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Endurance E-3120 Wind Turbine Noise Performance Test

Report HM: 2300/R1

23rd March 2011

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ENDURANCE E-3120 WIND TURBINE

NOISE PERFORMANCE TEST

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Final Version

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1. Introduction

1.1 A turbine noise performance test has been carried out on a Endurance E-3120 wind turbine at East Ash Farm located approximately 2.5km NNE of Bradworthy, Devon, in the UK.

1.2 The turbine has a hub height of 25m and a downwind rotor with a diameter of 19.2m. The wind turbine is passive stall regulated and has a rated power of 55 kW, which is achieved at a wind speed of approximately 14 m/s at hub height.

1.3 The objective of this test was to measure the noise performance characteristics of the wind turbine. The test consisted of measurement of the sound power level and tonal characteristics.

1.4 This noise test was conducted in accordance with IEC 61400-11 (2006) *Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques*.

1.5 The noise measurements were carried out on 1st and 2nd February 2011.

1.6 Analysis of the data was carried out according to Method 2: *determination of wind speed with an anemometer* described in IEC 61400-11, as it was not possible to derive the wind speed from the power output of the turbine.

2. Turbine Specification

2.1 The wind turbine is a three-bladed, passive stall regulated (constant speed) downwind turbine. A summary of the turbine's specification, as supplied by the manufacturer, is shown in Table 1 below.

Table 1 - Turbine Specifications

Parameter	Value/Feature
Manufacturer	Endurance Wind Power
Model Number	E-3120
Type (upwind/downwind)	Downwind
Hub Height	25m
Rotor Diameter	19.2m
Rated Power	55 kW (at 14 m/s at rotor centre)
Tower Type	Free-standing Monopole
Turbine Control (stall/pitch)	Passive stall
Rotational Speed	Constant, 41 rpm
Number of Blades	3
Cut-in Wind Speed	3.5 m/s
Cut-out Wind Speed	25 m/s

3. Measurement

Site Layout and Measurement Position

3.1 The site layout is shown at Appendix A. The site was characterised as open farmland bordered by hedgerows, which includes occasional trees. The E-3120 turbine which was the subject of these tests is the only wind turbine on this site.

3.2 IEC 61400-11 (2006) *Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques* [1] specifies that the microphone used for the noise tests is to be mounted on a 1 m diameter ground-mounted board, facing in the direction of the wind turbine under test, at a distance corresponding to the tip height of the turbine (+/- 20%) directly downwind of the turbine. According to [1], measured noise data is valid as long as the board is within the downwind sector (i.e. +/- 15° of the directly downwind direction). Photos of the noise monitoring equipment set up are shown at Appendix B.

3.3 The microphone was fitted inside a primary hemispherical open cell foam wind shield of 90 mm in diameter laid flat on the board. The primary wind shield was surrounded by a secondary hemispherical foam wind shield of 450 mm diameter and 50 mm thickness.

3.4 An anemometer was positioned approximately 45m upwind of the rotor of the turbine to measure wind speed. This is within the 2 to 4 D range specified by IEC 61400-11, where D is the rotor diameter of the wind turbine (here D = 19.2 m). Wind speed values are valid as long as the anemometer position is within the upwind sector (i.e. +/- 30° of the directly upwind direction).

3.5 Wind speed and wind direction measurements, time-synchronised to the noise measurements, were made using a Second Wind C3 anemometer and an NRG #200P wind vane mounted at 10 m height connected to a Nomad 2 GSM data logger.

3.6 The microphone and the met mast position were within the acceptable ranges relative to the position of the nacelle, specified by IEC 61400-11 as discussed at paragraph 3.2, throughout the whole measurement period.

3.7 Table 2 details the measurement positions. $R_{0,i}$ is the reference distance on each measurement day and is the horizontal distance from the microphone to the nacelle. R_1 is the resultant slant distance from the measurement position to the nacelle.

Table 2 - Distances and Reference Values

Parameter	Symbol	Value
Hub Height	H	25.3 m[1]
Rotor Diameter	D	19.2 m
Reference Distance day 1	$R_{0,1}$	31.5 m
Reference Distance day 2	$R_{0,2}$	31.5 m
Slant Distance day 1	R_1	40.4 m
Slant Distance day 2	R_2	40.4 m
Reference Roughness Length	z_{0ref}	0.05 m
Anemometer Height	z	10 m

3.8 During the noise tests the wind turbine was shut down for certain periods to allow for background noise measurements in order to establish the level of contribution from other noise sources.

3.9 Whilst on site, the average 1-minute electrical power output of the turbine was noted down during noise measurements, although at present there is not a power curve available to determine the 10m-height wind speed from the power output. Method 2 described in IEC 61400-11 has therefore been used to determine the sound power level output of the turbine. It will be possible to re-analyse the data with wind speed derived from the electrical power output of the turbine once a power curve (measured according to IEC 61400-12) is available for this turbine if necessary.

3.10 Amendment 1 (2006) to IEC 61400-11 states that where the hub height is lower than 30m, wind speed may be taken from an anemometer between 10m and hub height.

3.11 It should be noted that correlating the noise measurements with the measured 10m-height wind speed introduces a level of uncertainty to the measurements that would not apply if the noise measurements were correlated with the power output of the turbine.

[1] Including concrete base

4. Instrumentation

4.1 Noise measurements were carried out using the following equipment:

General

Bruel & Kjær Type 4231 calibrator (Serial No. 2218188)

Reference Position

01dB Symphonie Measurement System (Serial No. 00587)

PCB Microphone (Serial No. 377A02)

G.R.A.S. Type 26AK Pre-Amplifier (Serial No. 22826)

4.2 Meteorological measurements were carried out using the following equipment:

Logger

Second Wind Nomad II (S/N 05587)

Anemometer and Wind Vane

Second Wind C3 Anemometer (S/N 05531)
NRG #200P Wind Vane (S/N AV1102)

Temperature and Pressure Sensors

Second Wind Thermistor Temperature Probe (S/N TH84)

Setra Model 276 Barometric Pressure Sensor (S/N 4404452)

4.3 The noise measurement equipment was field calibrated prior to each measurement being performed and checked at the end. There was no recorded drift in the calibration of the equipment for any measurements. All equipment was within its laboratory calibration period.

4.4 Noise and wind measurements were time-synchronised to GMT.

5. Results

Measured Noise Levels

5.1 The measured 1-minute average L_{Aeq} noise data was plotted against the measured average 1-minute 10m height wind speed for operational periods and separately for shutdown periods. All noise data has been filtered such that any 1-minute period that was affected by specific extraneous noises such as vehicles passing on local roads, and any other anomalies, have been removed from the assessment.

5.2 Appendix C shows the measured operational noise and measured background noise at the microphone position, plotted against the measured 10m-height wind speed. Table 3 below details the number of operational data points in each wind speed range measured over the 2 days.

5.3 Appendix C also shows the measured 1-minute average L_{Aeq} noise data was plotted against electrical power output of the turbine.

Table 3 – Number of 1-minute Noise Data Points Recorded per Wind Speed Bin

Period		2	3	4	5	6	7	8	9	10	11	12	Total
1st February 2011	Turbine Operational	2	33	31	16	14	1	0	0	0	0	0	97
	Background Noise	0	14	20	10	2	0	0	0	0	0	0	46
2nd February 2011	Turbine Operational	0	0	0	1	12	20	19	9	16	12	5	94
	Background Noise	0	0	0	0	5	13	7	9	4	8	5	51
Totals	Turbine Operational	2	33	31	17	26	21	19	9	16	12	5	191
	Background Noise	0	14	20	10	7	13	7	9	4	8	5	97

Calculation of $L_{WA,k}$

5.4 IEC 61400-11 requires that a 4th order regression line is plotted through the measured operational data. A 3rd order polynomial regression line has been plotted thorough the turbine shutdown noise data.

5.5 The $L_{WA,k}$ has been calculated using the formula below specified in IEC 61400-11.

$$L_{WA,k} = L_{Aeq,c,k} - 6 + lg\left[\frac{4\pi R_1^2}{S_0}\right]$$

Where

$L_{Aeq,c,k}$ is the background corrected A-weighted sound pressure level at the integer wind speeds and under reference conditions

R_1 is the slant distance in meters from the rotor centre to the microphone as shown

S_0 is a reference area, $S_0 = 1m^2$

5.6 The results are plotted at Appendix D and in tabular form below at Table 4.

Table 4 - Calculation of Sound Power Level using 4th Order Regression Line

10m-height wind speed (m/s)	3	4	5	6	7	8	9	10	11	12
Total Measured Operational Noise Levels (dB L_{Aeq})	49.8	50.1	50.3	50.8	51.8	53.4	55.4	57.3	58.6	58.6
Background Noise Level (dB L_{Aeq})	35.9	35.8	36.6	38.2	40.3	42.9	45.8	48.6	51.4	53.8
Difference Between Total and Background Noise (dB)	13.9	14.3	13.7	12.6	11.5	10.5	9.6	8.7	7.3	4.8
Background Corrected Sound Pressure Level, $L_{Aeq,c,k}$ (dB L_{Aeq})	49.6	49.9	50.1	50.5	51.5	53.0	54.9	56.7	57.7	57.3
Apparent Sound Power Level, $L_{WA,k}$ (dB L_{WA})	**86.7**	**87.0**	**87.2**	**87.7**	**88.6**	**90.2**	**92.0**	**93.8**	**94.9**	**94.4***

5.7 It should be noted that the difference between the total measured noise and measured turbine shutdown noise levels at 12m/s is less than 6dB. Therefore 1.3dB has been subtracted from the measured turbine noise as required by IEC 61400-11 and the result marked with an '*'.

1/3 Octave Band Data

5.8 As required by IEC 61400-11, the three one minute average periods closest to each integer wind speed have been used to calculate the energy average 1/3 octave band spectra between 20 and 10kHz for the operational turbine noise. The average background noise spectra have also been calculated from the nearest three nearest 1-minute average background noise periods closest to each integer wind speed. The results are plotted at Appendix E, which also shows the octave band levels.

5.9 It should be noted that there were only two 1-minute periods available for the operational wind speed of 12m/s. It should also be noted that only two 1-minute periods were available for the shutdown periods wind speed of 6, 8, and 10 m/s, and no data available for a wind speed of 7m/s.

5.10 The sound power level has been calculated for wind speeds for 6-8m/s as required by IEC 61400-11 for each 1/3 octave as measured and the results are shown in Appendix F, which also shows the octave band levels. The operational turbine noise spectra have been corrected for the presence of background noise by subtracting the average background noise. Where the difference between the measured turbine noise and measured background noise levels is less than 6dB the measured turbine noise has been corrected for background noise by subtracting 1.3dB as required by IEC 61400-11 and the result marked with an '*'.

5.11 It should be noted that it has not been possible to calculate the 1/3 octave sound power levels for wind speeds above 8m/s due to the influence of background noise.

Narrow Band Analysis

5.12 The presence of tones has been determined for wind speeds of 6-10 m/s following the procedure set out in IEC 61400-11, with the results presented at Appendix G.

5.13 The results of the narrow band analysis identified the presence of tones at 6m/s wind speed. No tones were identified at any other wind speed.

6. Other Acoustic Characteristics

6.1 The operational noise from the turbine can be characterised by aerodynamic noise from the blades rotating, together with a mechanical component from the gearbox.

6.2 It should be noted that the wind turbine tower is fitted with an external ladder and safety line. At wind speeds above about 8m/s a tonal noise was noted during the background noise measurements due to wind passing the ladder and safety line. This can be seen on the narrowband analysis charts shown Appendix G for wind speeds of 8-10 m/s at frequencies of 840 and 1015 Hz.

6.3 An audible pulse was noted from the wind turbine at higher wind speeds as the turbine blades pass the wake caused by wind around the tower. No assessment of impulsivity has been carried out, as it was not deemed significant enough to warrant further analysis.

7. Uncertainty

7.1 An assessment of measurement uncertainty has been carried out, based on the procedure outlined in Annex D of IEC 61400-11, as follows: Type A uncertainties are evaluated from the extent to which the measured values vary around the derived mean based on the regression analysis; Type B uncertainties are a measure of the assumed accuracy of various factors in the measurements procedure and have been based on the factors shown at the Annex D. The total uncertainty U_C is evaluated from the square root of the sum of the squares of each individual component.

7.2 The standard uncertainty of the apparent sound power is calculated in Table 5 using Equation D.1 in Annex D of IEC 61400-11. The total uncertainty of the measured L_{WA} calculated from all uncertainties, as given in Table 6, is ± 1.6 dB for the Reference Position.

Table 5 - Calculation of L_{WA} Uncertainty U_A

Number of Elements	191
Standard Error U_A	0.728

Table 6 - Calculation of Uncertainty U_C

Type A Uncertainty	
Standard Error of L_{WA} Estimate from Regression Analysis	0.728
Type B Uncertainty	
Calibration	0.2
Instrument	0.2
Board & Mounting	0.3
Distance	0.2
Impedance	0.1
Turbulence	0.4
Wind Speed Measured	1.2
Background	0.3
Total Uncertainty	
Total, U_C	1.6

8. Conclusions

8.1 A noise test has been carried out, according to IEC 61400-11 on an Endurance E-3120 Wind Turbine at East Ash Farm, Bradworthy, Devon, to measure the sound power level and tonal characteristics.

8.2 The apparent sound power level of the wind turbine was calculated over a range of wind speeds from 3-12m/s together with the one third octave band levels for wind speeds of 6-8 m/s. It was not possible to calculate the 1/3 octave sound power levels above 8m/s due to the contrition of background noise.

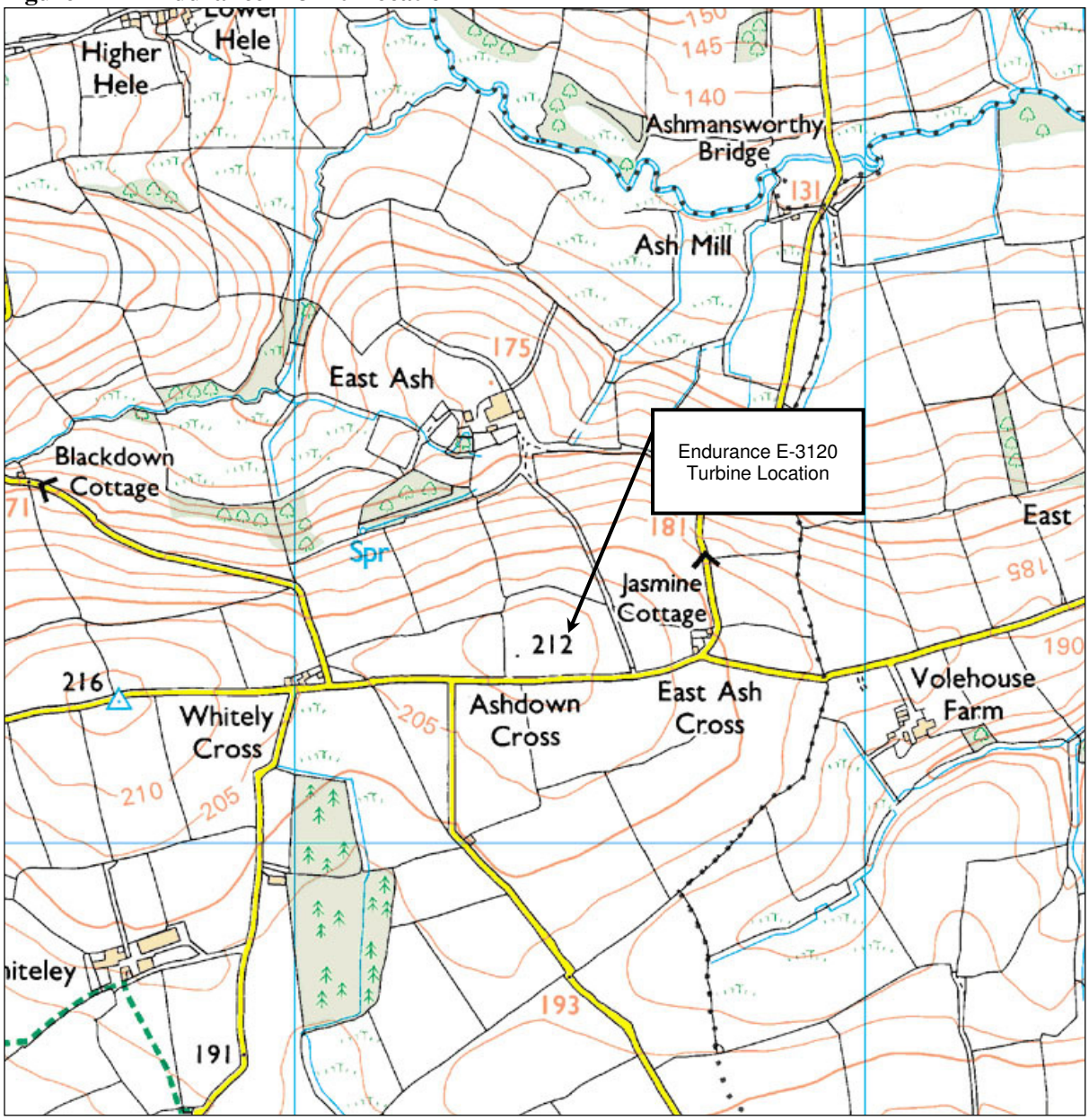
8.3 The tonal output from the Endurance E-3120 turbine has been assessed using the methodology prescribed by IEC 61400-11 for wind speeds of 6-10 m/s and has been determined to be not tonal, except at a wind speed of 6m/s where tones were identified.

9. References

[1] BS EN 61400-11 *Wind turbine generator systems – Part 11: Acoustic noise measurement techniques*, (Amendment 1 May 2006), International Electrotechnical Commission

Appendix A
Site Layout

Figure A1 – Endurance E-3120 Location



Appendix B
Site Photos

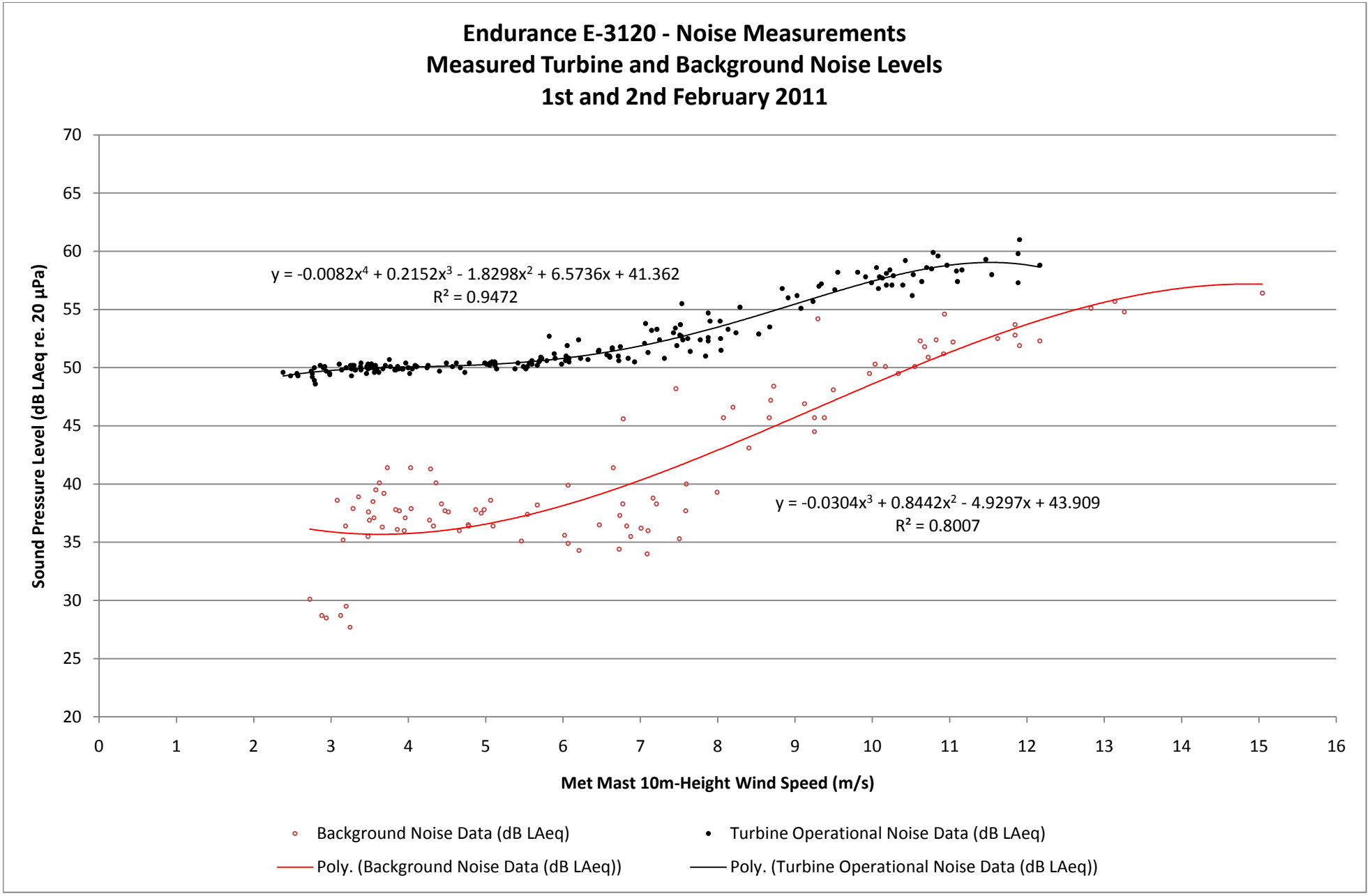
Figure B1 –Photo Showing Turbine and 10m Meteorological Mast

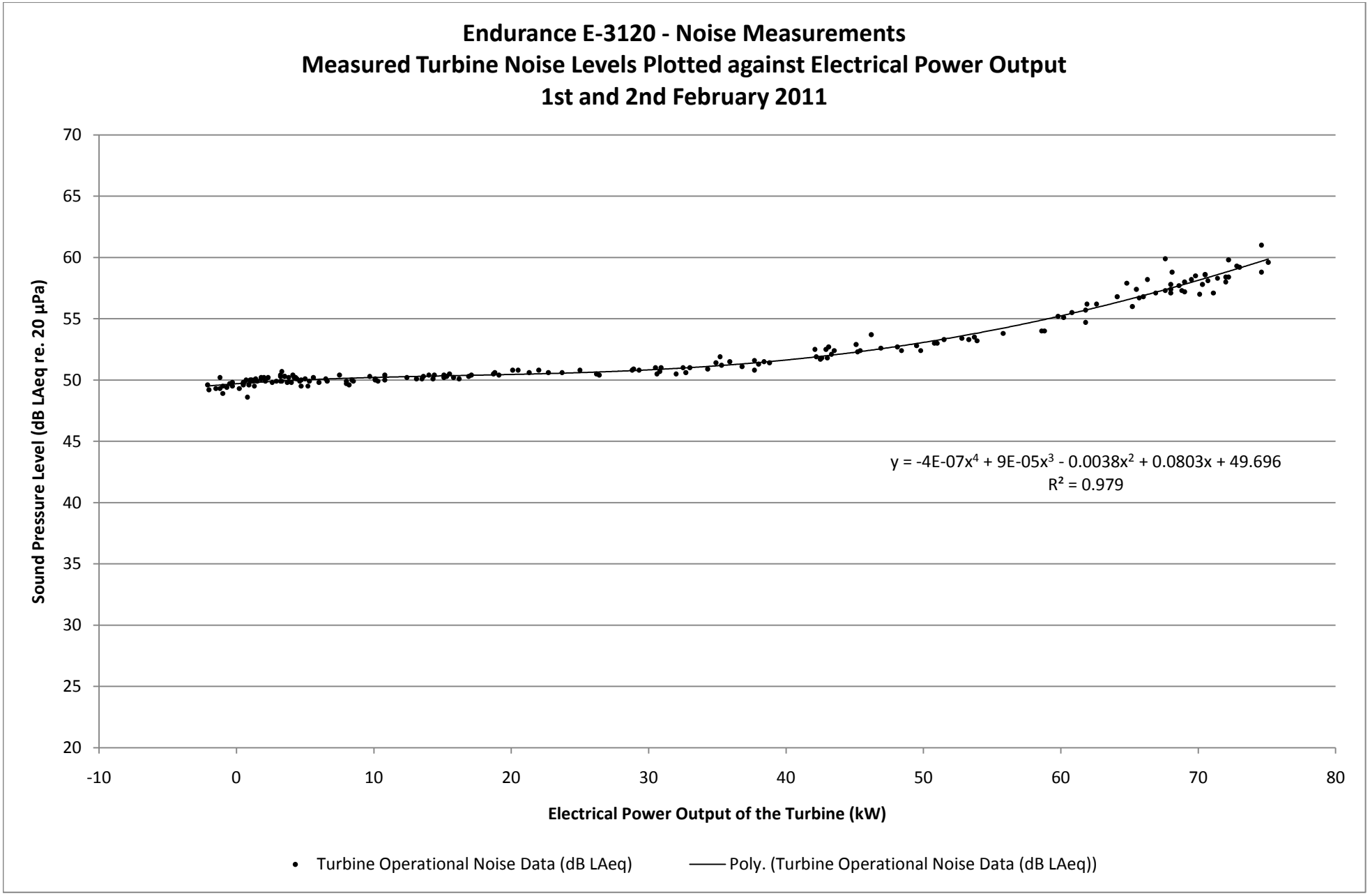
Figure B2 –Photo Showing View of Ground Board fromTurbine

Figure B3 –Photo Showing Noise Measurement Location

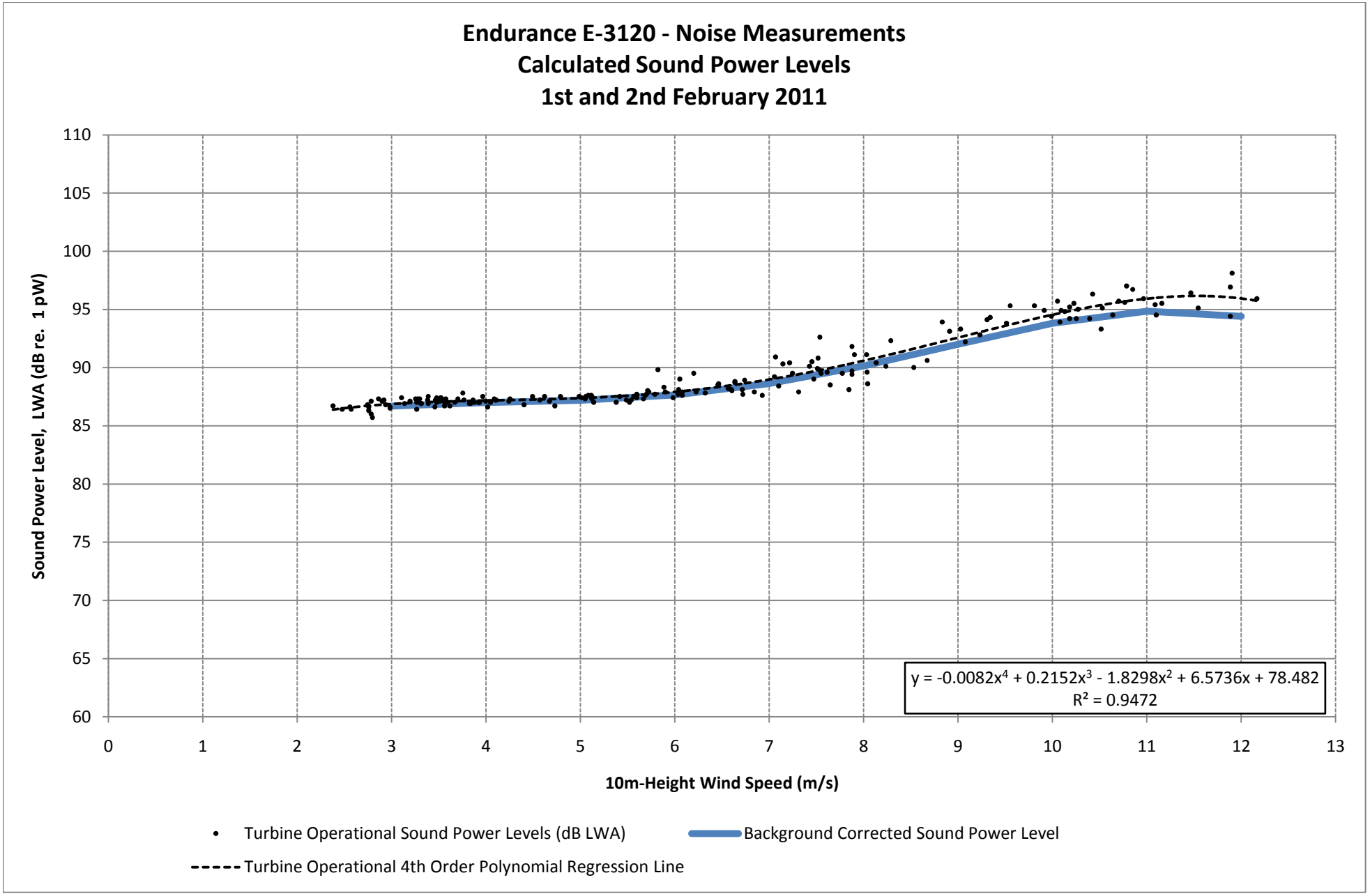
Figure B4 –Photo Showing Detail of Ground Board Location

Appendix C
Measured Turbine and Background Data


Endurance E-3120 - Noise Measurements
Measured Turbine and Background Noise Levels
1st and 2nd February 2011
Sound Pressure Level (dB LAeq re. 20 µPa)
Met Mast 10m-Height Wind Speed (m/s)
y = -0.0082x4 + 0.2152x3 - 1.8298x2 + 6.5736x + 41.362
R² = 0.9472
y = -0.0304x3 + 0.8442x2 - 4.9297x + 43.909
R² = 0.8007
Background Noise Data (dB LAeq)
Turbine Operational Noise Data (dB LAeq)
Poly. (Background Noise Data (dB LAeq))
Poly. (Turbine Operational Noise Data (dB LAeq))


Endurance E-3120 - Noise Measurements
Measured Turbine Noise Levels Plotted against Electrical Power Output
1st and 2nd February 2011
Sound Pressure Level (dB LAeq re. 20 µPa)
70
65
60
55
50
45
40
35
30
25
20
-10
0
10
20
30
40
50
60
70
80
Electrical Power Output of the Turbine (kW)
y = -4E-07x4 + 9E-05x3 - 0.0038x2 + 0.0803x + 49.696
R² = 0.979
Turbine Operational Noise Data (dB LAeq)
Poly. (Turbine Operational Noise Data (dB LAeq))

Appendix D
Calculation of Sound Power Level


Endurance E-3120 - Noise Measurements
Calculated Sound Power Levels
1st and 2nd February 2011
Sound Power Level, LWA (dB re. 1 pW)
110
105
100
95
90
85
80
75
70
65
60
0
1
2
3
4
5
6
7
8
9
10
11
12
13
10m-Height Wind Speed (m/s)
y = -0.0082x4 + 0.2152x3 - 1.8298x2 + 6.5736x + 78.482
R² = 0.9472
Turbine Operational Sound Power Levels (dB LWA)
Background Corrected Sound Power Level
Turbine Operational 4th Order Polynomial Regression Line

Appendix E
Measured One Third Octave Levels

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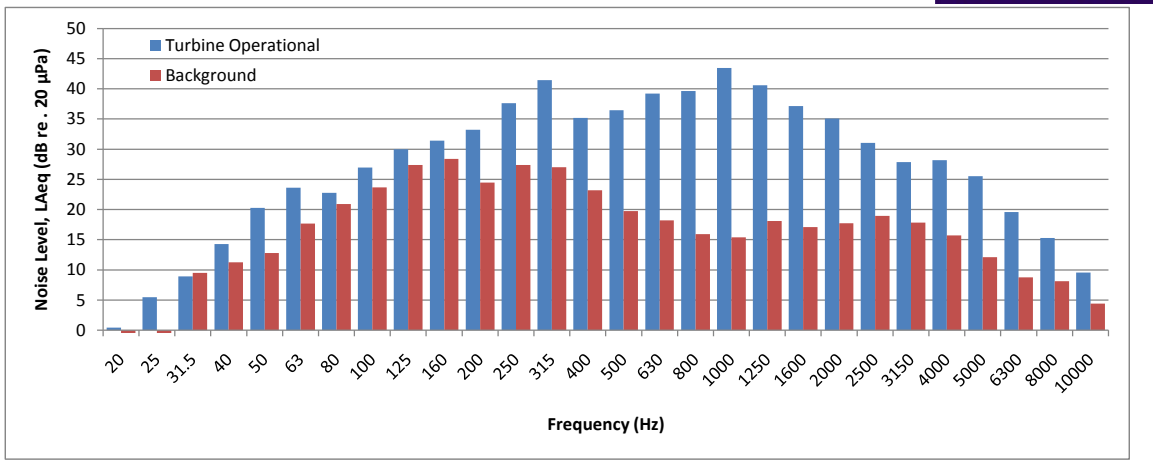
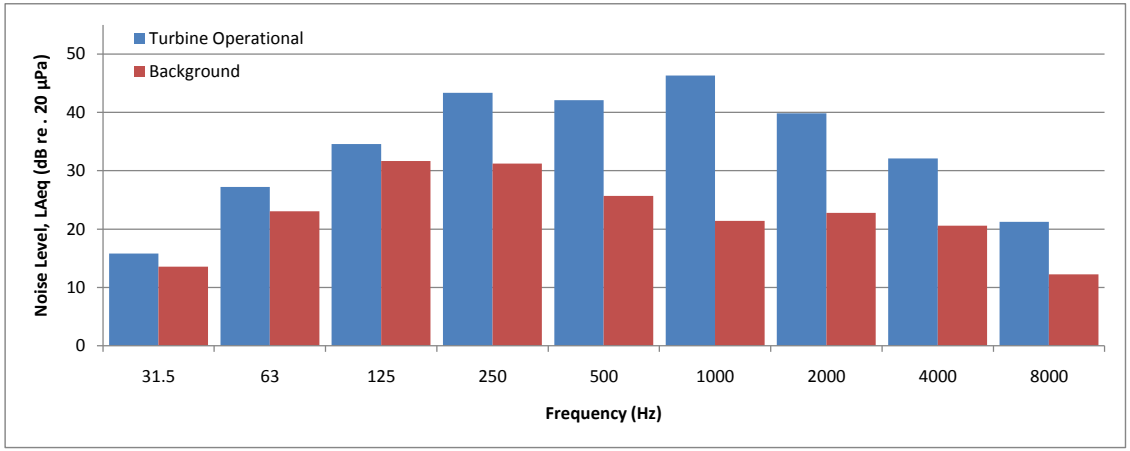
Endurance E-3120 Wind Turbine
Wind Speed - 3 m/s

	Turbine Operational		Background	
Frequency (Hz)	1/3 Octave Band (dB(A))	Octave Band (dB (A))	1/3 Octave Band (dB(A))	Octave Band (dB (A))
20	0.5		-10.1	
25	5.5	15.8	-2.7	13.6
31.5	8.9		9.5	
40	14.3		11.2	
50	20.3	27.2	12.8	23.0
63	23.6		17.7	
80	22.7		20.9	
100	27.0	34.6	23.7	31.7
125	30.0		27.4	
160	31.4		28.4	
200	33.2	43.4	24.5	31.2
250	37.6		27.4	
315	41.4		27.0	
400	35.2	42.1	23.2	25.7
500	36.4		19.8	
630	39.2		18.2	
800	39.6	46.3	15.9	21.4
1000	43.4		15.4	
1250	40.6		18.1	
1600	37.2	39.9	17.1	22.8
2000	35.1		17.7	
2500	31.0		19.0	
3150	27.9	32.1	17.9	20.6
4000	28.2		15.7	
5000	25.5		12.1	
6300	19.6	21.3	8.8	12.3
8000	15.3		8.1	
10000	9.6		4.4	

Overall	49.8	35.8





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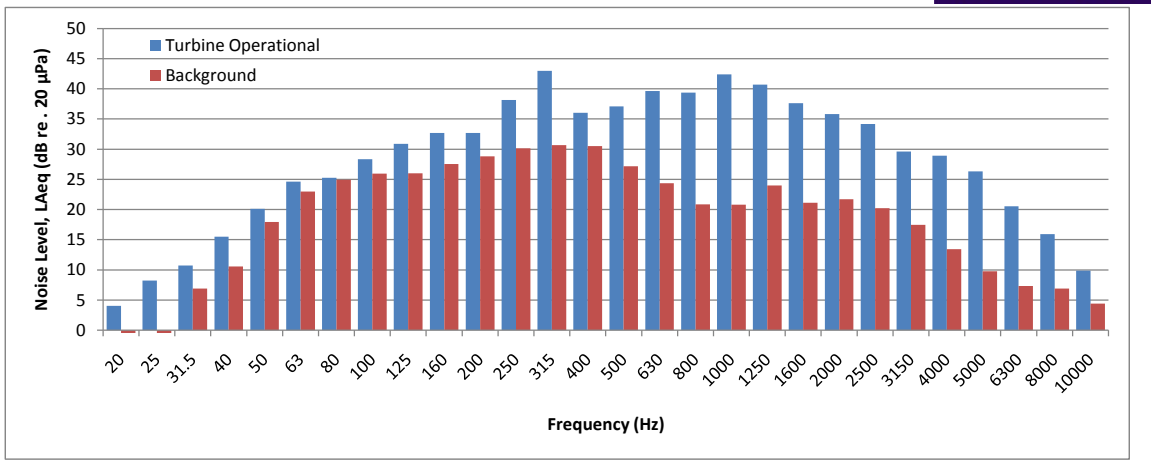
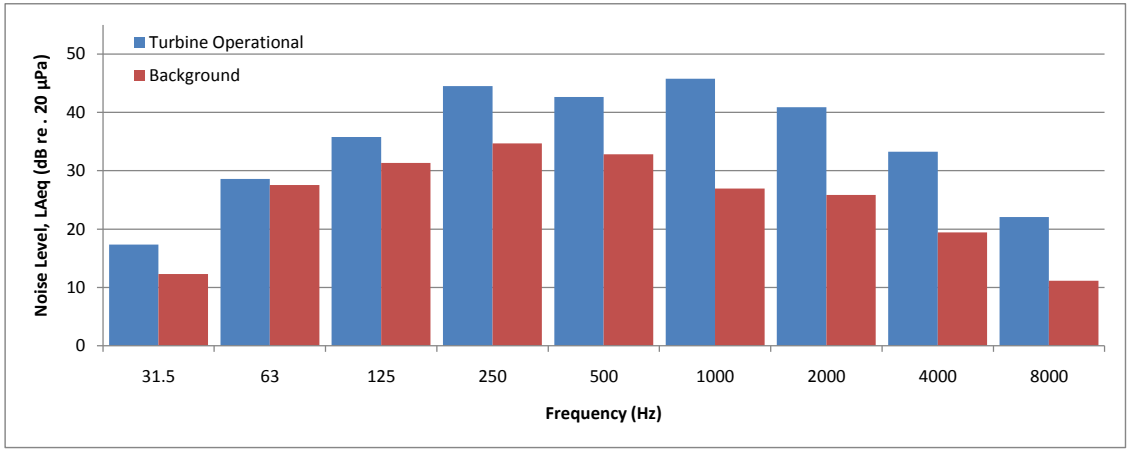
Endurance E-3120 Wind Turbine
Wind Speed - 4 m/s

	Turbine Operational		Background	
Frequency (Hz)	1/3 Octave Band (dB(A))	Octave Band (dB (A))	1/3 Octave Band (dB(A))	Octave Band (dB (A))
20	4.1		-9.1	
25	8.2		-1.0	
31.5	10.7	17.3	6.9	12.3
40	15.5		10.6	
50	20.1		17.9	
63	24.6	28.6	23.0	27.6
80	25.3		24.9	
100	28.4		26.0	
125	30.9	35.8	26.0	31.3
160	32.7		27.5	
200	32.7		28.8	
250	38.2	44.5	30.1	34.7
315	43.0		30.7	
400	36.0		30.5	
500	37.1	42.6	27.2	32.8
630	39.6		24.4	
800	39.4		20.9	
1000	42.4	45.8	20.8	26.9
1250	40.7		24.0	
1600	37.6		21.1	
2000	35.8	40.9	21.7	25.8
2500	34.2		20.2	
3150	29.6		17.5	
4000	28.9	33.3	13.4	19.4
5000	26.3		9.8	
6300	20.5		7.3	
8000	15.9	22.1	6.9	11.2
10000	9.9		4.4	

Overall	50.1	38.9





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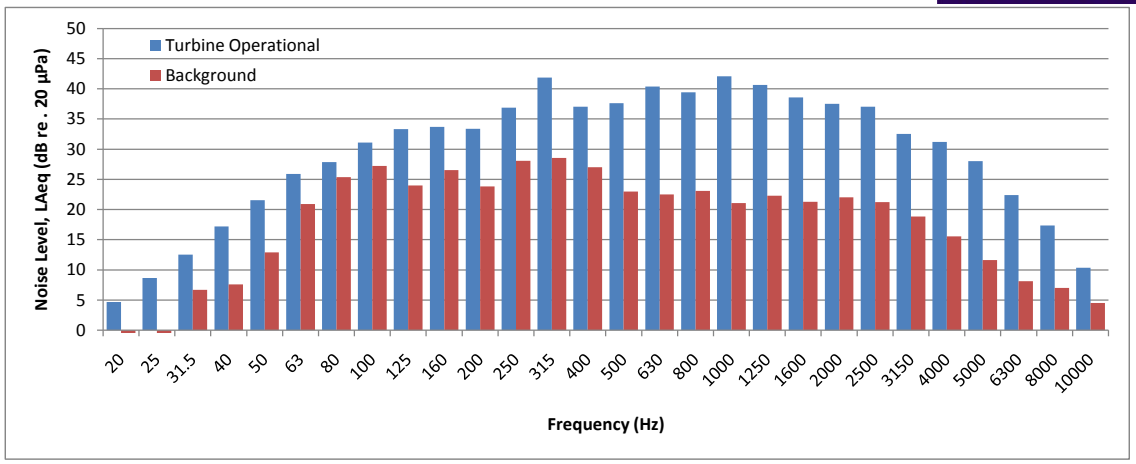
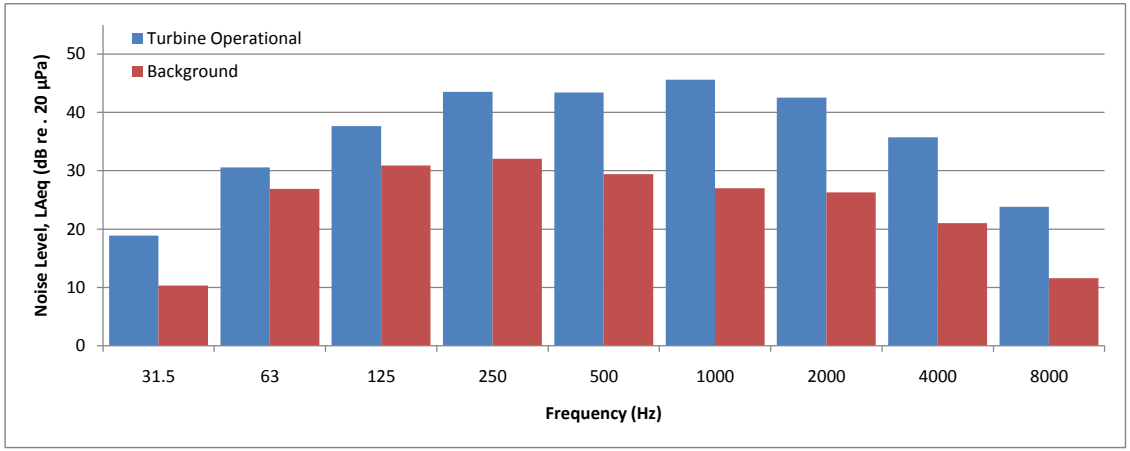
Endurance E-3120 Wind Turbine
Wind Speed - 5 m/s

	Turbine Operational		Background	
Frequency (Hz)	1/3 Octave Band (dB(A))	Octave Band (dB (A))	1/3 Octave Band (dB(A))	Octave Band (dB (A))
20	4.7		-10.9	
25	8.6	18.9	-4.5	10.3
31.5	12.5		6.7	
40	17.2		7.6	
50	21.6	30.6	12.9	26.9
63	25.9		20.9	
80	27.8		25.4	
100	31.1	37.6	27.2	30.9
125	33.3		24.0	
160	33.7		26.5	
200	33.4	43.5	23.8	32.0
250	36.9		28.1	
315	41.9		28.6	
400	37.0	43.4	27.0	29.4
500	37.6		23.0	
630	40.4		22.5	
800	39.4	45.6	23.1	27.0
1000	42.1		21.1	
1250	40.7		22.3	
1600	38.6	42.5	21.3	26.3
2000	37.5		22.0	
2500	37.1		21.2	
3150	32.5	35.7	18.8	21.0
4000	31.2		15.5	
5000	28.0		11.6	
6300	22.4	23.8	8.1	11.6
8000	17.4		7.0	
10000	10.4		4.5	

Overall	50.4	37.2



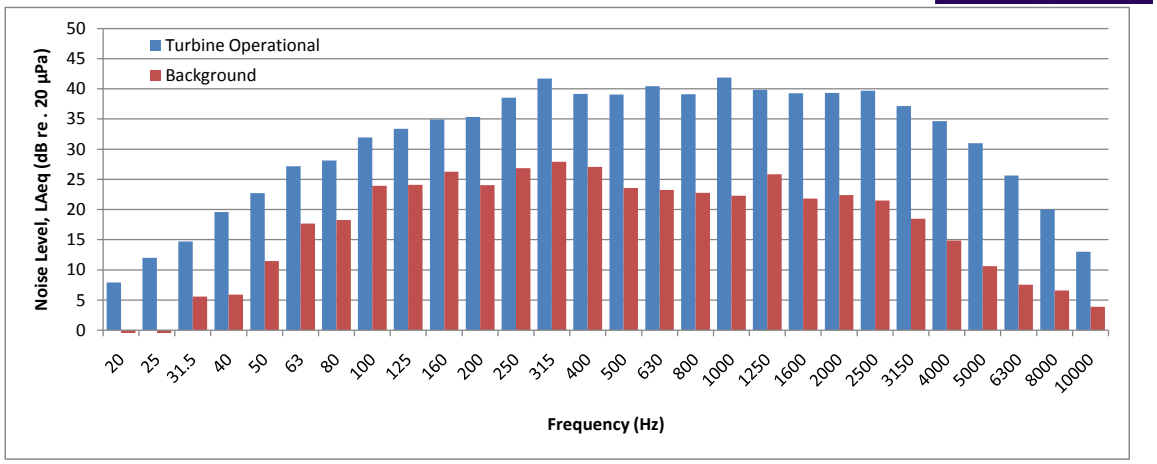


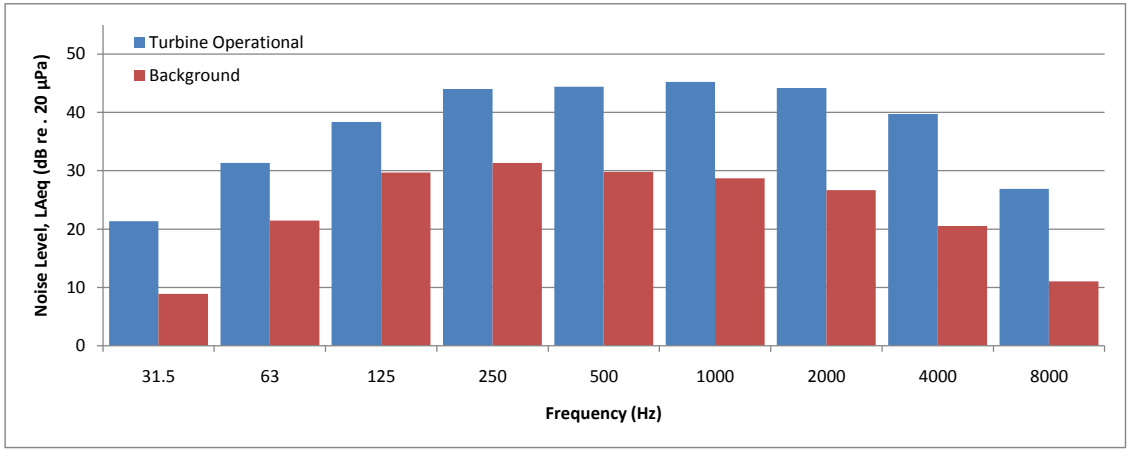
HM:2300/R1

Endurance E-3120 Wind Turbine
Wind Speed - 6 m/s

	Turbine Operational		Background	
Frequency (Hz)	1/3 Octave Band (dB(A))	Octave Band (dB (A))	1/3 Octave Band (dB(A))	Octave Band (dB (A))
20	7.9		-12.8	
25	12.0	21.4	-6.4	8.9
31.5	14.7		5.6	
40	19.6		5.9	
50	22.7	31.3	11.5	21.4
63	27.2		17.7	
80	28.1		18.2	
100	32.0	38.4	23.9	29.7
125	33.4		24.1	
160	34.9		26.3	
200	35.3	44.0	24.0	31.3
250	38.5		26.8	
315	41.7		27.9	
400	39.2	44.4	27.1	29.8
500	39.0		23.6	
630	40.4		23.2	
800	39.1	45.2	22.8	28.7
1000	41.9		22.3	
1250	39.8		25.9	
1600	39.3	44.2	21.8	26.7
2000	39.3		22.4	
2500	39.7		21.5	
3150	37.2	39.7	18.5	20.5
4000	34.6		14.9	
5000	31.0		10.6	
6300	25.6	26.9	7.5	11.0
8000	20.0		6.6	
10000	13.0		3.9	

Overall	51.1	36.7



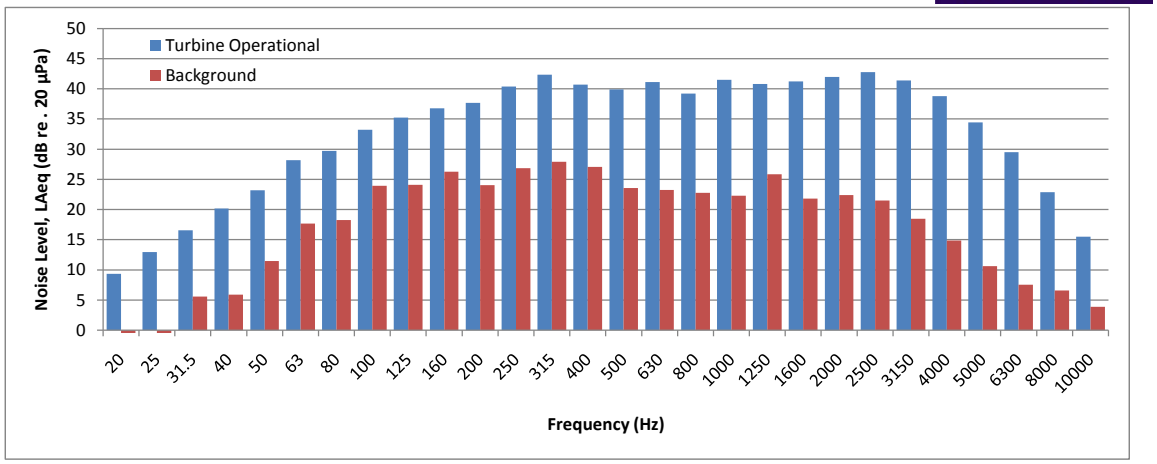


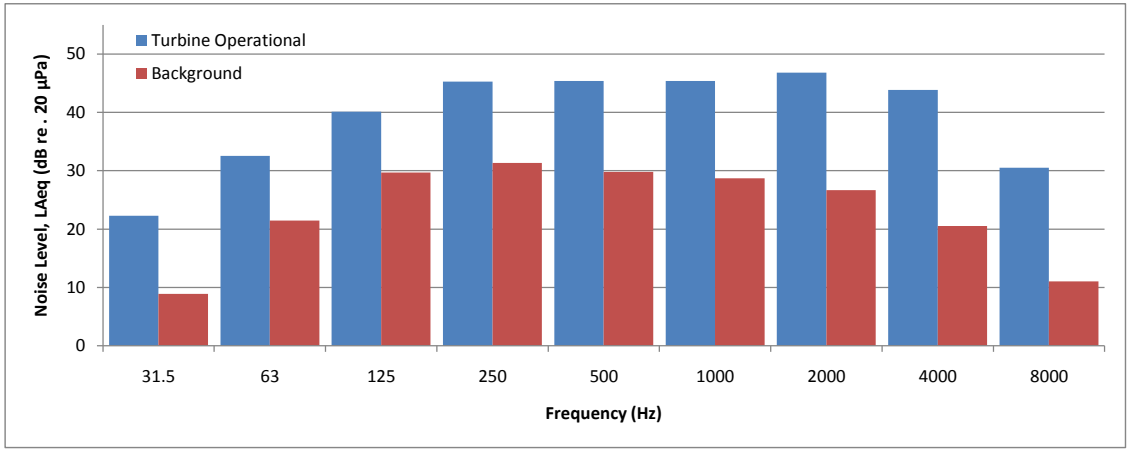
HM:2300/R1

Endurance E-3120 Wind Turbine
Wind Speed - 7 m/s

	Turbine Operational		Background	
Frequency (Hz)	1/3 Octave Band (dB(A))	Octave Band (dB (A))	1/3 Octave Band (dB(A))	Octave Band (dB (A))
20	9.3		-12.8	
25	13.0	22.3	-6.4	8.9
31.5	16.6		5.6	
40	20.2		5.9	
50	23.2	32.6	11.5	21.4
63	28.2		17.7	
80	29.7		18.2	
100	33.2	40.1	23.9	29.7
125	35.3		24.1	
160	36.8		26.3	
200	37.7	45.3	24.0	31.3
250	40.4		26.8	
315	42.3		27.9	
400	40.7	45.4	27.1	29.8
500	39.9		23.6	
630	41.1		23.2	
800	39.2	45.4	22.8	28.7
1000	41.5		22.3	
1250	40.8		25.9	
1600	41.2	46.8	21.8	26.7
2000	42.0		22.4	
2500	42.8		21.5	
3150	41.4	43.8	18.5	20.5
4000	38.8		14.9	
5000	34.4		10.6	
6300	29.5	30.5	7.5	11.0
8000	22.9		6.6	
10000	15.5		3.9	

Overall	52.7	36.7



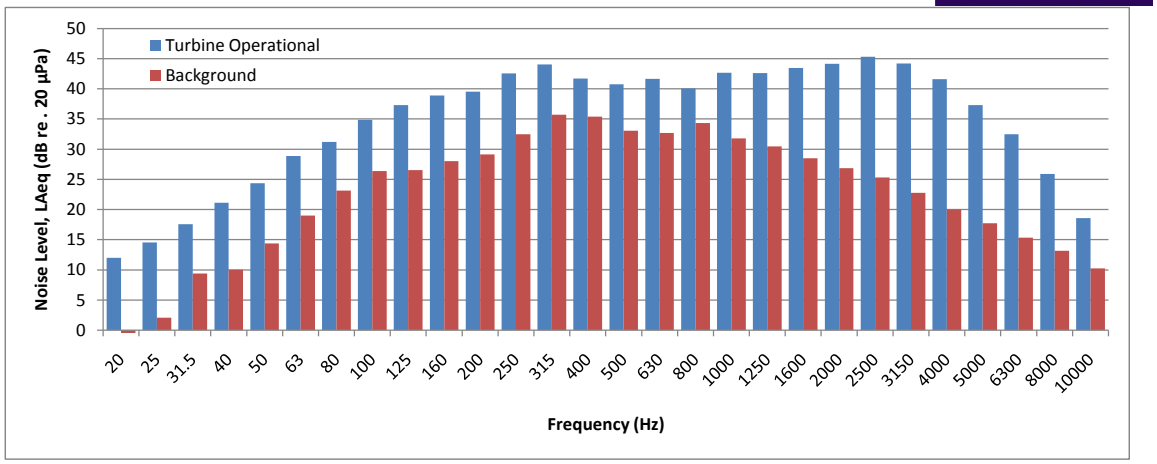


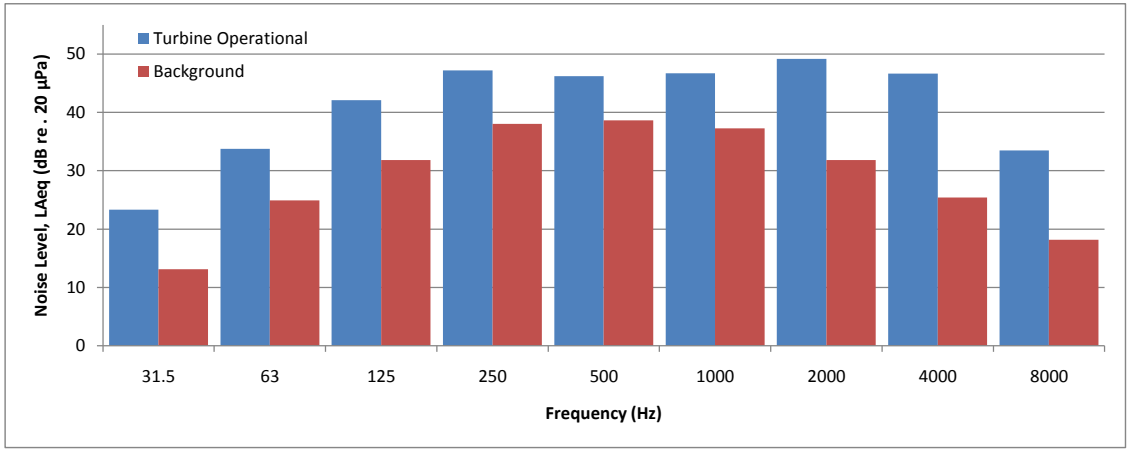
HM:2300/R1

Endurance E-3120 Wind Turbine
Wind Speed - 8 m/s

	Turbine Operational		Background	
Frequency (Hz)	1/3 Octave Band (dB(A))	Octave Band (dB (A))	1/3 Octave Band (dB(A))	Octave Band (dB (A))
20	12.0		-2.0	
25	14.6	23.3	2.1	13.1
31.5	17.6		9.4	
40	21.1		10.1	
50	24.4	33.7	14.4	24.9
63	28.9		19.0	
80	31.2		23.1	
100	34.9	42.1	26.4	31.8
125	37.3		26.6	
160	38.9		28.0	
200	39.5	47.2	29.2	38.0
250	42.5		32.5	
315	44.0		35.7	
400	41.7	46.2	35.4	38.6
500	40.8		33.0	
630	41.7		32.7	
800	40.0	46.7	34.3	37.3
1000	42.7		31.8	
1250	42.6		30.5	
1600	43.4	49.1	28.5	31.8
2000	44.2		26.9	
2500	45.3		25.3	
3150	44.2	46.6	22.8	25.4
4000	41.6		20.0	
5000	37.3		17.7	
6300	32.5	33.5	15.4	18.2
8000	25.9		13.1	
10000	18.6		10.2	

Overall	54.6	43.6



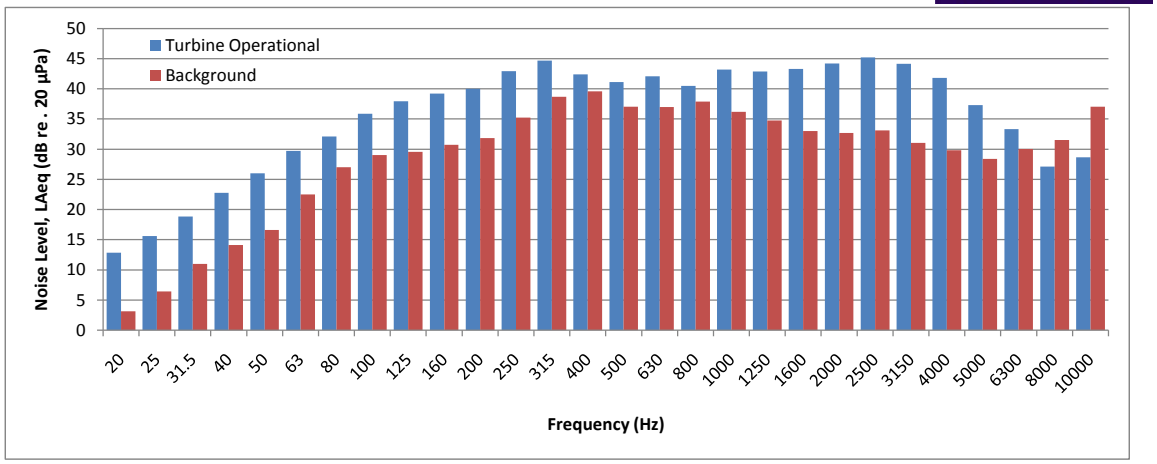


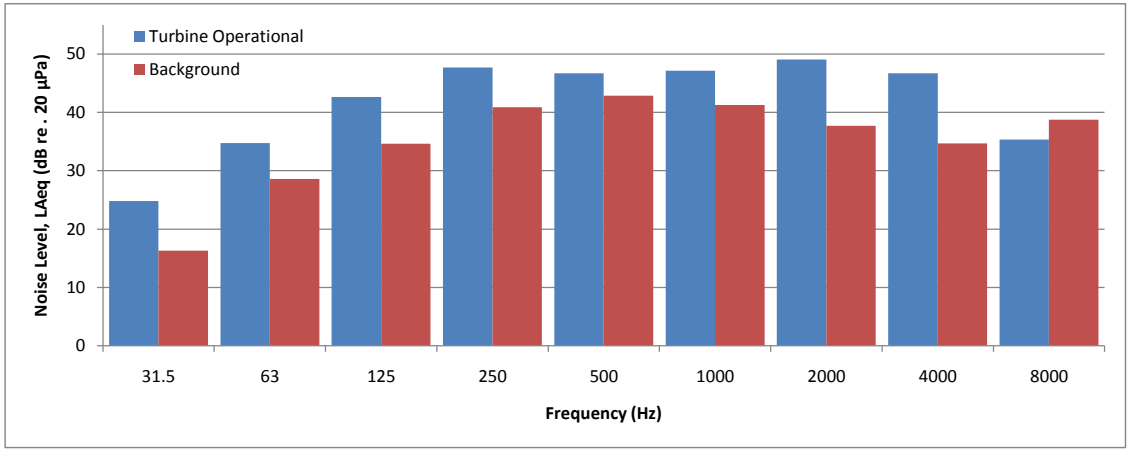
HM:2300/R1

Endurance E-3120 Wind Turbine
Wind Speed - 9 m/s

	Turbine Operational		Background	
Frequency (Hz)	1/3 Octave Band (dB(A))	Octave Band (dB (A))	1/3 Octave Band (dB(A))	Octave Band (dB (A))
20	12.8		3.2	
25	15.6	24.8	6.4	16.3
31.5	18.8		11.0	
40	22.8		14.1	
50	26.0	34.7	16.6	28.6
63	29.7		22.5	
80	32.1		27.0	
100	35.8	42.7	29.0	34.6
125	37.9		29.6	
160	39.2		30.7	
200	40.0	47.7	31.9	40.9
250	42.9		35.2	
315	44.7		38.7	
400	42.4	46.7	39.6	42.8
500	41.1		37.0	
630	42.1		37.0	
800	40.5	47.1	37.9	41.3
1000	43.2		36.2	
1250	42.9		34.8	
1600	43.3	49.1	33.0	37.7
2000	44.2		32.7	
2500	45.2		33.1	
3150	44.1	46.7	31.1	34.7
4000	41.8		29.8	
5000	37.3		28.4	
6300	33.3	35.3	30.0	38.7
8000	27.1		31.5	
10000	28.7		37.0	

Overall	54.9	48.1



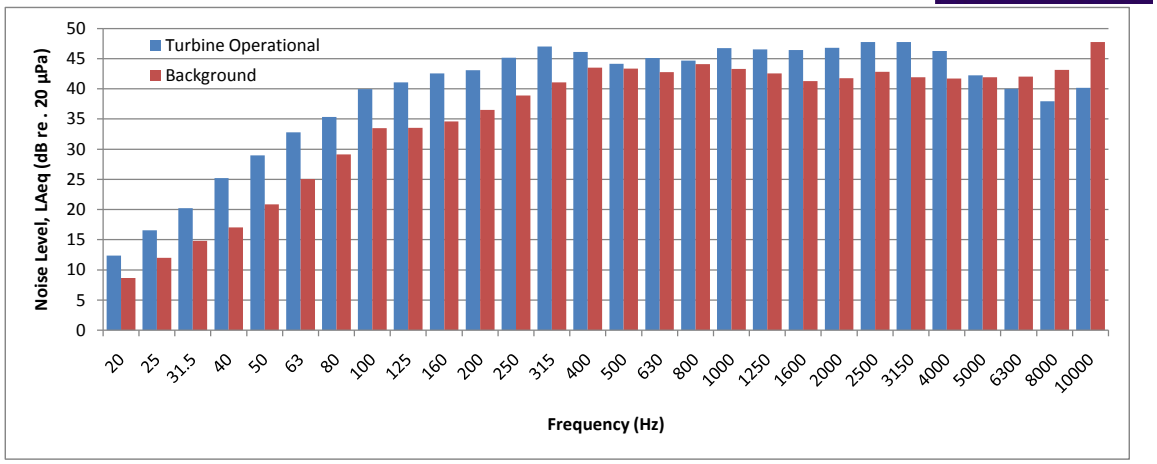


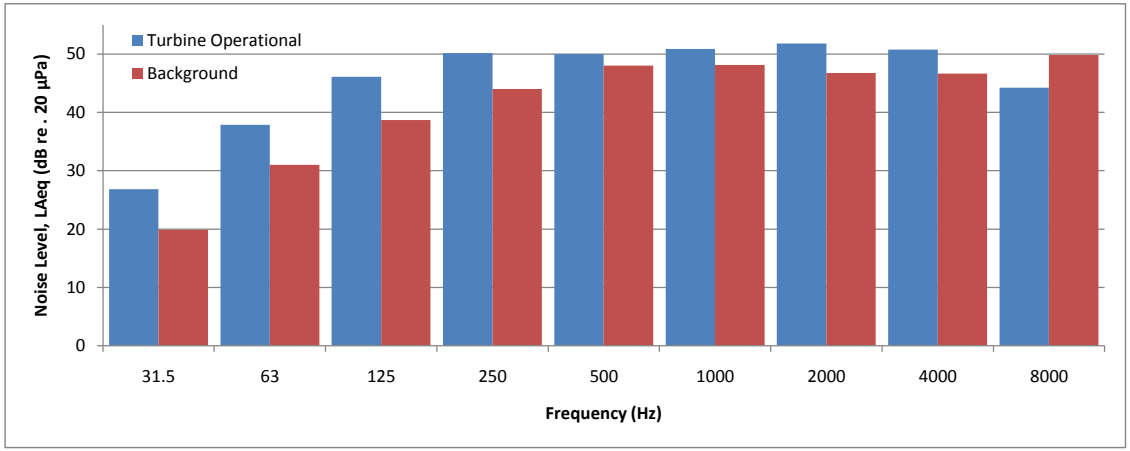
HM:2300/R1

Endurance E-3120 Wind Turbine
Wind Speed - 10 m/s

	Turbine Operational		Background	
Frequency (Hz)	1/3 Octave Band (dB(A))	Octave Band (dB (A))	1/3 Octave Band (dB(A))	Octave Band (dB (A))
20	12.4		8.7	
25	16.5	26.8	12.0	19.9
31.5	20.2		14.8	
40	25.2		17.0	
50	29.0	37.9	20.8	31.0
63	32.8		25.1	
80	35.3		29.2	
100	39.9	46.1	33.5	38.7
125	41.1		33.5	
160	42.5		34.6	
200	43.1	50.1	36.5	44.0
250	45.2		38.9	
315	47.0		41.1	
400	46.1	50.0	43.5	48.0
500	44.1		43.4	
630	45.1		42.8	
800	44.7	50.9	44.1	48.1
1000	46.8		43.3	
1250	46.5		42.6	
1600	46.4	51.8	41.3	46.8
2000	46.8		41.8	
2500	47.8		42.8	
3150	47.7	50.7	41.9	46.6
4000	46.3		41.7	
5000	42.2		41.9	
6300	40.0	44.2	42.0	49.8
8000	38.0		43.1	
10000	40.1		47.7	

Overall	58.2	55.5



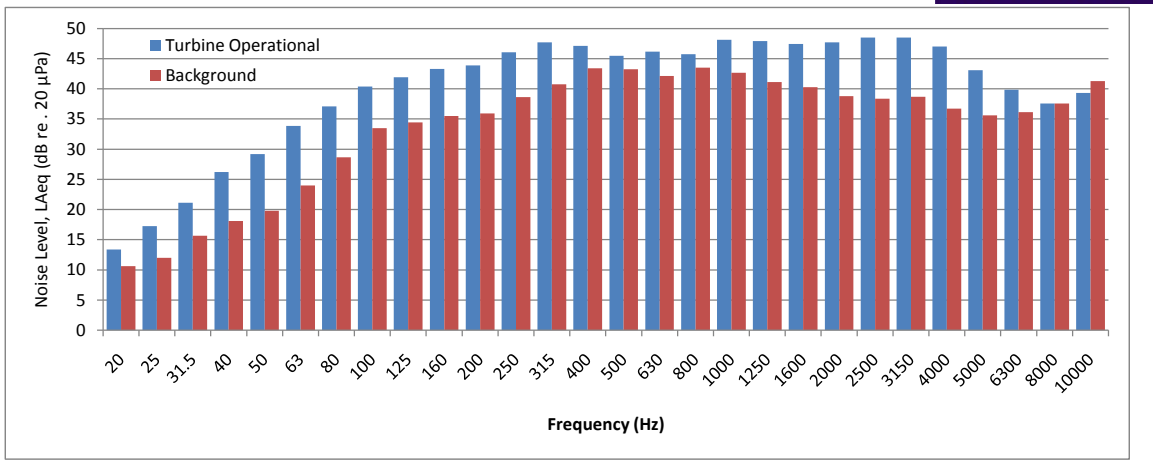


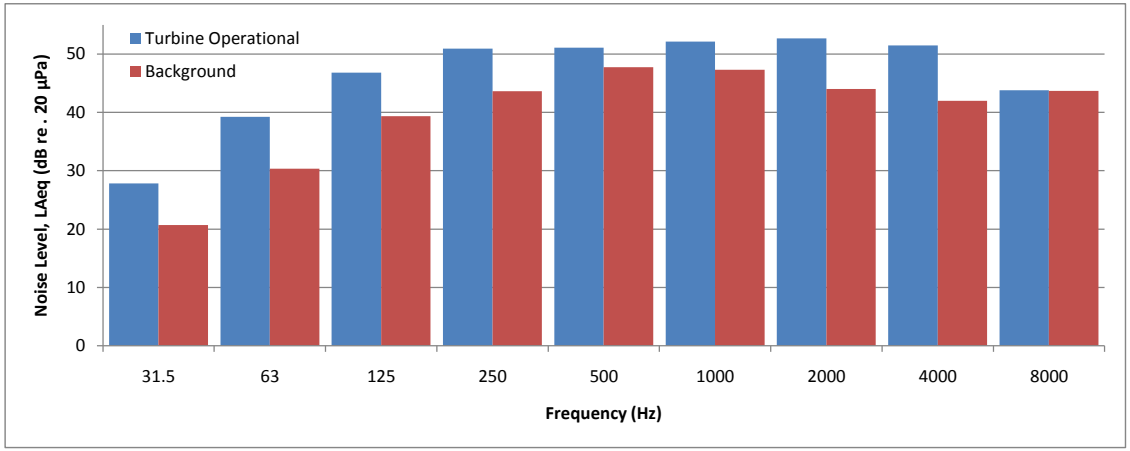
HM:2300/R1

Endurance E-3120 Wind Turbine
Wind Speed - 11 m/s

	Turbine Operational		Background	
Frequency (Hz)	1/3 Octave Band (dB(A))	Octave Band (dB (A))	1/3 Octave Band (dB(A))	Octave Band (dB (A))
20	13.4		10.6	
25	17.2	27.8	12.0	20.7
31.5	21.1		15.7	
40	26.2		18.1	
50	29.2	39.2	19.8	30.3
63	33.8		24.0	
80	37.1		28.7	
100	40.4	46.8	33.5	39.3
125	41.9		34.4	
160	43.3		35.5	
200	43.9	50.9	35.9	43.6
250	46.0		38.7	
315	47.7		40.7	
400	47.1	51.1	43.4	47.7
500	45.5		43.2	
630	46.1		42.1	
800	45.7	52.1	43.5	47.3
1000	48.1		42.6	
1250	47.9		41.1	
1600	47.5	52.7	40.3	44.0
2000	47.7		38.8	
2500	48.5		38.3	
3150	48.5	51.5	38.7	42.0
4000	47.0		36.7	
5000	43.1		35.6	
6300	39.8	43.8	36.1	43.7
8000	37.6		37.6	
10000	39.3		41.3	

Overall	59.1	53.2



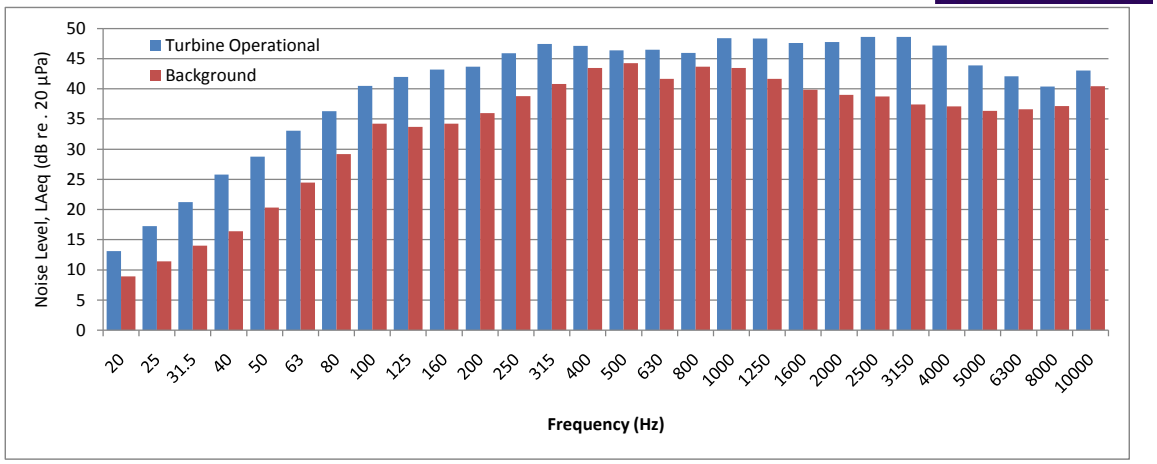


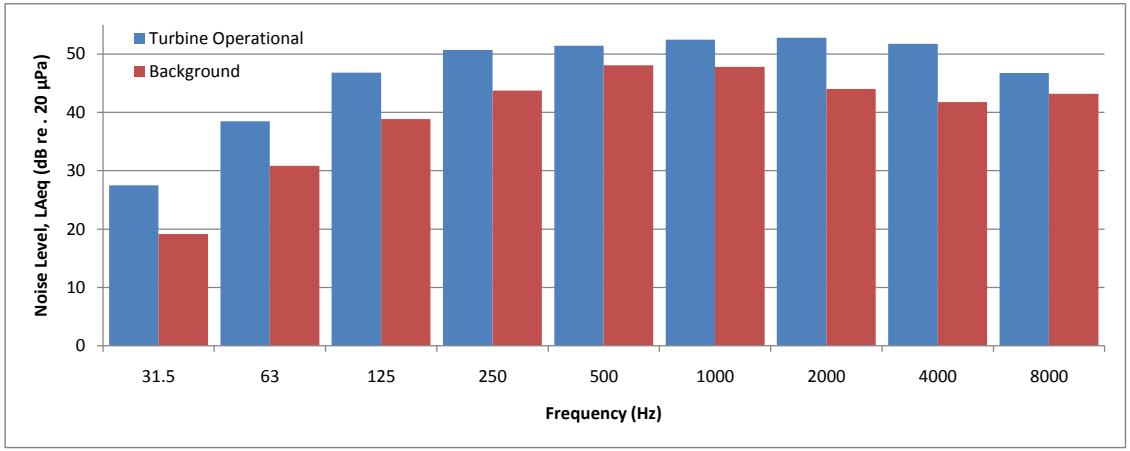
HM:2300/R1

Endurance E-3120 Wind Turbine
Wind Speed - 12 m/s

	Turbine Operational		Background	
Frequency (Hz)	1/3 Octave Band (dB(A))	Octave Band (dB (A))	1/3 Octave Band (dB(A))	Octave Band (dB (A))
20	13.1		8.9	
25	17.3	27.5	11.4	19.2
31.5	21.2		14.0	
40	25.8		16.4	
50	28.7	38.5	20.3	30.9
63	33.1		24.4	
80	36.3		29.2	
100	40.5	46.8	34.3	38.8
125	42.0		33.7	
160	43.2		34.2	
200	43.7	50.7	36.0	43.7
250	45.9		38.8	
315	47.5		40.8	
400	47.1	51.4	43.5	48.0
500	46.4		44.3	
630	46.5		41.6	
800	46.0	52.5	43.7	47.8
1000	48.4		43.5	
1250	48.4		41.7	
1600	47.6	52.8	39.8	44.0
2000	47.8		39.0	
2500	48.6		38.8	
3150	48.6	51.7	37.4	41.7
4000	47.2		37.1	
5000	43.9		36.4	
6300	42.1	46.7	36.6	43.2
8000	40.4		37.1	
10000	43.0		40.4	

Overall	59.4	53.4





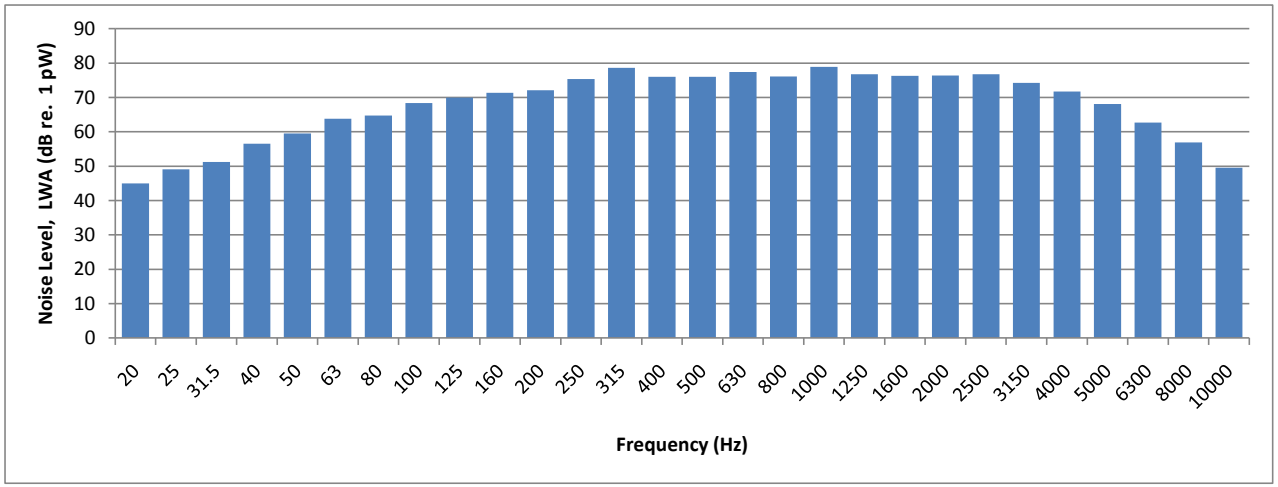
Appendix F
Background Corrected One Third Octave Sound Power Levels

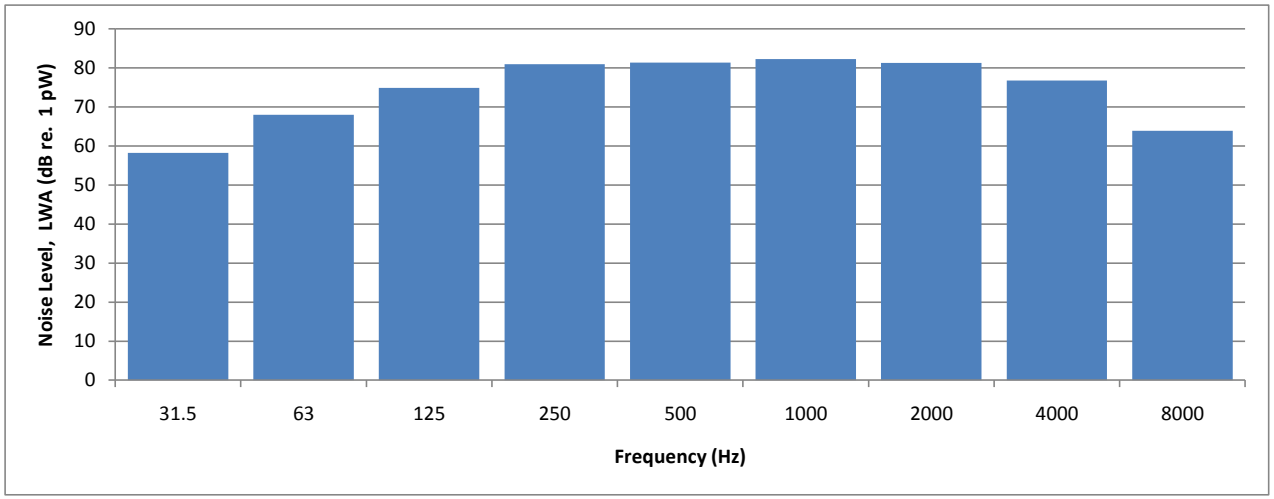
HM:2300/R1

Endurance E-3120 Wind Turbine
Wind Speed - 6 m/s

Frequency (Hz)	1/3 Octave Band (dB LWA)	Octave Band (dB LWA)
20	45.0	
25	49.1	58.2
31.5	51.2	
40	56.5	
50	59.5	68.0
63	63.8	
80	64.8	
100	68.3	74.9
125	70.0	
160	71.4	
200	72.1	80.9
250	75.3	
315	78.6	
400	76.0	81.3
500	76.0	
630	77.4	
800	76.1	82.2
1000	78.9	
1250	76.8	
1600	76.3	81.2
2000	76.3	
2500	76.7	
3150	74.2	76.8
4000	71.7	
5000	68.1	
6300	62.7	63.9
8000	56.9	
10000	49.5	

Overall	88.1



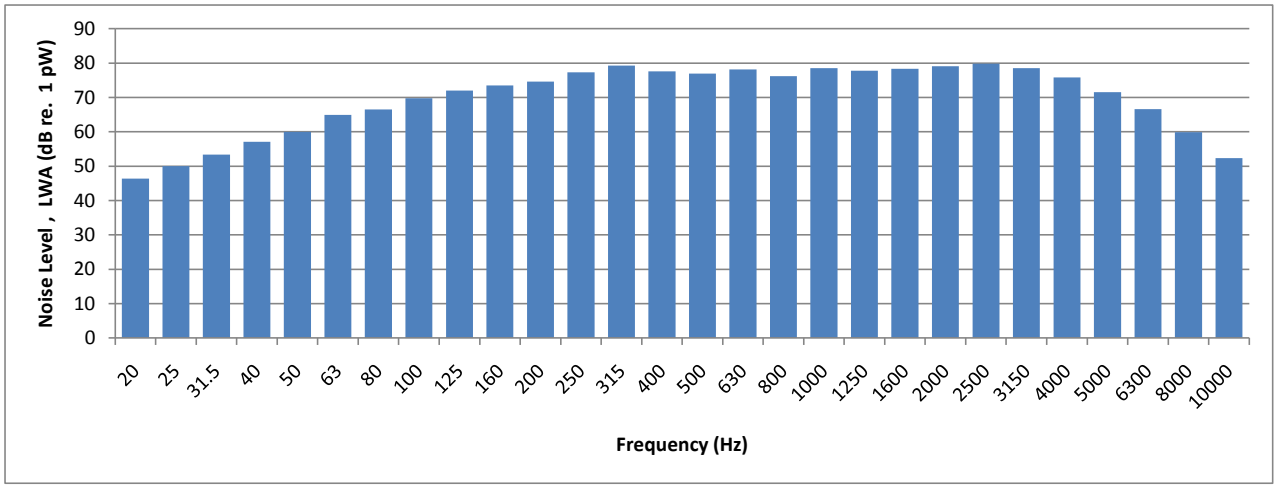


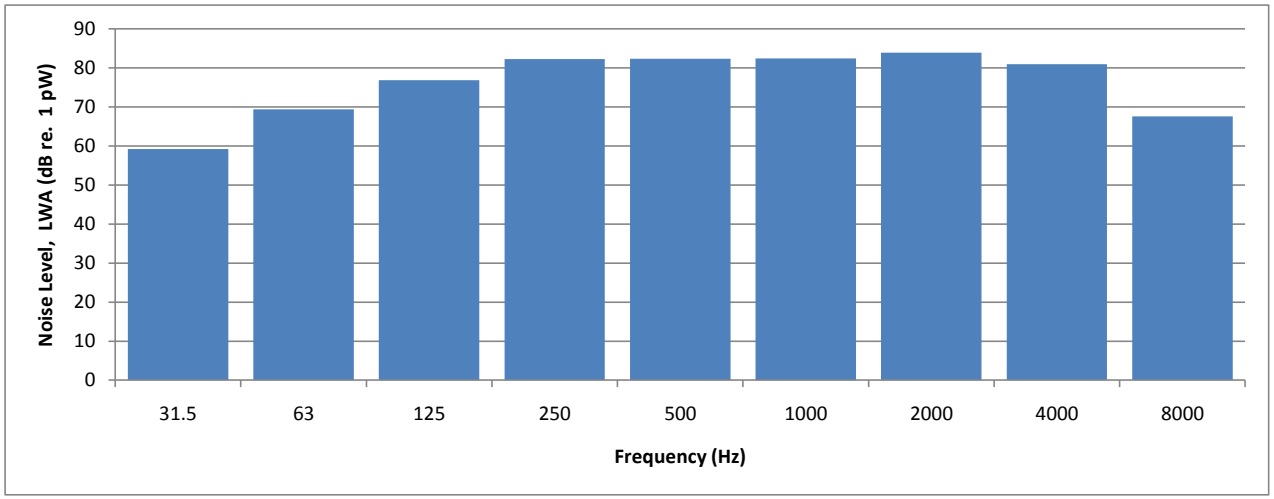
HM:2300/R1

Endurance E-3120 Wind Turbine
Wind Speed - 7 m/s

Frequency (Hz)	1/3 Octave Band (dB LWA)	Octave Band (dB LWA)
20	46.4	
25	50.0	59.2
31.5	53.3	
40	57.1	
50	60.0	69.3
63	64.9	
80	66.5	
100	69.8	76.8
125	72.0	
160	73.5	
200	74.6	82.2
250	77.3	
315	79.3	
400	77.6	82.4
500	76.9	
630	78.2	
800	76.2	82.4
1000	78.5	
1250	77.8	
1600	78.3	83.9
2000	79.1	
2500	79.9	
3150	78.5	80.9
4000	75.9	
5000	71.5	
6300	66.6	67.6
8000	59.9	
10000	52.3	

Overall	89.7



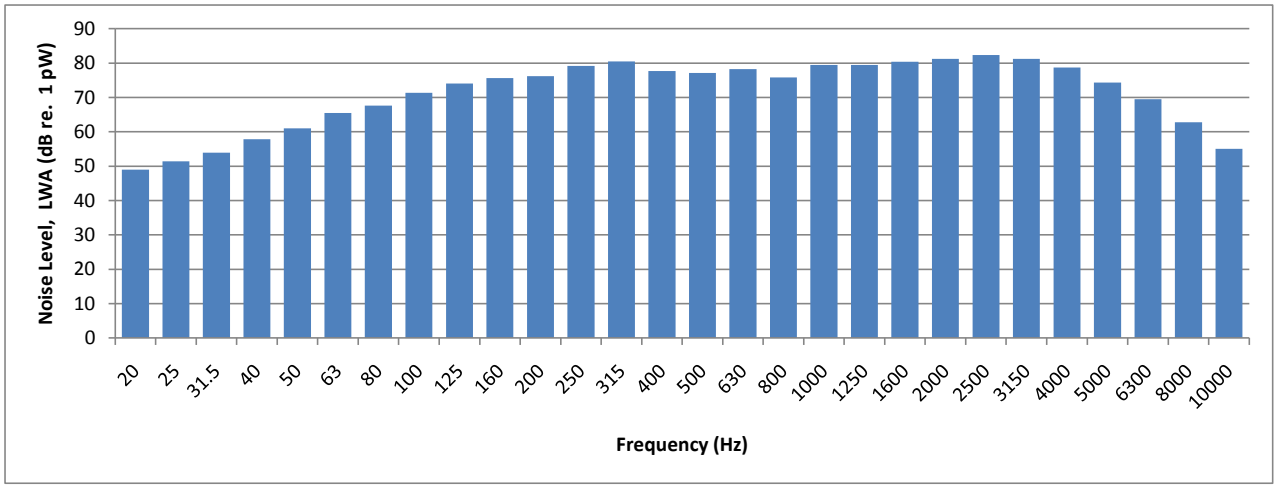


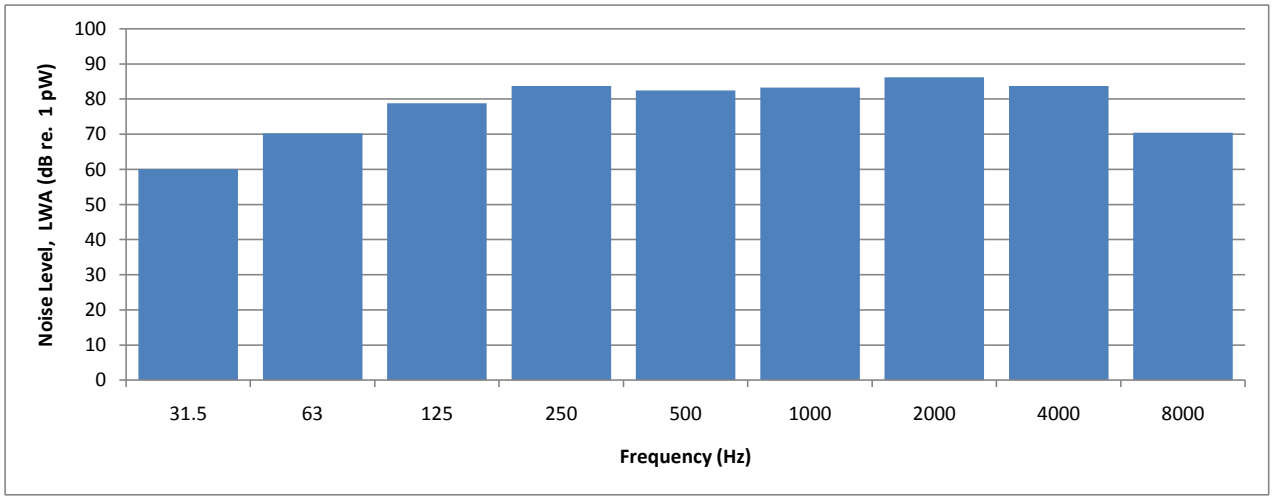
HM:2300/R1

Endurance E-3120 Wind Turbine
Wind Speed - 8 m/s

Frequency (Hz)	1/3 Octave Band (dB LWA)	Octave Band (dB LWA)
20	49.0	
25	51.4	60.0
31.5	54.0	
40	57.9	
50	61.0	70.3
63	65.5	
80	67.6	
100	71.3	78.8
125	74.0	
160	75.7	
200	76.2	83.7
250	79.2	
315	80.5	
400	77.7	82.5
500	77.1	
630	78.2	
800	75.9*	83.3
1000	79.4	
1250	79.4	
1600	80.4	86.2
2000	81.2	
2500	82.4	
3150	81.3	83.7
4000	78.7	
5000	74.3	
6300	69.5	70.5
8000	62.8	
10000	55.0	

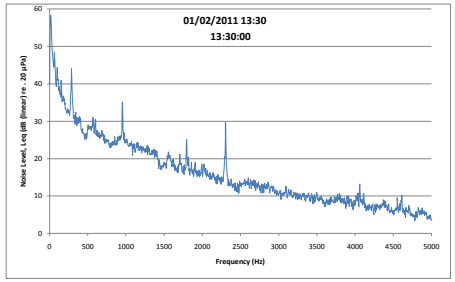
Overall	91.4

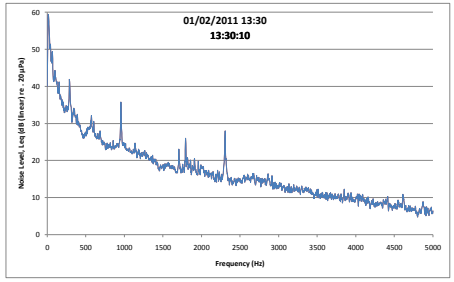


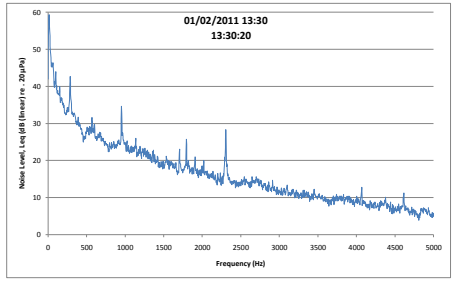


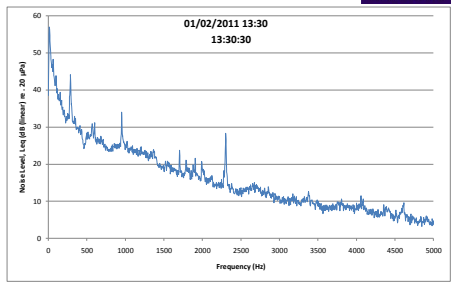
Appendix G
Narrowband Analysis

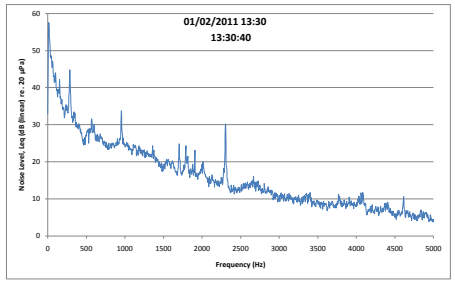
Endurance E-3120 - Narrowband Spectra
6m/s Wind Speed

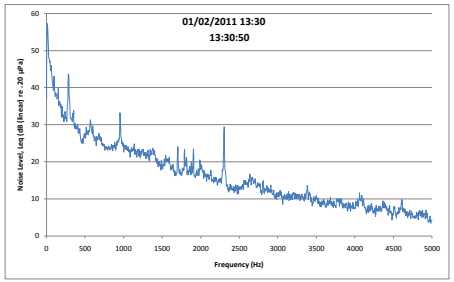


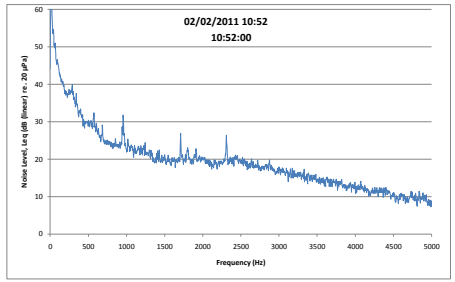


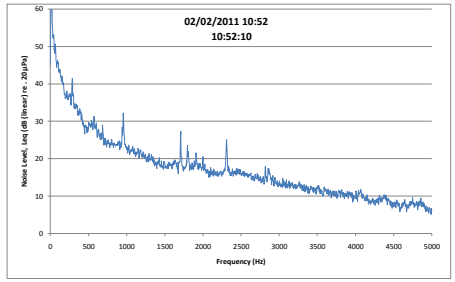


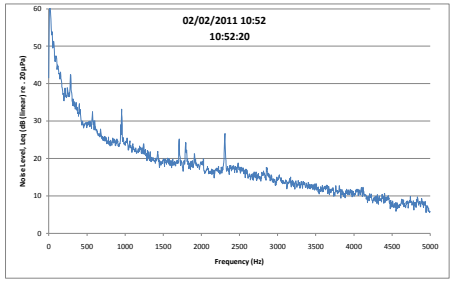


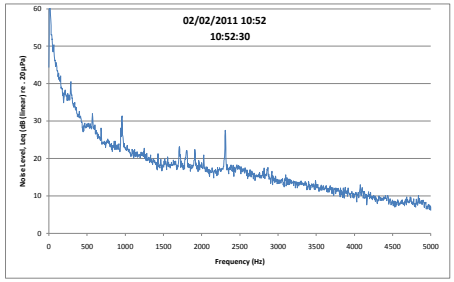


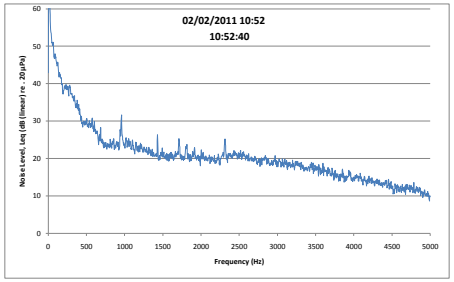


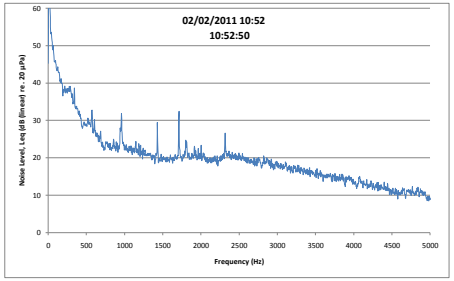


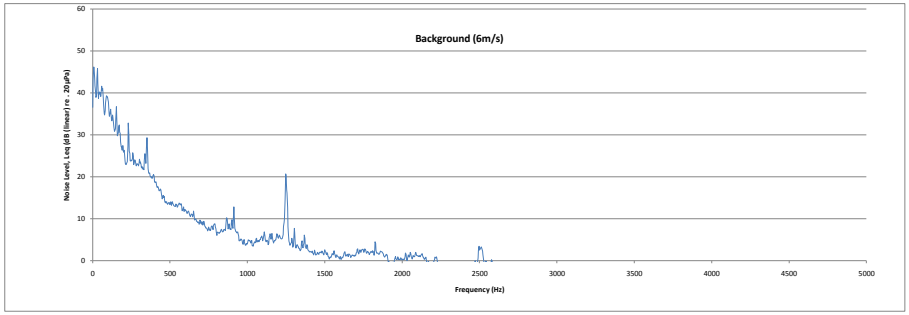








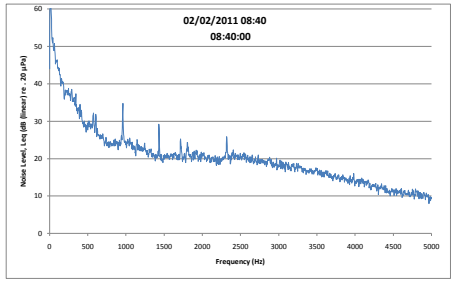


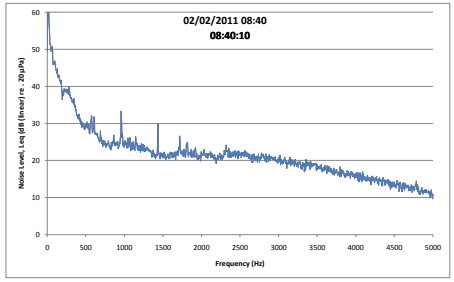


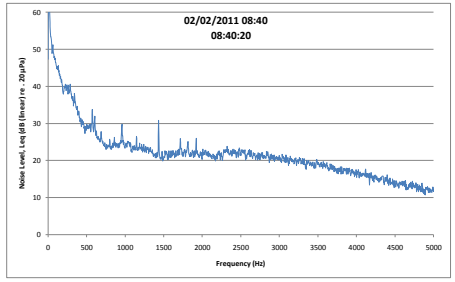
Results of tonal assessment

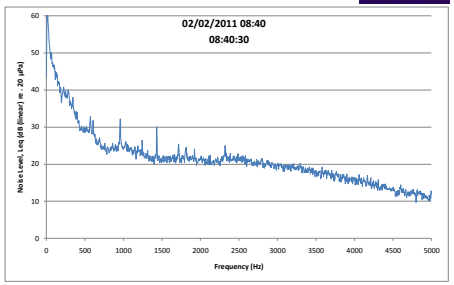
Frequency (Hz)	Tonal Audibility (dB)
287.2	-0.99
955.2	-2.08
2307.8	-0.01

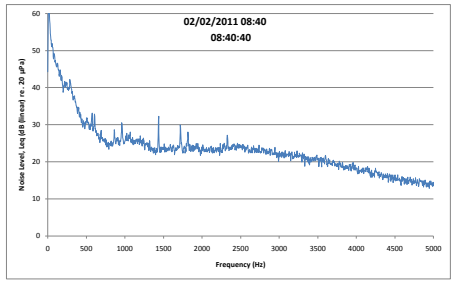
Endurance E-3120 - Narrowband Spectra
7m/s Wind Speed

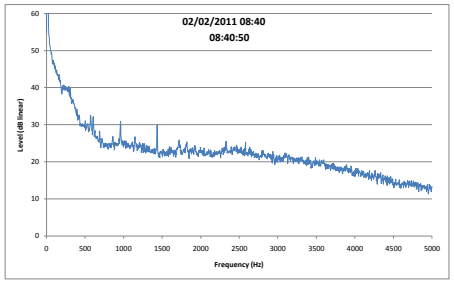


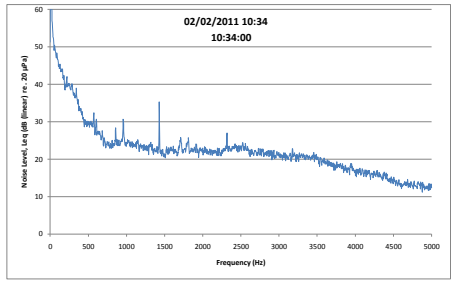


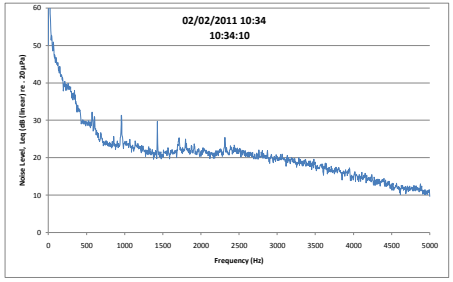


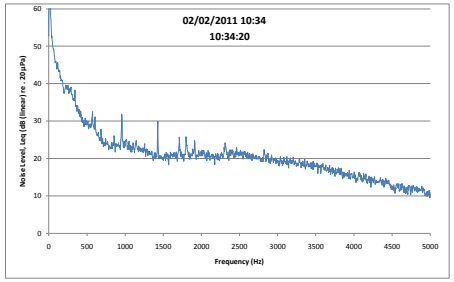


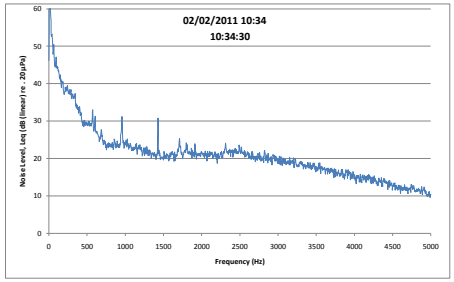


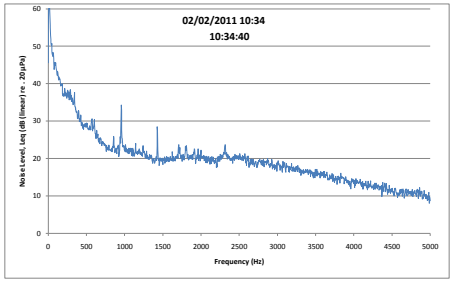


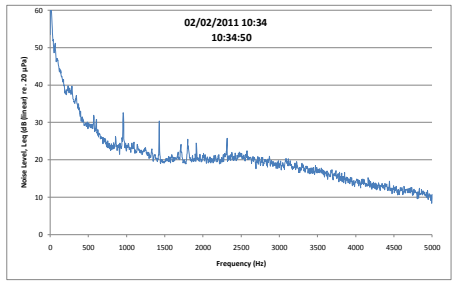


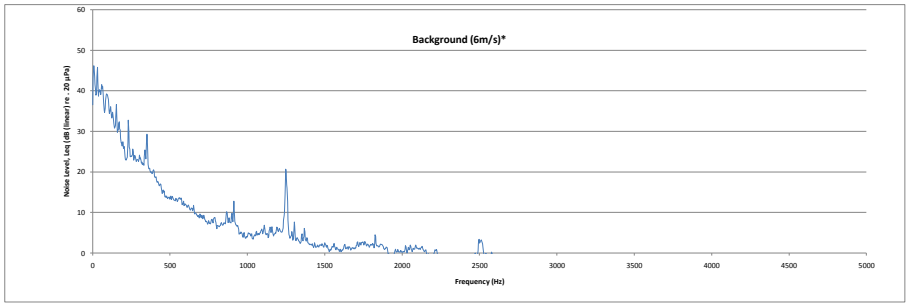










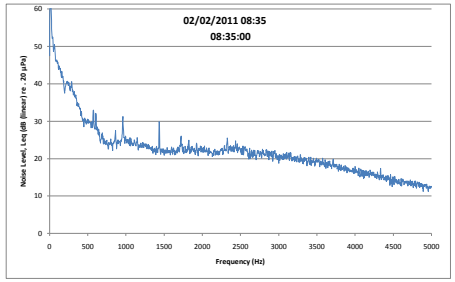


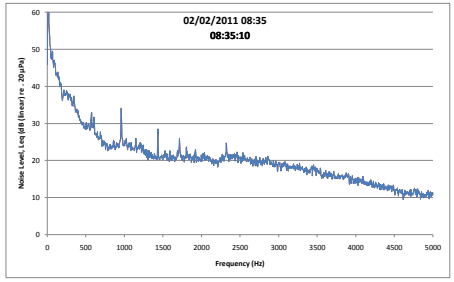
*No background noise data for 7m/s

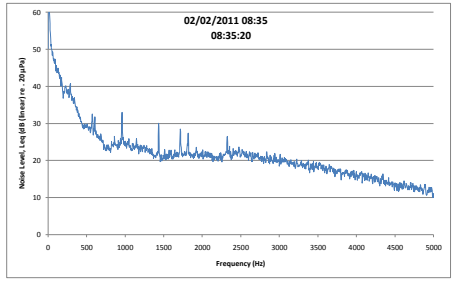
Results of tonal assessment

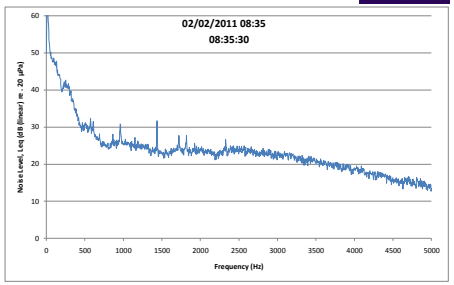
Frequency (Hz)	Tonal Audibility (dB)
No tones identified	

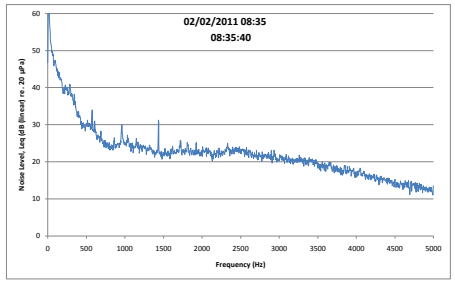
Endurance E-3120 - Narrowband Spectra
8m/s Wind Speed

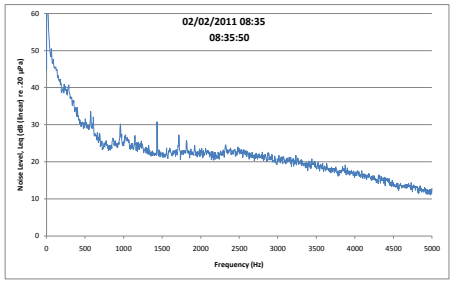


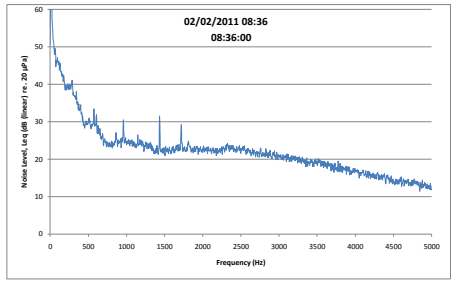


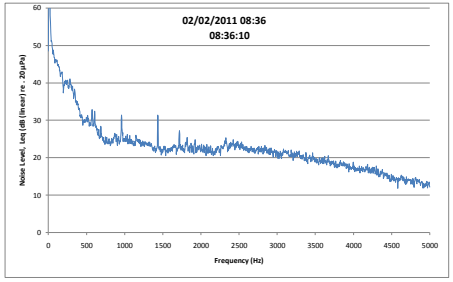


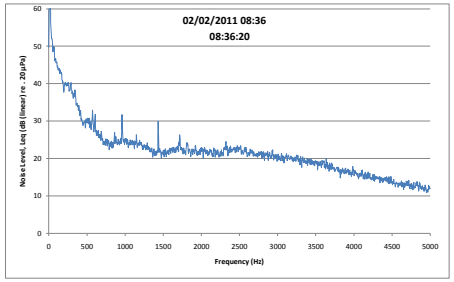


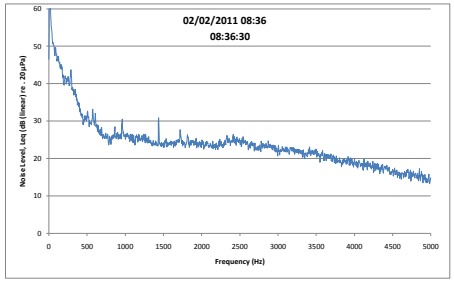


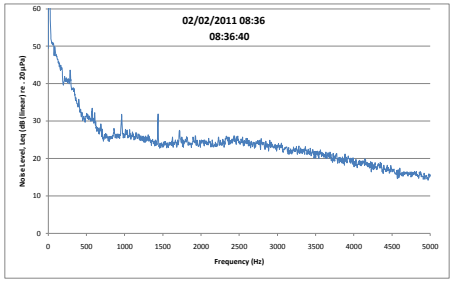


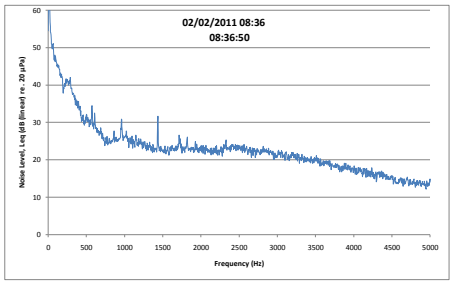


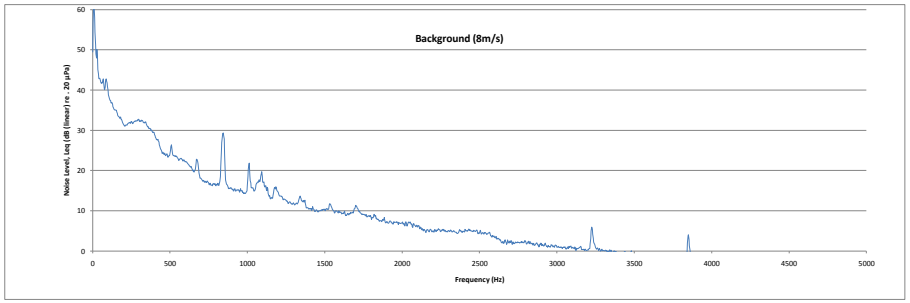








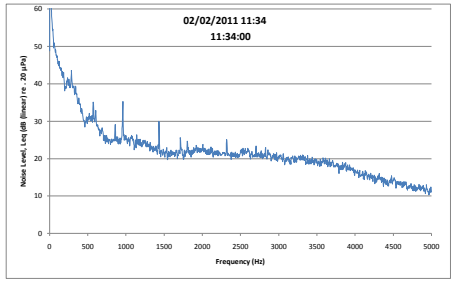


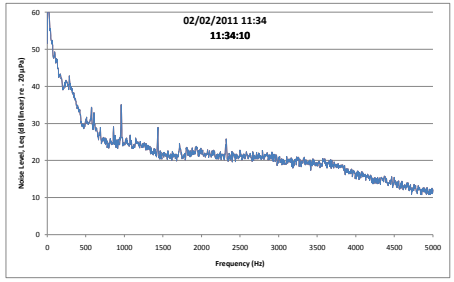


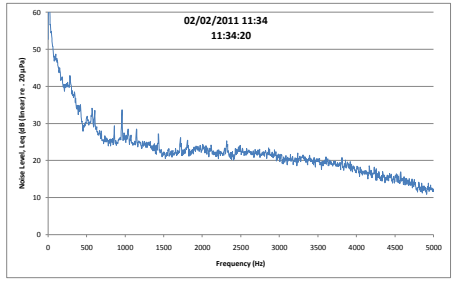
Results of tonal assessment

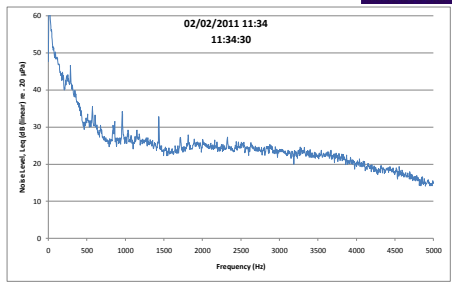
Frequency (Hz)	Tonal Audibility (dB)
No tones identified	

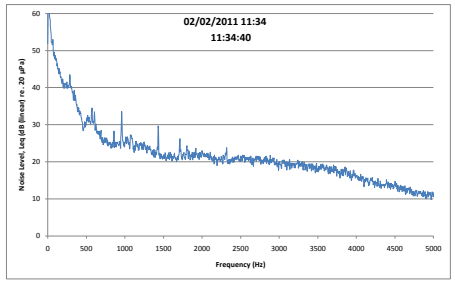
Endurance E-3120 - Narrowband Spectra
9m/s Wind Speed

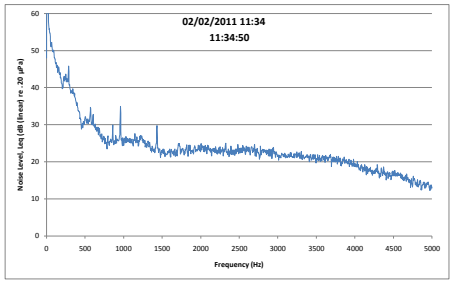


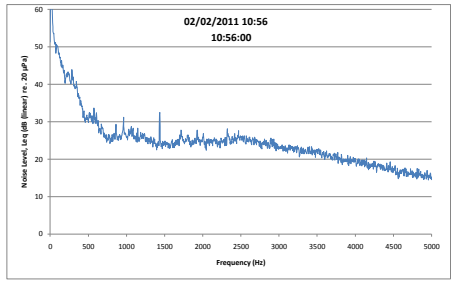


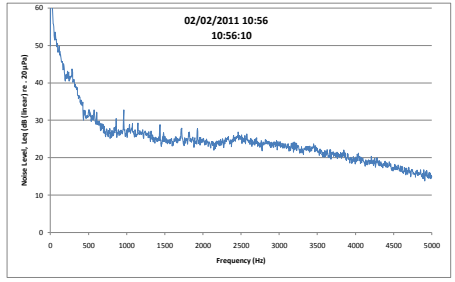


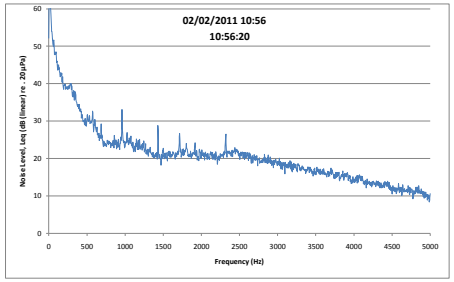


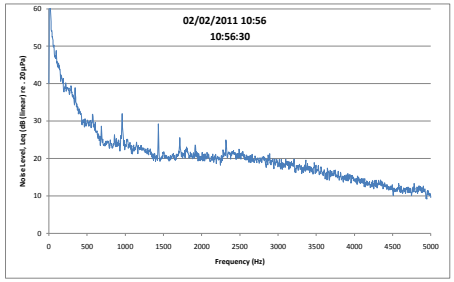


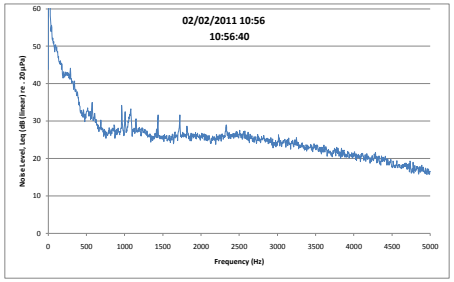


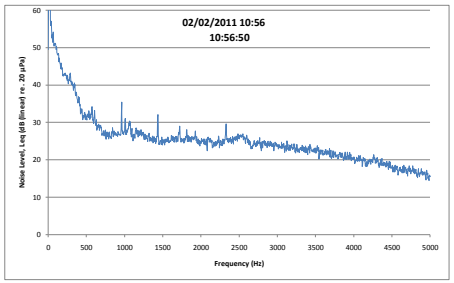


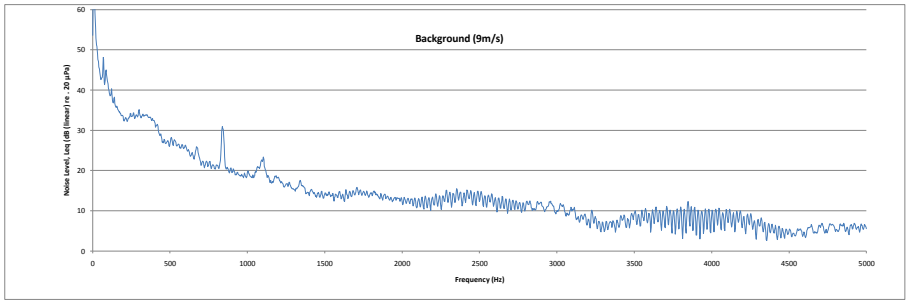








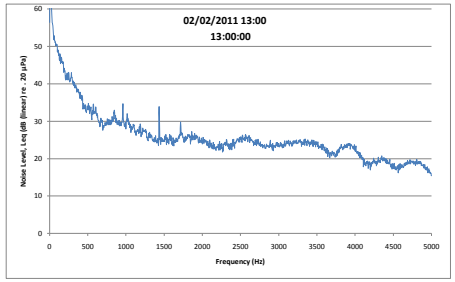


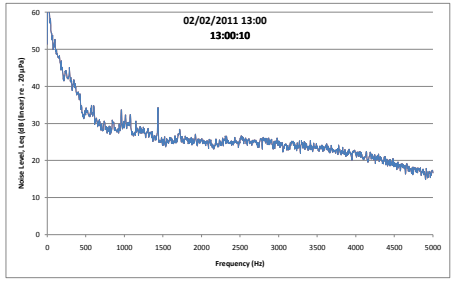


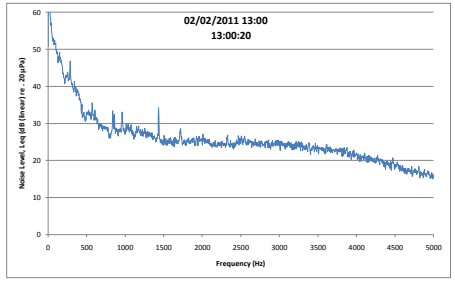
Results of tonal assessment

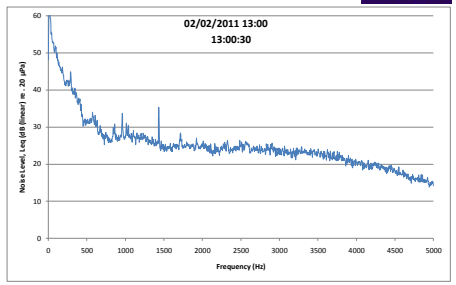
Frequency (Hz)	Tonal Audibility (dB)
No tones identified	

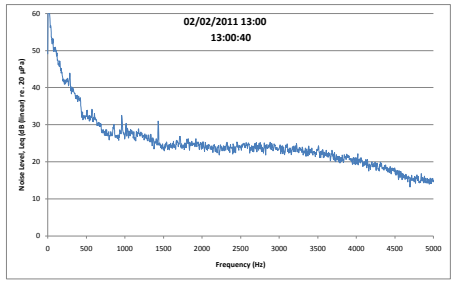
Endurance E-3120 - Narrowband Spectra
10m/s Wind Speed

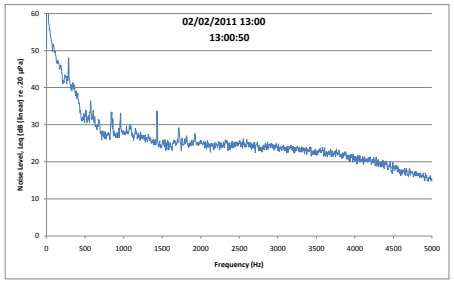


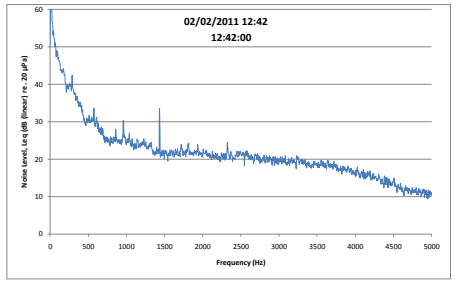


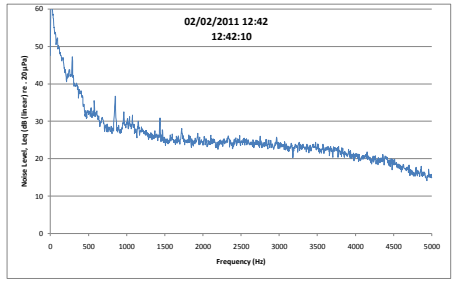


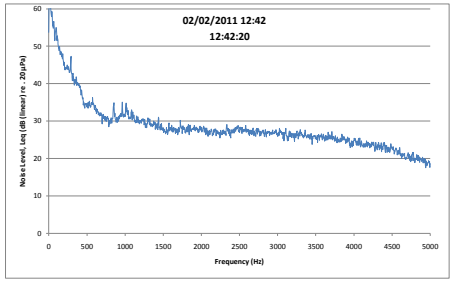


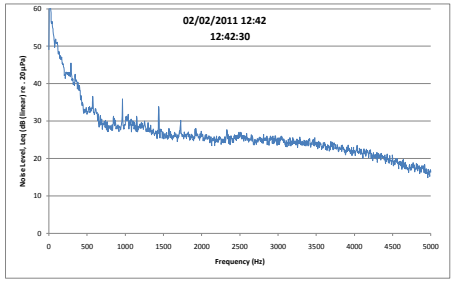


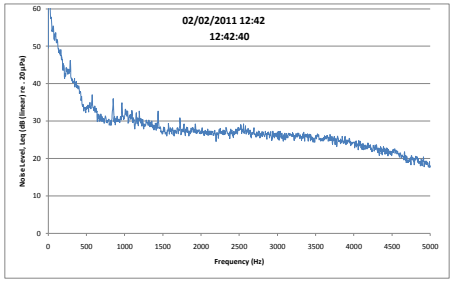


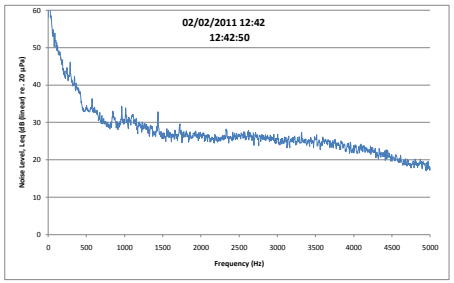


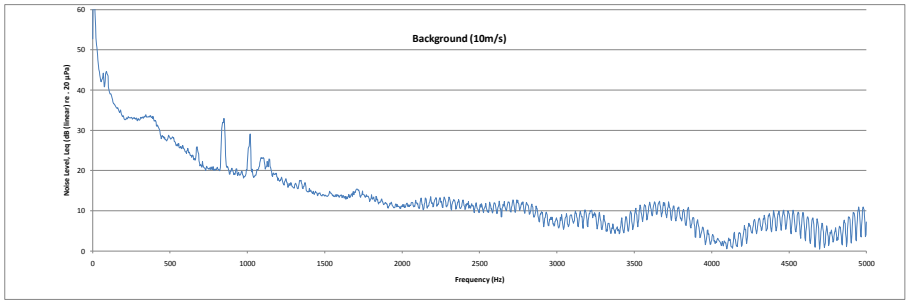












Results of tonal assessment

Frequency (Hz)	Tonal Audibility (dB)
No tones identified	