recovered [%]	99.777

The high Gross Data Recovery Percentage is an indication that the logger was recording and transmitting properly. The high Net Data Recovery Percentage is an indication that the sensors were functioning properly and that little or no icing conditions were present.

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 which is included in APPENDIX A. Data which 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 is 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, the wind speed (TF1) is greater than Factor 2, and the temperature (CF2) is less than Factor 3.

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

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. It should be noted that, while this test is tuned to detect sensor icing events, it is possible for the conditions that are representative of icing to occur at other times. The error due to this possibility is considered to be insignificant.

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 from 1 quarter (3 months). The following graphs are included:

- Time Series – 10-minute average wind speeds are plotted against time.
- Wind Speed Distribution – A histogram plot giving the percentage of time that the wind is at a given wind speed. The maximum percentage is between 4 and 5 m/s.
- Monthly Average – A plot of the monthly average wind speed over a 12-month period. This graph shows the trends in the wind speed from Jan 2003 – September 2003
- Diurnal – A plot of the average wind speed for each hour of the day. This graph shows a pattern of greater wind speeds in the evening, peaking at between 8 and 9 PM.
- Turbulence Intensity – A plot of turbulence intensity as a function of wind speed. Turbulence Intensity is calculated as the standard deviation of the wind speed divided by the wind speed and is a measure of the gustiness of a wind resource. Lower turbulence results in lower mechanical loads on a wind turbine. The turbulence intensities recorded during the summer were around 0.22.

- Wind Rose – 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 a strong prevailing WNW and S wind directions. The wind in June primarily blew from the WNW, while rest of the summer, the wind primarily blew from the S. The directional distribution of average wind speeds appears fairly even, with the highest speeds recorded from the NNE and WNW.

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

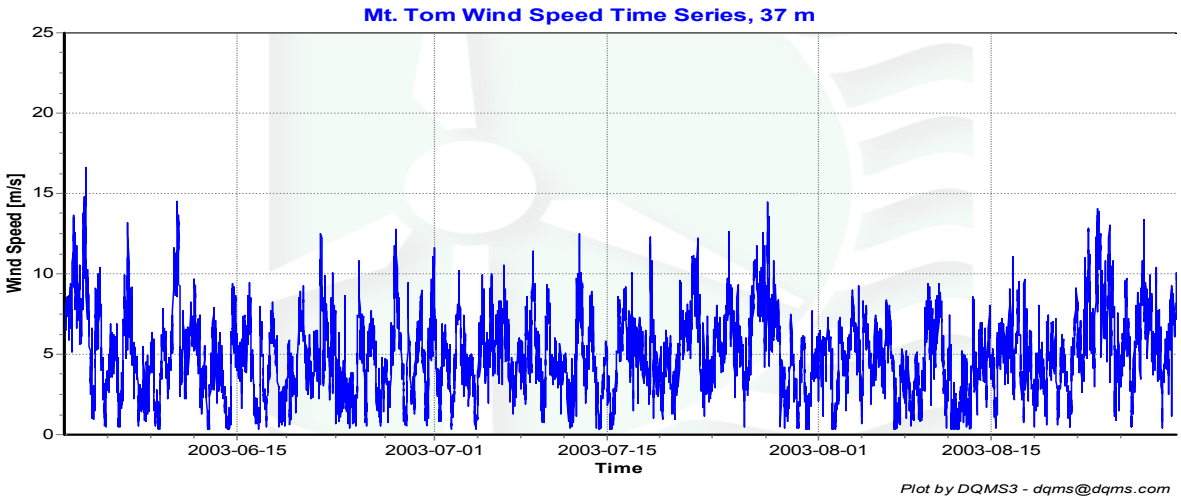

Figure 2 - Wind Speed Time Series, June 2003 – August 2003

Wind Speed Distributions

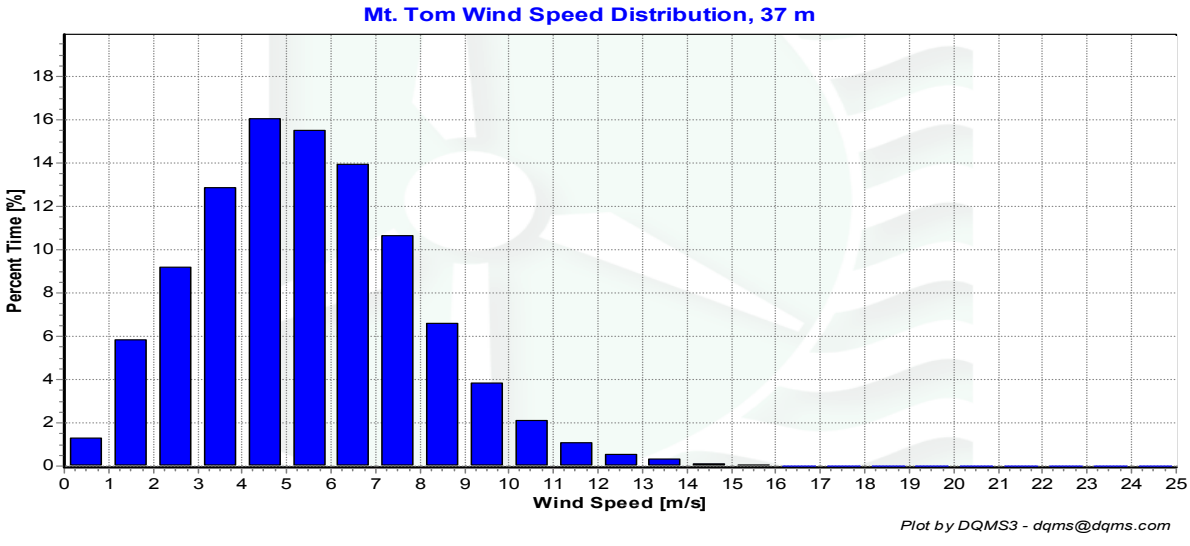

Figure 3 - Wind Speed Distribution, June 2003 – August 2003

Monthly Average Wind Speeds

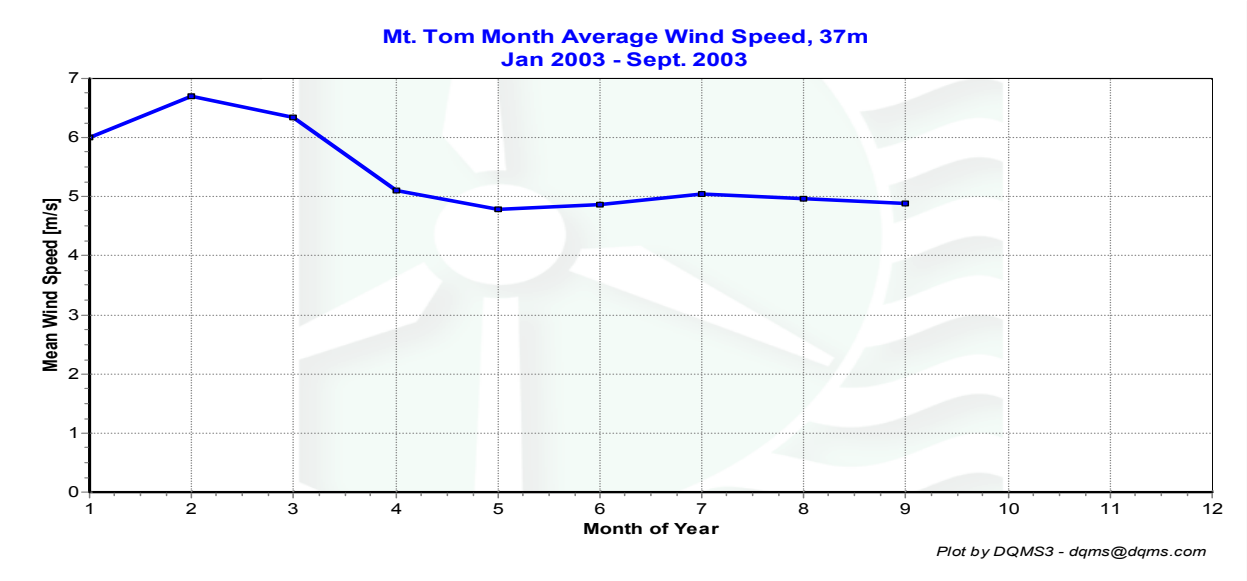

Figure 4 - Monthly average wind speed

Diurnal Average Wind Speeds

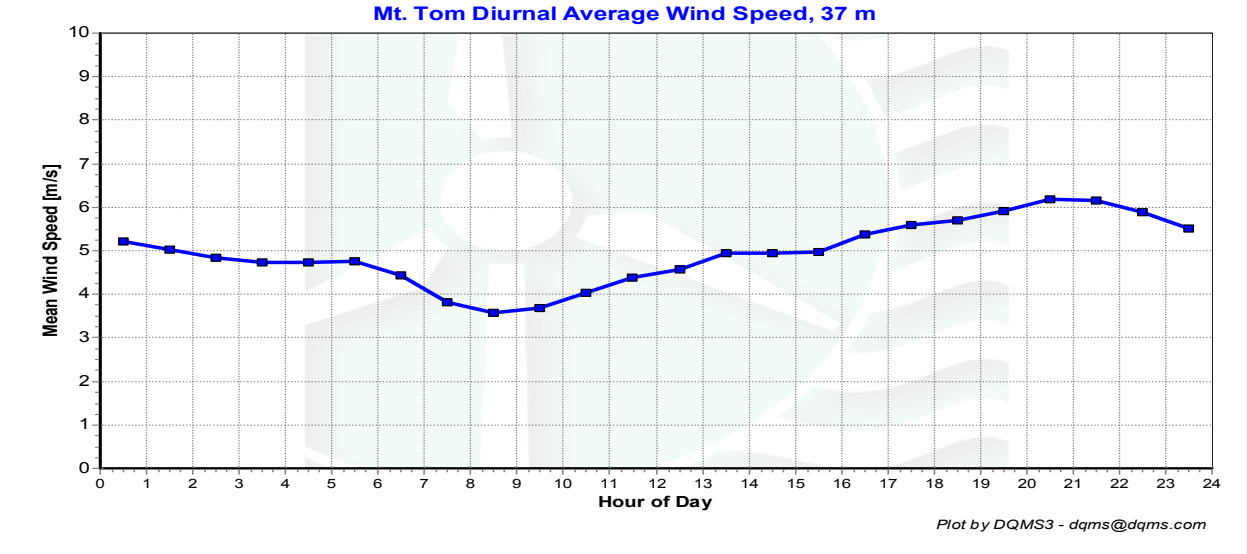

Figure 5 - Diurnal Wind Speed, June 2003 – August 2003

Turbulence Intensities

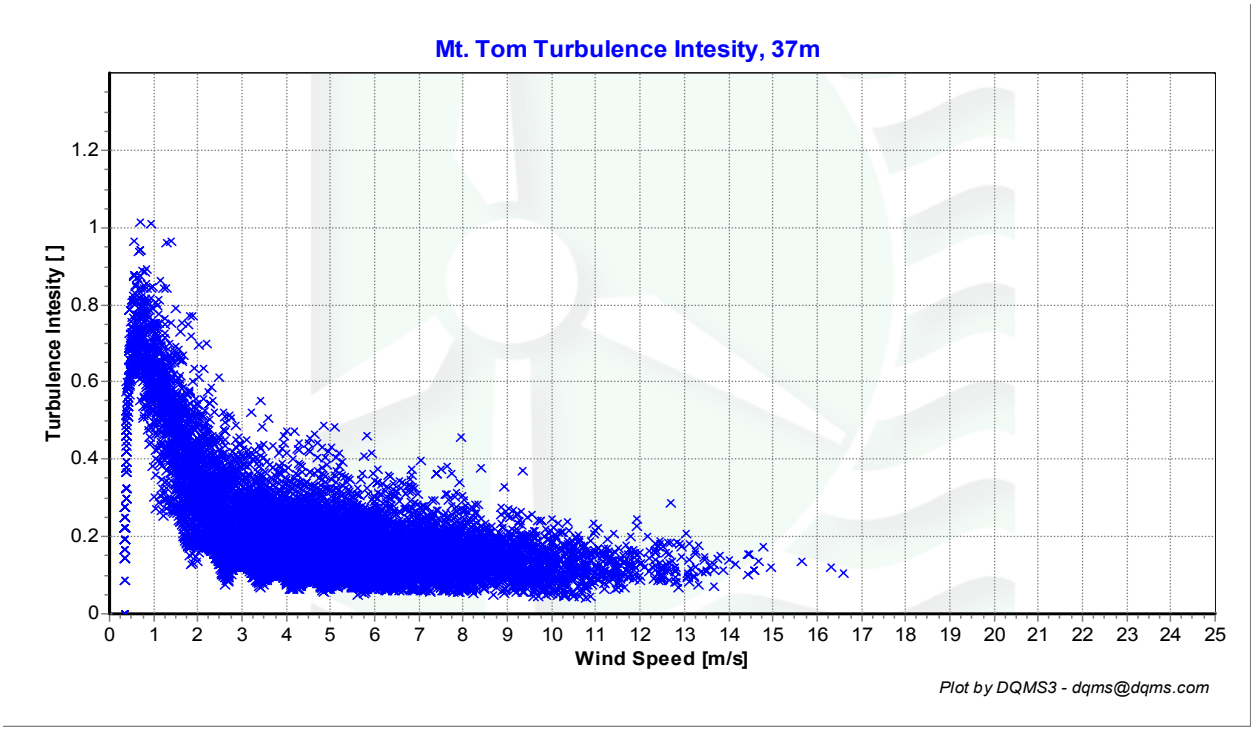

Figure 6 - Turbulence Intensity vs Wind Speed, June 2003 – August 2003

Wind Roses

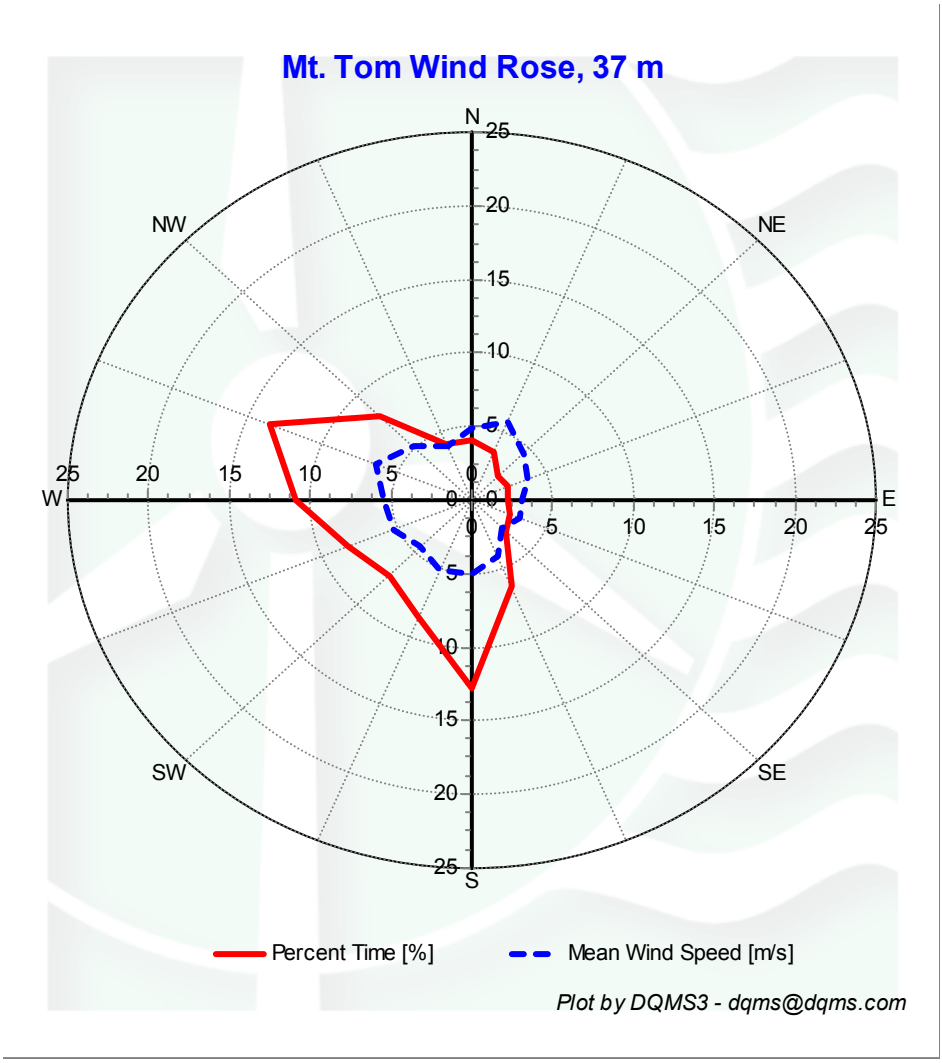

Figure 7 - Wind Rose, June 2003 – August 2003

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	4		
21	AnemSD24bMS					MinMax	0	4		
22	AnemSD37aMS					MinMax	0	4		
23	AnemSD37bMS					MinMax	0	4		
24	AnemSD18bMS					MinMax	0	4		
25	AnemSD21aMS					MinMax	0	4		
26	AnemSD24yMS					MinMax	0	4		
27	AnemSD37yMS					MinMax	0	4		
40	Pyro6aWMS					MinMax	0	1500		
41	PyroSD6aWMS					MinMax	0	100		
50	Turb24zNONE					MinMax	0	2		
51	Turb37zNONE					MinMax	0	2		
60	Wshr0zNONE					MinMax	-100	100		
70	Pwrd24zWMC					MinMax	0	2000		
71	Pwrd37zWMC					MinMax	0	2000		
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	

301	Anem24bMS	AnemSD24bMS	Vane24aDEG	VaneSD24aDEG	Etmp3aDEGC	Icing	0.5	1	2	
302	Anem37aMS	AnemSD37aMS	Vane37aDEG	VaneSD37aDEG	Etmp3aDEGC	Icing	0.5	1	2	
303	Anem37bMS	AnemSD37bMS	Vane37aDEG	VaneSD37aDEG	Etmp3aDEGC	Icing	0.5	1	2	
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	13248	100	0	0	0	100
Batt3aVDC	13248	13248	100	0	0	0	100
Anem24aMS	13248	13248	100	0	0.833	2.833	99.834
AnemSD24aMS	13248	13248	100	0	0.833	2.833	99.834
Anem24bMS	13248	13248	100	0	0.833	3.5	99.804
AnemSD24bMS	13248	13248	100	0	0.833	3.5	99.804
Anem37aMS	13248	13248	100	0	0.833	0.5	99.94
AnemSD37aMS	13248	13248	100	0	0.833	0.5	99.94
Anem37bMS	13248	13248	100	0	0.833	27.833	98.702
AnemSD37bMS	13248	13248	100	0	0.833	27.833	98.702
Vane24aDEG	13248	13248	100	1.167	0.833	0	99.909
VaneSD24aDEG	13248	13248	100	1.167	0.833	0	99.909
Vane37aDEG	13248	13248	100	0.667	0.833	0	99.932
VaneSD37aDEG	13248	13248	100	0.667	0.833	0	99.932
Etmp3aDEGC	13248	13248	100	0.833	0	0	99.962
EtmpSD3aDEGC	13248	13248	100	0	0	0	100
Pyro6aWMS	13248	13248	100	0	0	0	100
Total	**225216**	**225216**	**100**	**4.5**	**10**	**69.333**	**99.777**

APPENDIX B - Plot Data

Wind Speed Distribution Data

Bin Center Wind Speed [m/s]	Percent of Time [%]
0.5	1.28
1.5	5.86
2.5	9.18
3.5	12.85
4.5	16.03
5.5	15.53
6.5	13.96
7.5	10.63
8.5	6.62
9.5	3.86
10.5	2.11
11.5	1.06
12.5	0.53
13.5	0.35
14.5	0.09
15.5	0.04
16.5	0.02
17.5	0.01
18.5	0
19.5	0
20.5	0
21.5	0
22.5	0
23.5	0
24.5	0

Table 1 - Wind Speed Distribution

Monthly Average Wind Speed Data

Date	10 min Mean [m/s]
2003	
Jan	6.01
Feb	6.71
Mar	6.34
Apr	5.11
May	4.78
Jun	4.86
Jul	5.05
Aug	4.97

Table 2 - Wind Speed Averages

Diurnal Average Wind Speed Data

Hour of Day	Average Wind Speed [m/s]
0	5.21
1	5.04
2	4.84
3	4.73
4	4.74
5	4.76
6	4.43
7	3.83
8	3.57
9	3.69
10	4.04
11	4.38
12	4.56
13	4.95
14	4.95
15	4.97
16	5.38
17	5.59
18	5.7
19	5.92
20	6.2
21	6.17
22	5.9
23	5.51

Table 3 - Diurnal Average Wind Speeds

Wind Rose Data

Direction	Percent Time [%]	Mean Wind Speed [m/s]
N	4.02	4.86
NNE	3.56	5.68
NE	2.24	4.49
ENE	2.47	3.69
E	2.29	3.15
ESE	2.58	3.18
SE	3.05	2.68
SSE	6.34	4.1
S	12.78	5.08
SSW	8.58	5.12
SW	7.21	4.52
WSW	8.29	5.17
W	10.94	5.41
WNW	13.5	6.45
NW	8.09	5.12
NNW	4.06	3.92

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