Document No 10/6298/001/GLA/O/R/001
Issue : B2

sgurr energy

Sustainable Engineering Worldwide

Kingspan Renewables Ltd

Kingspan KW6 Wind Turbine Noise Performance Test

December 2011

Sustainable Engineering Worldwide

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Kingspan KW6 Wind Turbine Noise Performance Test

SUMMARY:

A wind turbine noise performance test has been performed according to BWEA Small Wind Turbine Performance and Safety Standard (Ref 1) on a Kingspan KW6 (formerly known as Proven P11) wind turbine generator (WTG).

The WTG has been calculated to have an apparent sound power level of 85.2 dB(A) ±1.87 dB(A) at 8 m/s hub height wind speed.

The declared apparent sound power level has been calculated to be 88.3 dB(A) at 8 m/s hub height wind speed.

Tonality of the Kingspan KW6 has been assessed according to the BWEA Small Wind Turbine Performance and Safety Standard. The WTG was found not to be tonal.

CLIENT: Kingspan Renewables Ltd

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DISTRIBUTION :

Client: Ben Brown

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Date of Issue	21 December 2011	**Classification:**	Confidential

SF/04/023

AMENDMENT RECORD			
Revision	**Date**	**Changes from Previous Revision**	**Purpose of Revision**
A1	27/06/2011	None – First Draft	Draft, for internal review
A2	28/06/2011	Minor amendments	Draft, for internal review
B1	30/06/2011	Minor Changes	Client Issue
B2	21/12/2011	Change of WTG Name	Client Issue

Contents

TABLES

1 INTRODUCTION

SgurrEnergy has performed a wind turbine noise performance test on a Proven P11 wind turbine generator (WTG) at Prince Bank Barn, Lumb, approximately 7 km south of Burnley. The objective of the test was to determine the noise performance characteristic of the WTG. The sound power level, 1/3 octave band and narrow band characteristic were monitored during the survey.

The noise performance test was conducted according to the BWEA Small Turbine Performance and Safety Standard (Ref 1) which is based on BS EN 61400-11 Wind turbine generator systems – Part 11: Acoustic noise measurement techniques (Ref 2) with exceptions to allow for specific operational characteristics of small wind turbines.

Kingspan Renewables provided a certificate of conformity from TUV nel (Ref 3) verifying that the Kingspan KW6 WTG is identical in design to the tested Proven P11 WTG. The results are therefore transferable and the WTG will be referred to as Kingspan KW6 throughout the report.

2 TURBINE DESCRIPTION

The Kingspan KW6 is a three bladed, passive stall free yawing downwind WTG with self-regulating speed control. It has a rotor diameter of 5.5 m and the tested WTG has a hub height of 9 m. A summary of the WTG specifications is shown in Table 1.

Table 1: Turbine Specifications

Manufacturer	Kingspan Renewables Ltd.
Model	KW6
Type	Downwind
Number of Blades	3
Rated Power	5.2 kW
Hub height	9 m
Rotor Diameter	5.5 m
Cut-in wind speed	3.5 m/s
Cut-out wind speed	n/a
Survival wind speed	70 m/s
Control Mechanism	Passive stall
Tower Type	Tilt up monopole

3 ACOUSTIC DESCRIPTION OF THE AREA

The area around the WTG mainly consists of open farmland bordered by fences. The closest building to the WTG is Prince Bank Barn approximately 100 m to the west. In other directions land use appears to be mainly fields. There is an absence of noise emitting industrial premises in the surroundings of the WTG. During the measurement period background noise was dominated by the wind with infrequent contributions from distant traffic, high flying air traffic and farm noises. Data records where the contribution from these noise sources was considerable were removed during the screening of the gathered data.

At the time of the measurements no animals were kept on the field. Cows and sheep were grazing on the adjacent fields. The tested Kingspan KW6 is the only WTG on site.

A map of the site area is shown in Appendix A.

4 MEASUREMENT

The measurements were performed according to BWEA Small Wind Turbine Performance and Safety Standard (Ref 1) and BS EN 61400-11 (Ref 2) including amendment A1:2006 (Ref 4) with exceptions to allow for the specific operational characteristics of small wind turbines.

4.1 ACOUSTIC MEASUREMENTS

The microphone was placed in the centre of a 1m diameter ground mounted wooden board, with the diaphragm of the microphone in a plane normal to the board and the axis of the microphone pointing towards the WTG, as specified in BS EN 61400-11 (Ref 2). The distance between microphone and WTG base was 11.75 m which matches the tip height of the WTG.

The microphone was covered by a 90 mm open foam wind shield, which was cut to allow the microphone to lie flat on the board.

The microphone was positioned at an angle of 90° from the WTG. The wind direction varied between 230.2° and 296.7° during the measurement period, which lies within the specified allowable arc of ±60°. All gathered data points are in the acceptable range throughout the monitoring period.

4.2 WIND SPEED AND DIRECTION MEASUREMENTS

The wind speed and direction were measured using a 10 m telescopic mast, extended to 9 m height. The mast was installed upwind of the WTG at a distance of 13.75 m, which lies within 2 to 4 rotor diameters, as specified in BS EN 61400-11 (Ref 2).

The wind rose and time series of the measured wind speed are shown in Appendix B.

Table 2: Heights and Distances	
Hub height	9 m
Anemometer height	9 m
Distance WTG to met mast	13.75 m
Distance WTG to microphone	11.75 m
Slant distance WTG hub to microphone	14.8 m

Photographs of the monitoring setup are shown in Appendix C.

5 INSTRUMENTATION

- Bruel and Kjaer Type 2260 sound level meter serial number 2044353
- Bruel and Kjaer Type 4230 SLM calibrator serial number 2052327
- Bruel and Kjaer Type 4189 microphone serial number 2523678

The sound level meter was programmed to record the equivalent continuous sound pressure level L_{Aeq} and 1/3 octave band spectra in ten second intervals. These 10 second intervals were later averaged to obtain 30 second intervals.

The instrument was calibrated shortly before the surveys began, and the calibration has been checked again shortly after the surveys were complete. The calibration deviation after the monitoring period was -0.07dB compared to the calibration at the start of the measurement. A calibration history is available upon request.

Wind speed and direction were measured using a Vector A100L2 anemometer, NRG #200P vane and Campbell Scientific CR10X logger. The wind data were logged in ten second intervals and later averaged to 30 second intervals.

The logger and sound level meter were both set to GMT and synchronised before the start of the monitoring period.

6 RESULTS

6.1 MEASURED NOISE LEVELS

The ten second average measured L_{Aeq} total noise data and background noise data were averaged to 30 second periods. Any data points affected by extraneous noise, such as aircraft, vehicles or barking dogs were removed from the data set. The resulting dataset consisted of 206 data points for the total measured noise and 27 data points for the background noise. The data was plotted against the concurrent measured wind speed.

The total noise and background noise plotted against wind speed are shown in Appendix D.

6.2 SOUND POWER LEVEL CALCULATION

A linear regression line was fitted to the measured total noise and background noise to give the board sound pressure level for a wind speed of 8 m/s at rotor centre height, as specified in BWEA Small Wind Turbine Performance and Safety Standard (Ref 1). The equations obtained from the regression lines were used to calculate the total noise and background noise at each integer wind speed.

A background noise correction needs to be applied if the margin between total noise and background noise is less than 6 dB. The margin between the measured background and total noise was found to be at least 18.7 dB and therefore no correction was applied.

The Apparent Emission Sound Power Level of the WTG was calculated following the method described in BS EN 61400-11 (Ref 2). The results are shown in Table 3.

Table 3: Apparent Sound Power Level								
Hub Height Wind Speed [m/s]	4	5	6	7	8	9	10	11
Total Noise Level $L_{Aeq,total}$ [dB(A)]	50.4	52.0	53.7	55.3	56.9	58.5	60.1	61.8
Background Noise Level $L_{Aeq,BG}$ [dB(A)]	31.7	33.1	34.5	35.9	37.2	38.6	40.0	41.4
Margin ($L_{Aeq,total}$ - $L_{Aeq,BG}$) [dB(A)]	18.7	18.9	19.2	19.4	19.7	19.9	20.1	20.4
Apparent Sound Power Level $L_{WA,k}$ [dB(A)]	**78.7**	**80.4**	**82.0**	**83.6**	**85.2**	**86.9**	**88.5**	**90.1**

6.3 1/3 Octave Analysis

The 10 second averaged measured 1/3 octave band spectra have been averaged to get 30 second periods. The four 30 second averaged periods closest to 8 m/s, the four periods closest to 6 m/s and the four periods closest to 4 m/s wind speed were chosen to calculate the energy average 1/3 octave band spectra. The linear, A-weighted and C-weighted results are shown in Appendix E. No background correction was carried out.

The assessment of tonality was performed according to the methodology specified in ISO 1996-2: 2007 Annex D (Ref 4) as suggested in BWEA Small Wind Turbine Performance and Safety Standard (Ref 1).

A WTG is declared tonal if any 1/3 octave band is higher than its adjacent bands by:

- 15 dB in the low frequency bands (50 to 125 Hz)
- 8 dB in the mid-frequency bands (160 to 400 Hz)
- 5 dB in the high frequency bands (500 to 10000 Hz).

Each four 1/3 octave band spectra closest to 8 m/s, 6 m/s and 4 m/s wind speed were chosen for the analysis. The analysis was performed for the linear, A-weighted and C-weighted 1/3 octave bands. The results are shown in Appendix F. Based on the analysed 1/3 octave spectra the Kingspan KW6 WTG was not found to be tonal.

This assessment is valid for the reference point, where the noise measurement took place and describes the noise character for the proximity of the wind turbine only.

6.4 Narrow Band Analysis

In addition to the 1/3 octave data analysis narrow band measurements were taken on site and analysed according to the committee draft of IEC 61400-11 Wind Turbine – Part 11: Acoustic noise measurement techniques (Ref 6). The narrow band data was measured in 10 second averages. The twelve records closest to each wind speed bin were used in the analysis. The measured narrow band data at wind speed bins between 5 m/s and 9 m/s are shown in Appendix G.

Possible tones were identified from the graphs shown in Appendix G. Further analysis was performed on the possible tones at 101.1 Hz at 5 m/s, 74.7 Hz at 6 m/s and 76.2 Hz at 7 m/s. At higher wind speeds no significant local maxima were present in the data.

The narrow band analysis was performed using the methodology described in IEC 61400-11 (Ref 6). The results are shown in Table4.

Table 4: Determination of Audibility				
Wind Speed [m/s]	Centre Frequency	Critical Bandwidth	$\Delta L_{a,k}$	Audibility
5	101.1	100.74	-15.5	No Audible Tones
6	74.7	100.40	-15.9	No Audible Tones
7	76.2	100.42	-17.2	No Audible Tones

The energy average of the tones $\Delta L_{a,k}$ was found to be below the threshold of -3.0 dB, as described in IEC 61400-11 (Ref 6). The WTG was not found to be tonal

7 UNCERTAINTY

The measurement uncertainty was assessed in accordance with the methodology described in Annex D of BS EN 61400-11 (Ref 2). The uncertainties have been divided into type A and type B. Type A uncertainties are evaluated using statistical methods to determine the variation of the measurements around their mean value at each wind speed sector. Type B uncertainties are evaluated using judgment and experience from similar situations. The typical values presented in Table D.1 in Annex E of BS EN 61400-11 (Ref 2) have been used as a guideline to assess the type B uncertainties. The total uncertainty is evaluated from the square root of the sum of the squares of the individual type A and type B uncertainties.

The standard uncertainty of the sound power curve U_A was calculated using formula D.1 in Annex D of BS EN 61400-11 (Ref 2). The calculation parameters and result are shown in Table 5.

Table 5: Type A Uncertainty U_A	
Number of Elements	206
Sum $((y - y_{est})^2)$	174.4 dB
Type A Uncertainty U_A	0.926 dB

The type B uncertainties and the combined total uncertainty are shown in Table 6.

Table 6: Type B and Combined Uncertainty	
Standard Error U_A	0.93 dB
Calibration U_{B1}	0.2 dB
Instrument U_{B2}	0.2 dB
Board U_{B3}	0.5 dB
Distance U_{B4}	0.1 dB
Impedance U_{B5}	0.1 dB
Turbulence U_{B6}	0.5 dB
Wind Speed, measured U_{B7}	1.4 dB
Direction U_{B8}	0.3 dB
Background U_{B9}	-
Total U_C	**1.87 dB**

8 TABLES OF RESULTS

The declared apparent emission sound power level $L_{Wd,\ 8m/s}$ was calculated to a 95% confidence level, as described in BWEA Small Wind Turbine Performance and Safety Standard (Ref 1). The results are shown in Table 7.

Table 7: Noise Levels at 8m/s	
Apparent sound power level $L_{W,\ 8m/s}$ [dB (A)]	85.2
Measurement Uncertainty U_C [dB]	1.87
Declared apparent sound power level $L_{Wd,\ 8m/s}$ [dB (A)]	88.3
Wind Speed Dependance S_{dB} [dB/ms^{-1}]	1.62
Noise Penalty [dB]	-

The immission sound pressure levels at 25m and 60m slant distance were calculated in accordance to BWEA Small Wind Turbine Performance and Safety Standard (Ref 1). The results are shown in Table 8.

Table 8: Immission Sound Pressure Level at Slant Distance at 8m/s	
Immission Sound Pressure Level at 60m $L_{p,\ 60m}$	44.8 dB(A)
Immission Sound Pressure Level at 25m $L_{p,\ 25m}$	52.4 dB(A)
Slant Distance Required for 45dB(A)	58.5 m
Slant Distance Required for 40dB(A)	104 m

A noise label was determined according to BWEA Small Wind Turbine Performance and Safety Standard (Ref 1) and is shown in Appendix H.

9 CONCLUSIONS

9.1 A wind turbine noise performance test was performed according to BWEA Small Wind Turbine Performance and Safety Standard (Ref 1) on a Kingspan KW6 WTG installed at Prince Bank Barn in Lumb on 16 June 2011.

9.2 The WTG has been calculated to have an apparent sound power level of 85.2 dB(A) ±1.87 dB(A) at 8 m/s hub height wind speed.

9.3 The declared apparent sound power level was calculated to be 88.3 dB(A) at 8 m/s hub height wind speed.

9.4 Tonality of the Kingspan KW6 has been assessed according to the BWEA Small Wind Turbine Performance and Safety Standard (Ref 1). The WTG was found not to be tonal.

10 REFERENCES

1. Small Wind Turbine Performance and Safety Standard, British Wind Energy Association, 2008

2. Standards Policy and Strategy Committee: BS EN 61400-11 Wind turbine generator systems – Part 11: Acoustic noise measurement techniques (2003) BS EN 61400-11:2003 including Amendment A1:2006 Wind turbine generator systems – Part 11: Acoustic noise measurement techniques Incorporating Amendment no. 1 (identical with IEC 61400-11:2002 including amendment 1:2006) Standards Policy and Strategy Committee, August 2006

3. TUV nel. Type Certificate, Certification Number TUV0008, Certificate Number MCS/2011/05, November 2011

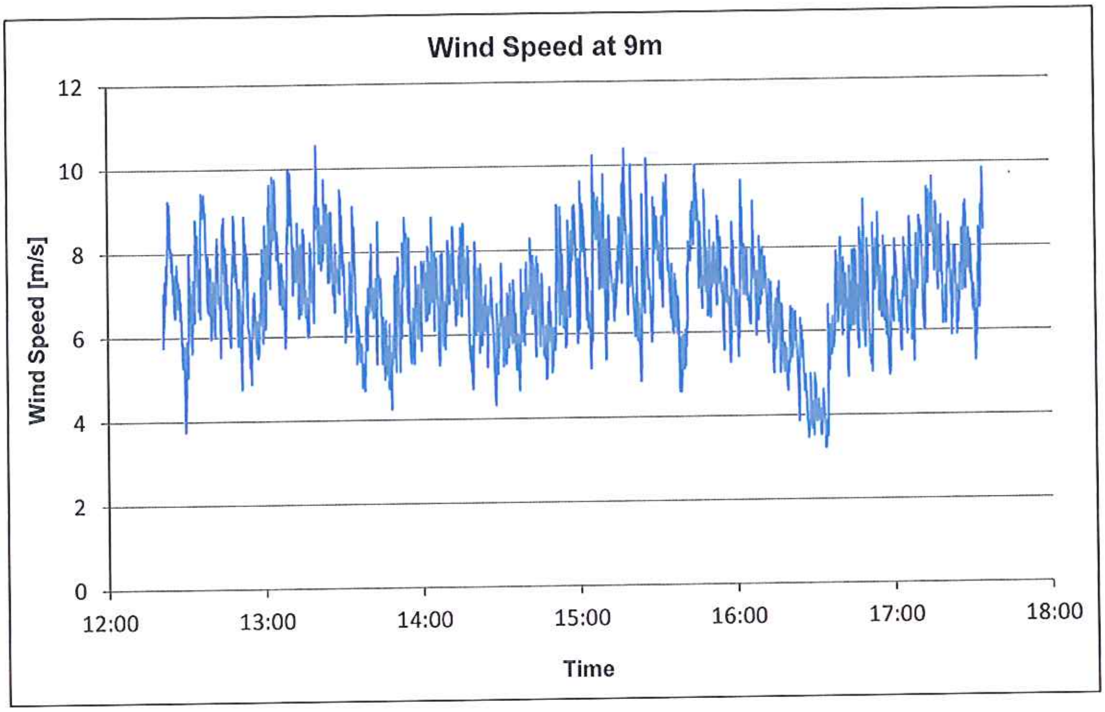
4. ISO 1996-2 Acoustics – Description, measurement and assessment of environmental noise, Part 2: Determination of environmental noise levels International Organization for Standardization, 2007

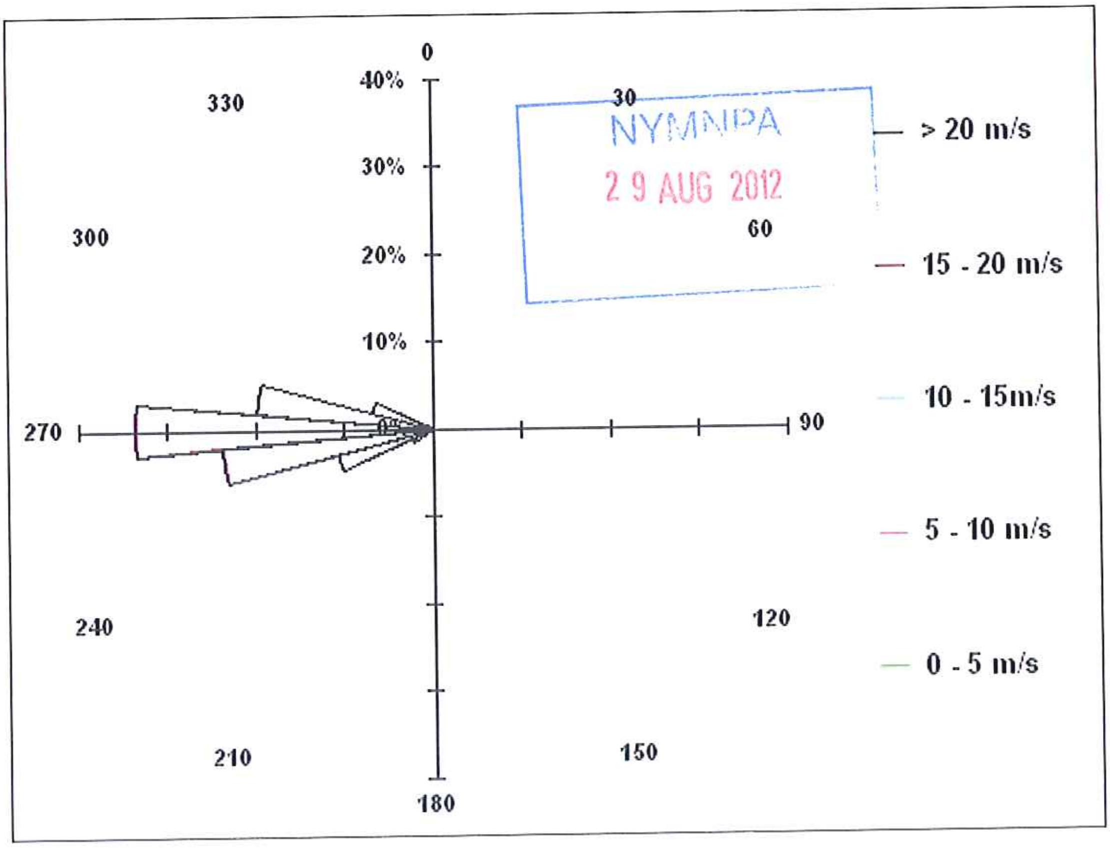
5. IEC TS 61400-14 Wind turbines – Part 14: Declaration of apparent sound power level and tonality values, International Electrotechnical Commission, 2005

6. IEC 61400-11 Wind Turbine – Part 11: Acoustic noise measurement techniques, International Electrotechnical Commission, 2011 (Committee Draft for Vote, 88/384/CDV)

APPENDIX A: MAP

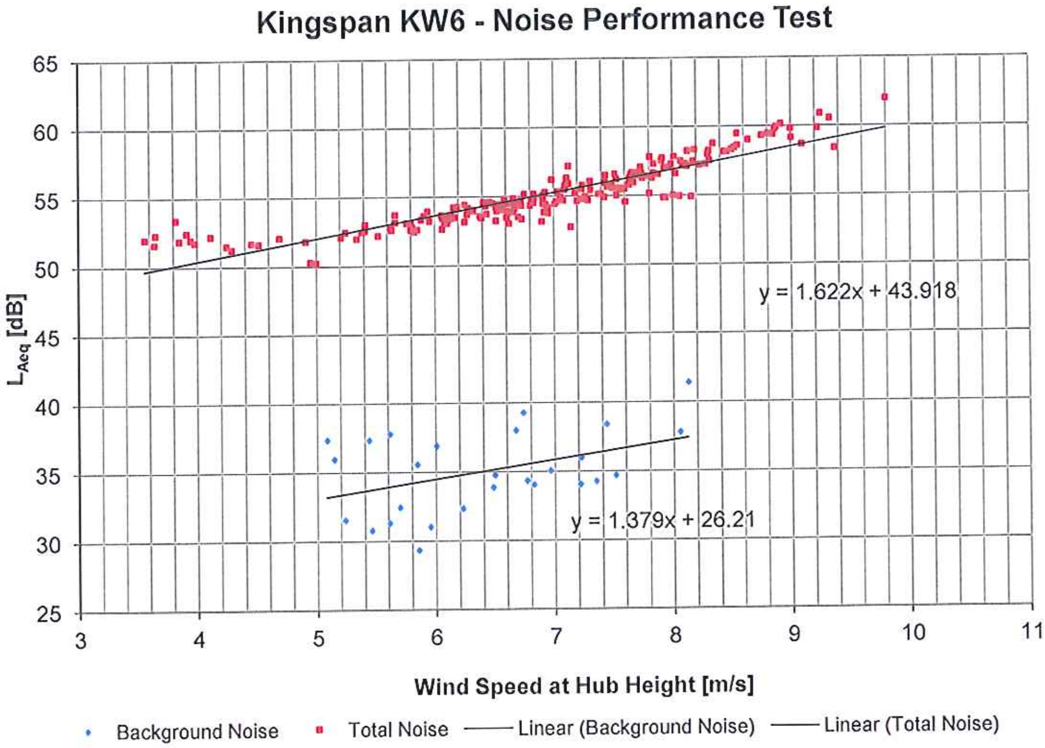
APPENDIX B: WIND CONDITIONS





APPENDIX C: PICTURES OF MEASUREMENT SETUP

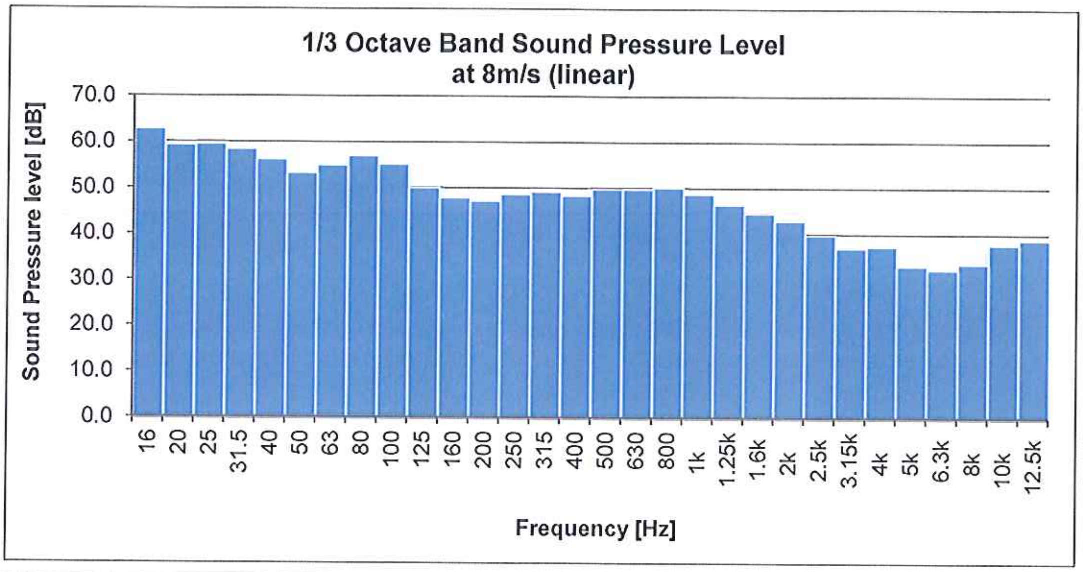
APPENDIX D: NOISE OVER WIND SPEED

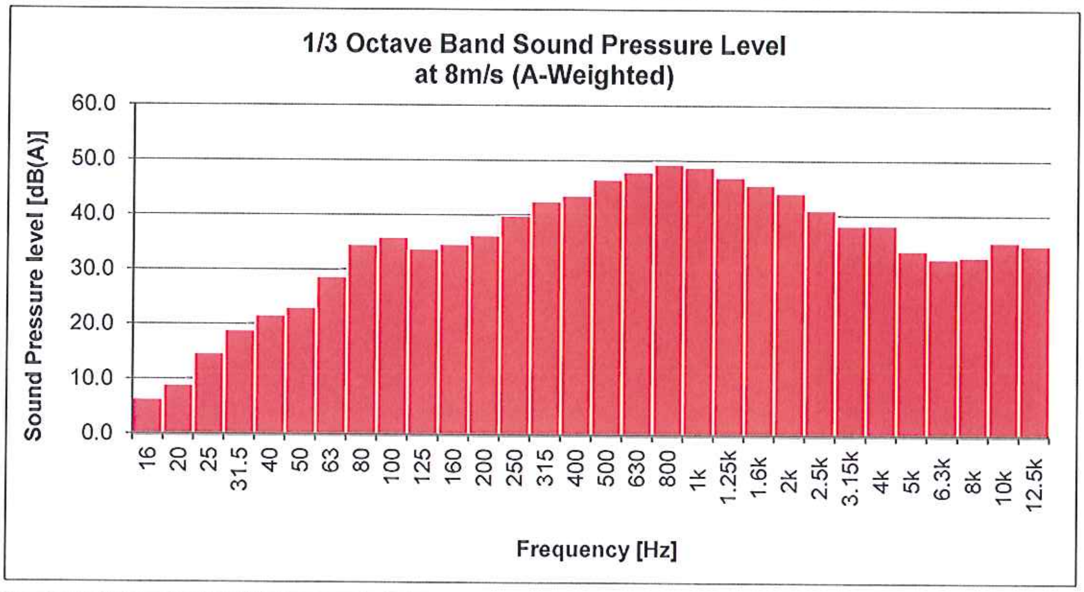


APPENDIX E: 1/3 OCTAVE BAND DATA

Table E1: 1/3 Octave Band Levels at 8m/s

Frequency [Hz]	$L_{W,\ 1/3\ Octave}$ [dB(lin)]	$L_{W,\ 1/3\ Octave}$ [dB(A)]	$L_{W,\ 1/3\ Octave}$ [dB(C)]
16	62.7	6.2	54.2
20	59.2	8.8	52.9
25	59.4	14.6	55.0
31.5	58.3	18.8	55.2
40	56.0	21.5	54.0
50	53.2	22.9	51.9
63	54.8	28.6	54.0
80	56.8	34.4	56.3
100	55.0	35.8	54.7
125	49.9	33.7	49.8
160	47.8	34.5	47.7
200	47.1	36.2	47.0
250	48.5	39.8	48.5
315	49.1	42.4	49.1
400	48.3	43.5	48.3
500	49.7	46.4	49.7
630	49.8	47.9	49.8
800	50.1	49.3	50.1
1k	48.7	48.7	48.7
1.25k	46.3	46.9	46.3
1.6k	44.5	45.5	44.4
2k	42.9	44.1	42.7
2.5k	39.7	41.0	39.4
3.15k	37.0	38.2	36.5
4k	37.3	38.3	36.5
5k	33.1	33.6	31.8
6.3k	32.3	32.2	30.3
8k	33.6	32.4	30.5
10k	37.7	35.2	33.3
12.5k	38.8	34.6	32.7


1/3 Octave Band Sound Pressure Level
at 8m/s (linear)
Sound Pressure level [dB]
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
16 20 25 31.5 40 50 63 80 100 125 160 200 250 315 400 500 630 800 1k 1.25k 1.6k 2k 2.5k 3.15k 4k 5k 6.3k 8k 10k 12.5k
Frequency [Hz]


1/3 Octave Band Sound Pressure Level
at 8m/s (A-Weighted)
Sound Pressure level [dB(A)]
60.0
50.0
40.0
30.0
20.0
10.0
0.0
16 20 25 31.5 40 50 63 80 100 125 160 200 250 315 400 500 630 800 1k 1.25k 1.6k 2k 2.5k 3.15k 4k 5k 6.3k 8k 10k 12.5k
Frequency [Hz]

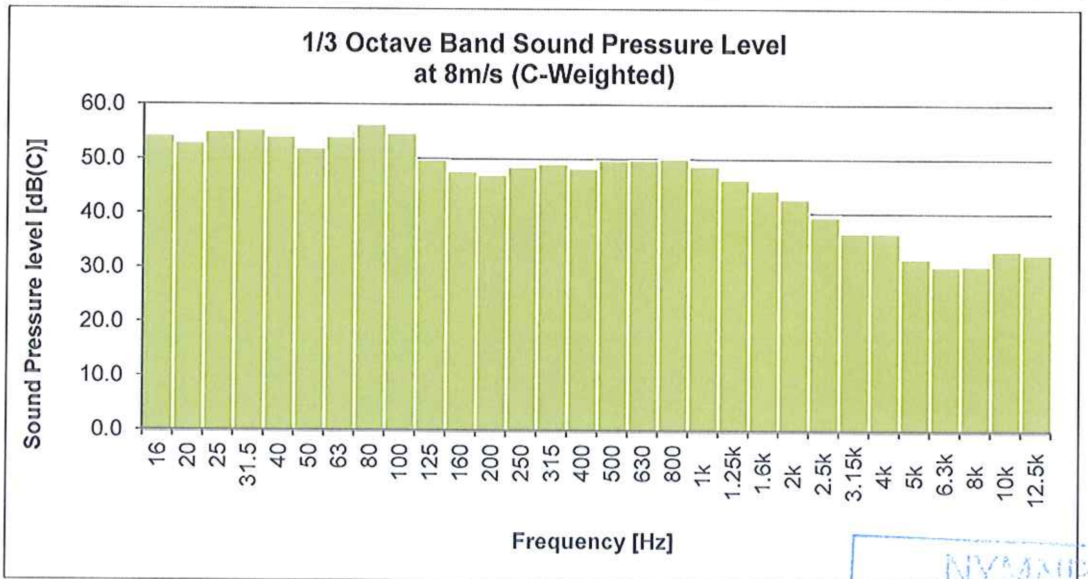
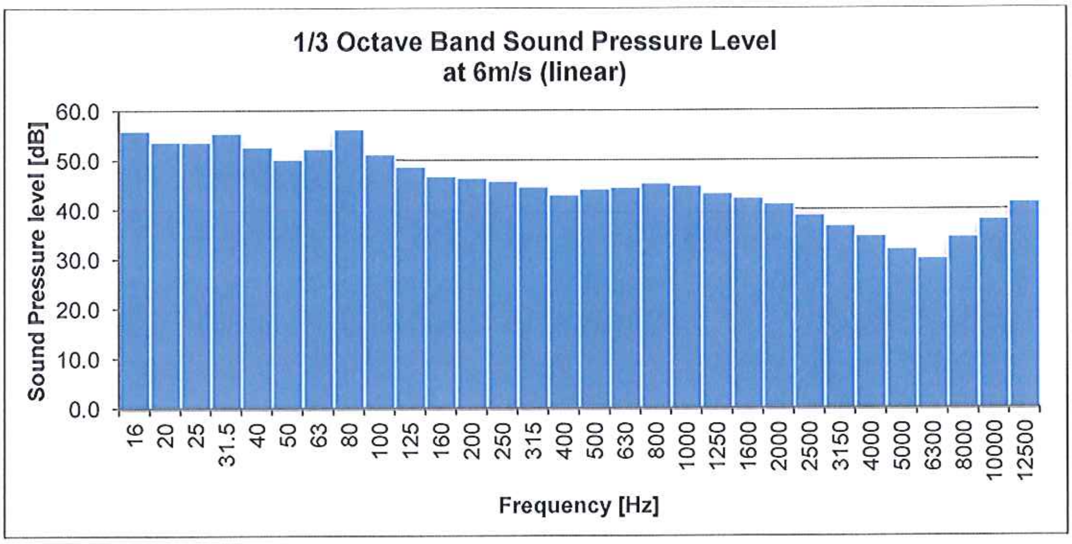
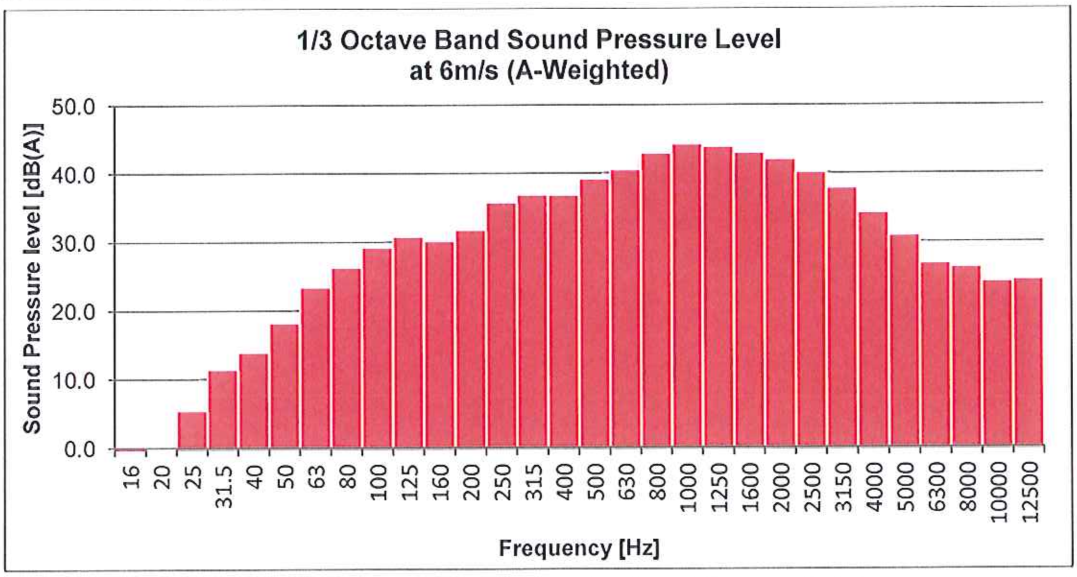

1/3 Octave Band Sound Pressure Level
at 8m/s (C-Weighted)
Sound Pressure level [dB(C)]
60.0
50.0
40.0
30.0
20.0
10.0
0.0
16 20 25 31.5 40 50 63 80 100 125 160 200 250 315 400 500 630 800 1k 1.25k 1.6k 2k 2.5k 3.15k 4k 5k 6.3k 8k 10k 12.5k
Frequency [Hz]

Table E2: 1/3 Octave Band Levels at 6m/s			
Frequency [Hz]	$L_{W,\ 1/3\ Octave}$ [dB(lin)]	$L_{W,\ 1/3\ Octave}$ [dB(A)]	$L_{W,\ 1/3\ Octave}$ [dB(C)]
16	56.0	-0.4	47.6
20	53.7	3.3	47.5
25	53.7	8.9	49.2
31.5	55.5	16.0	52.5
40	52.7	18.2	50.7
50	50.1	19.9	48.8
63	52.4	26.1	51.5
80	56.2	33.8	55.7
100	51.2	32.0	50.9
125	48.7	32.5	48.5
160	46.7	33.5	46.6
200	46.4	35.6	46.4
250	45.7	37.1	45.7
315	44.6	38.0	44.6
400	43.0	38.2	43.0
500	44.2	40.9	44.2
630	44.5	42.6	44.5
800	45.3	44.5	45.3
1000	44.9	44.9	44.9
1250	43.4	43.9	43.3
1600	42.4	43.4	42.3
2000	41.2	42.4	41.0
2500	38.9	40.2	38.6
3150	36.8	38.0	36.3
4000	34.7	35.7	33.9
5000	32.0	32.6	30.7
6300	30.2	30.1	28.2
8000	34.5	33.4	31.5
10000	38.0	35.5	33.6
12500	41.5	37.3	35.3


1/3 Octave Band Sound Pressure Level
at 6m/s (linear)
Sound Pressure level [dB]
0.0
10.0
20.0
30.0
40.0
50.0
60.0
16 20 25 31.5 40 50 63 80 100 125 160 200 250 315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000 6300 8000 10000 12500
Frequency [Hz]


1/3 Octave Band Sound Pressure Level
at 6m/s (A-Weighted)
Sound Pressure level [dB(A)]
0.0
10.0
20.0
30.0
40.0
50.0
16 20 25 31.5 40 50 63 80 100 125 160 200 250 315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000 6300 8000 10000 12500
Frequency [Hz]

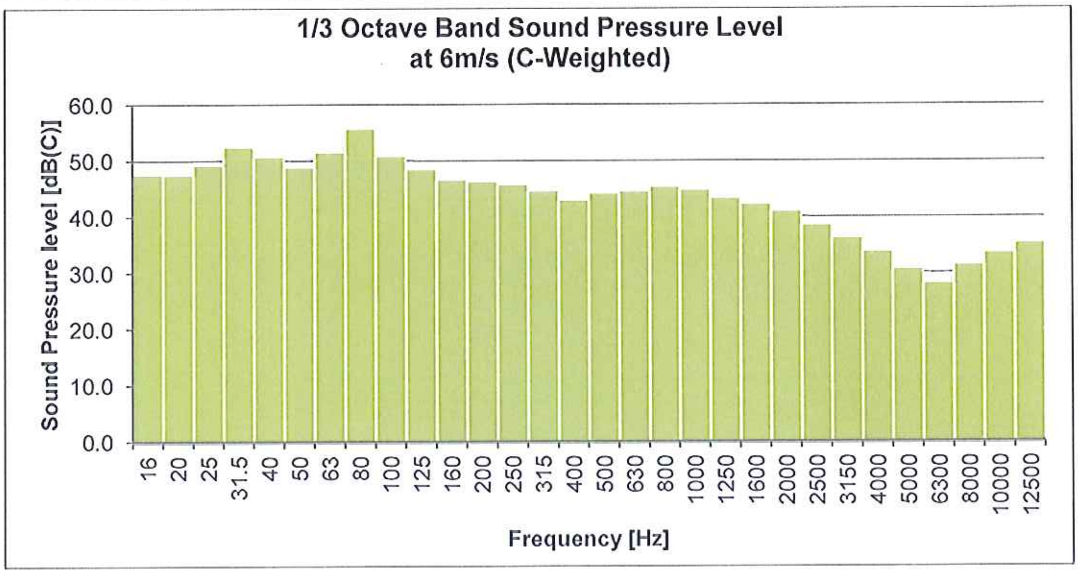
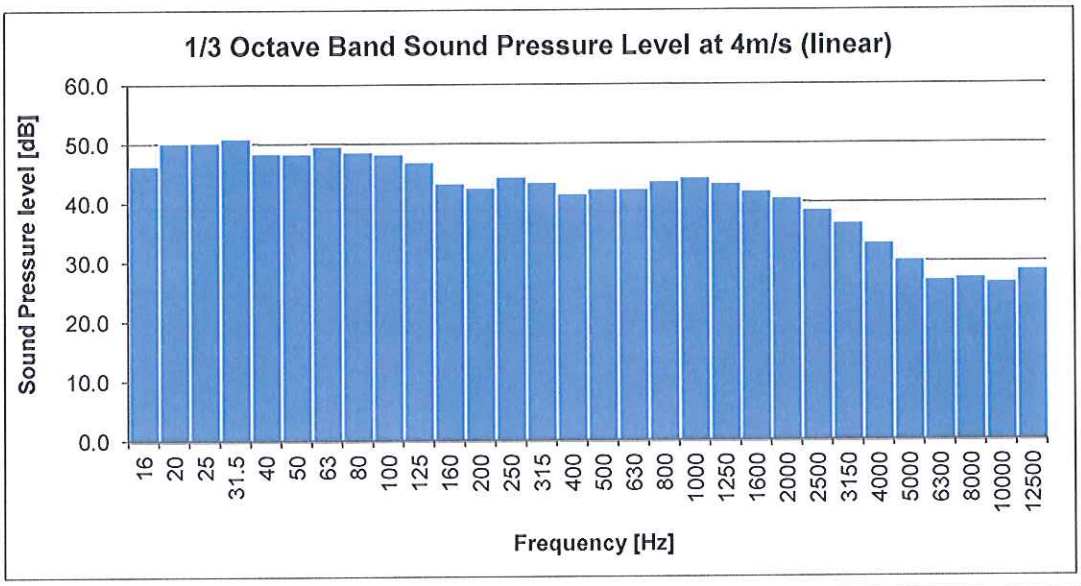
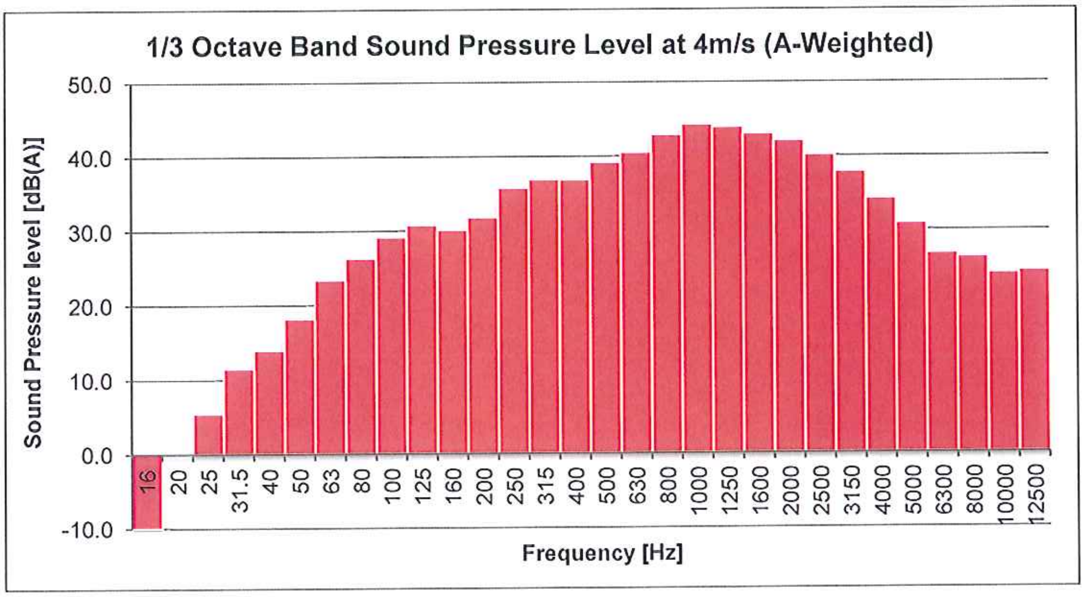

1/3 Octave Band Sound Pressure Level
at 6m/s (C-Weighted)
Sound Pressure level [dB(C)]
0.0
10.0
20.0
30.0
40.0
50.0
60.0
16 20 25 31.5 40 50 63 80 100 125 160 200 250 315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000 6300 8000 10000 12500
Frequency [Hz]

Table E3: 1/3 Octave Band Levels at 4m/s

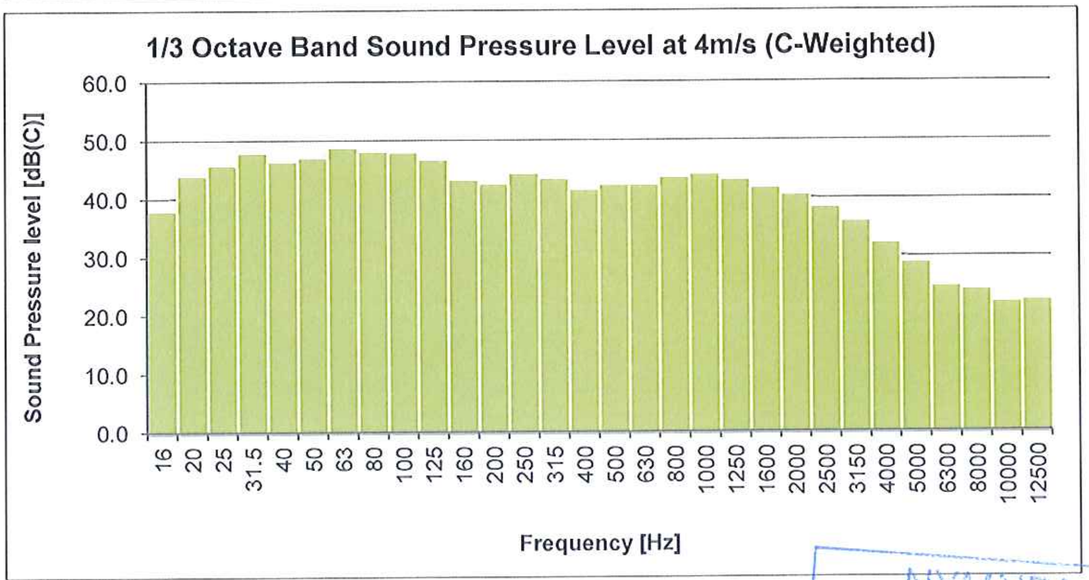
Frequency [Hz]	$L_{W,\ 1/3\ Octave}$ [dB(lin)]	$L_{W,\ 1/3\ Octave}$ [dB(A)]	$L_{W,\ 1/3\ Octave}$ [dB(C)]
16	46.4	-10.0	38.0
20	50.2	-0.2	44.0
25	50.2	5.4	45.8
31.5	50.9	11.4	47.9
40	48.4	13.9	46.4
50	48.4	18.1	47.1
63	49.6	23.4	48.8
80	48.6	26.2	48.1
100	48.3	29.1	48.0
125	46.9	30.7	46.7
160	43.3	30.0	43.2
200	42.5	31.7	42.5
250	44.3	35.7	44.3
315	43.4	36.8	43.5
400	41.5	36.7	41.5
500	42.3	39.1	42.4
630	42.3	40.4	42.3
800	43.6	42.8	43.6
1000	44.2	44.2	44.2
1250	43.2	43.8	43.2
1600	41.9	42.9	41.8
2000	40.8	42.0	40.6
2500	38.8	40.1	38.5
3150	36.5	37.7	36.0
4000	33.2	34.1	32.4
5000	30.3	30.8	29.0
6300	26.9	26.8	24.9
8000	27.4	26.2	24.3
10000	26.6	24.1	22.2
12500	28.7	24.4	22.5



1/3 Octave Band Sound Pressure Level at 4m/s (linear)

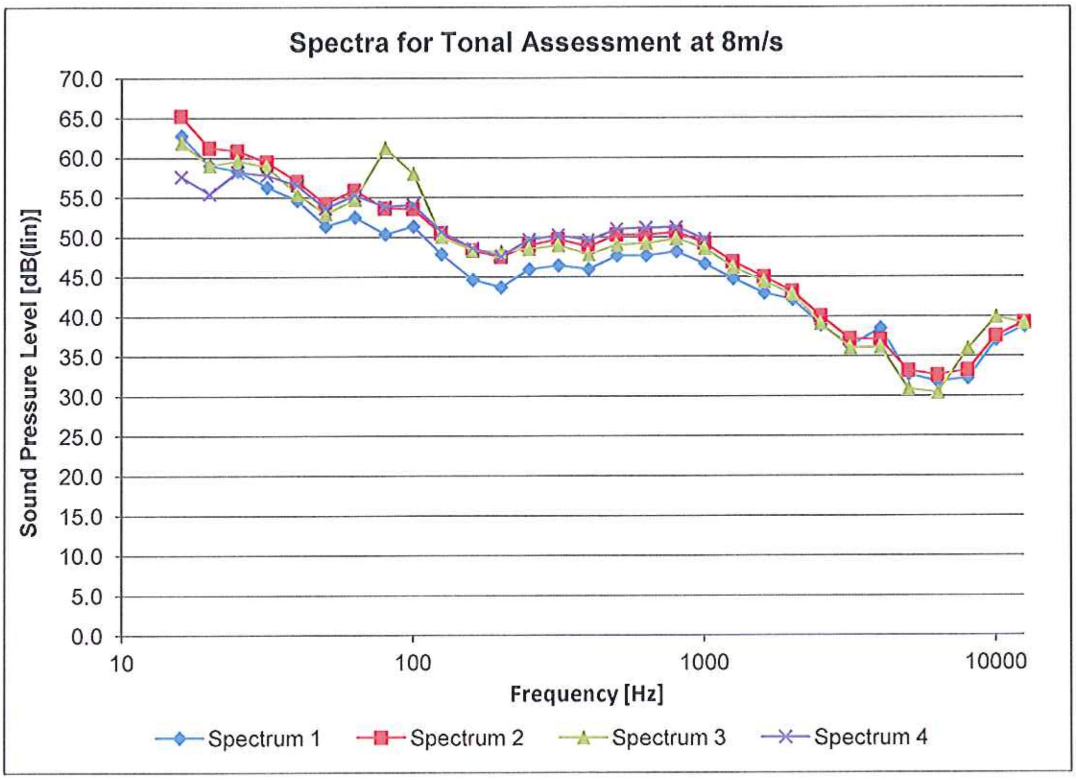


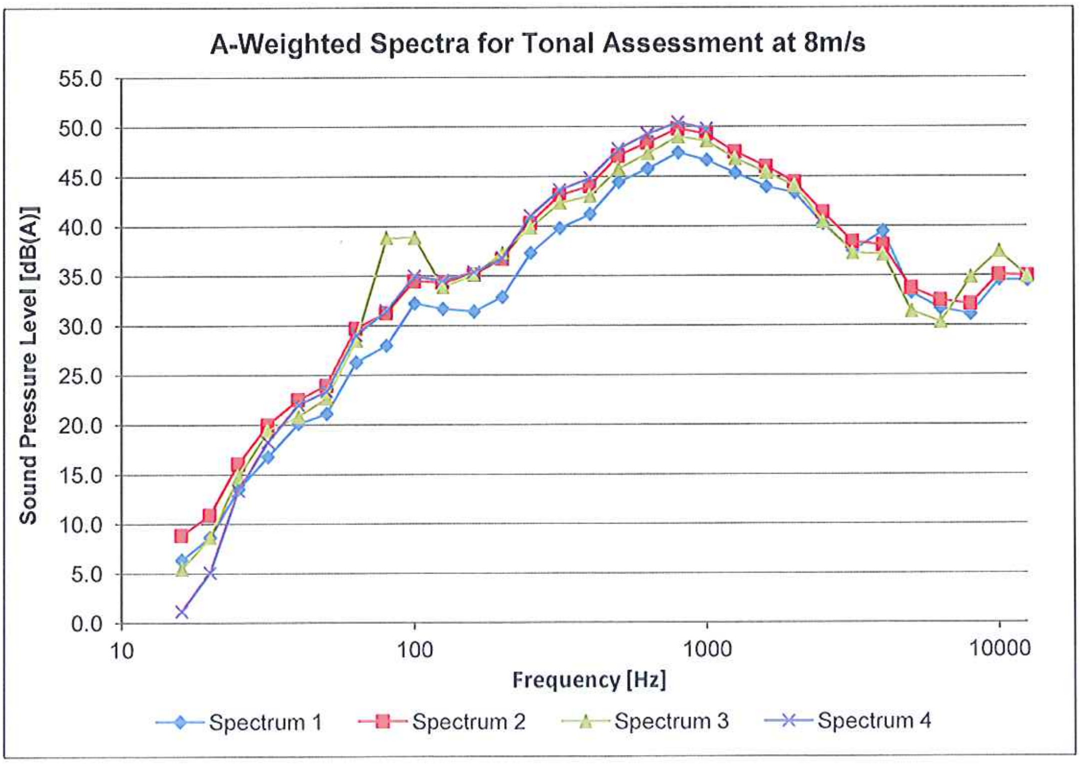
1/3 Octave Band Sound Pressure Level at 4m/s (A-Weighted)

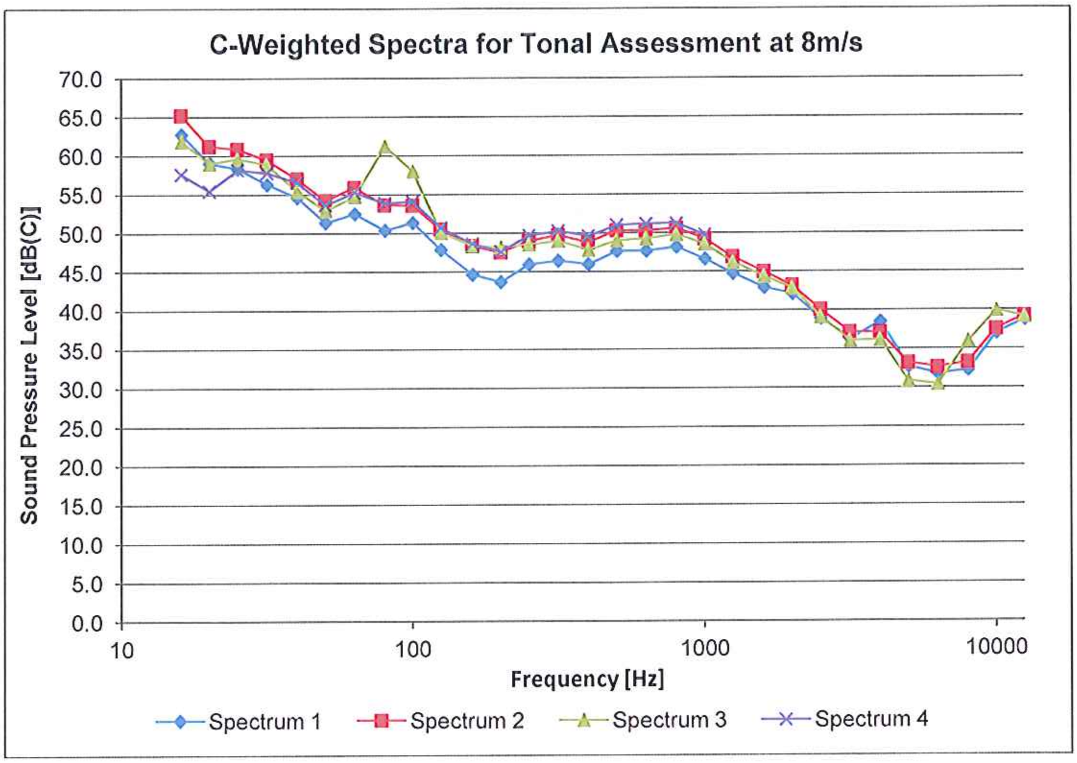


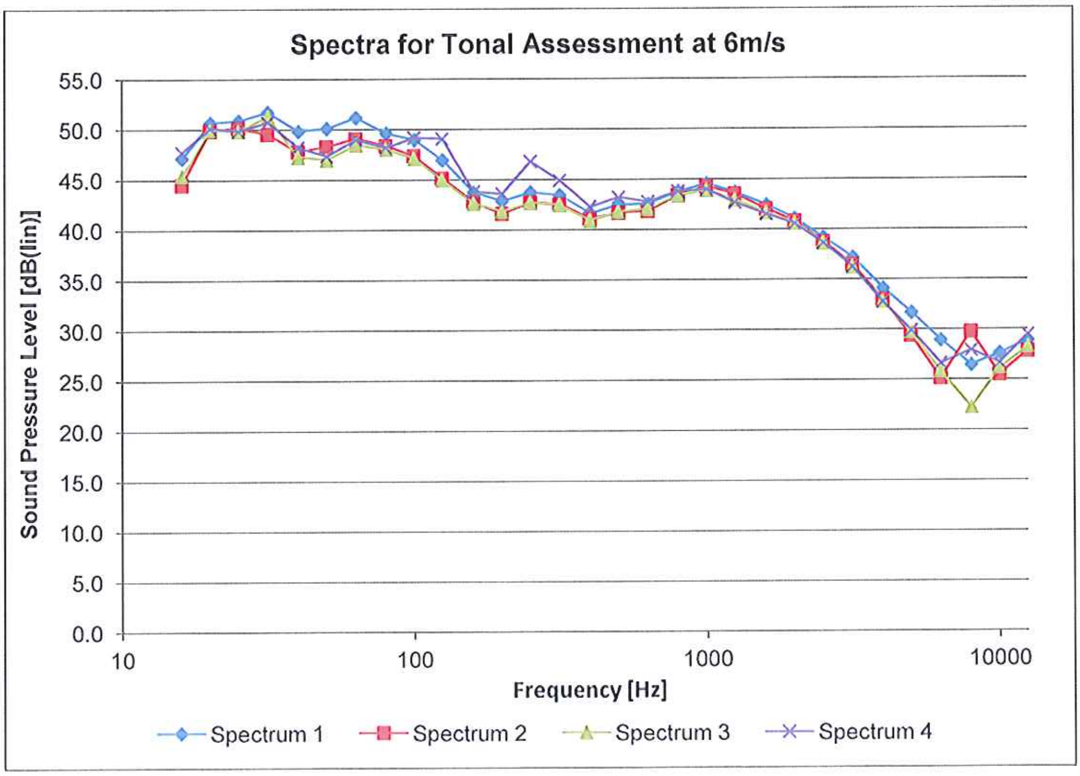
1/3 Octave Band Sound Pressure Level at 4m/s (C-Weighted)

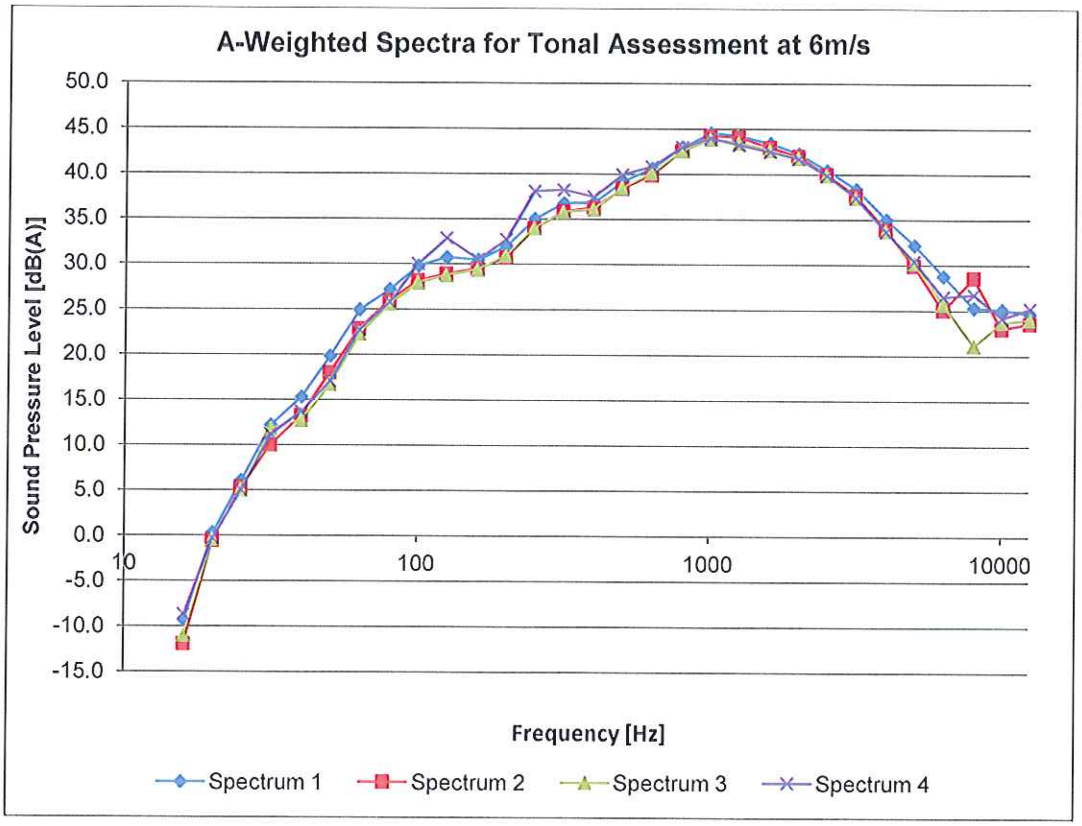
APPENDIX F: SPECTRA FOR TONALITY ASSESSMENT

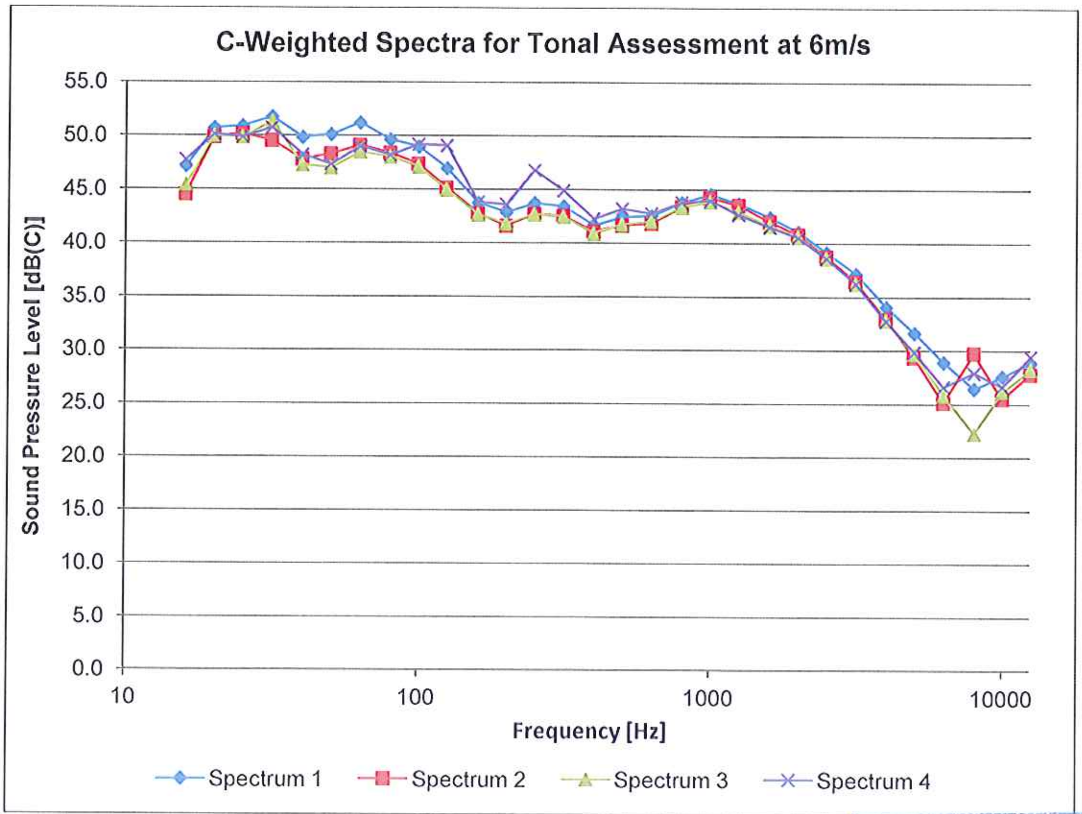


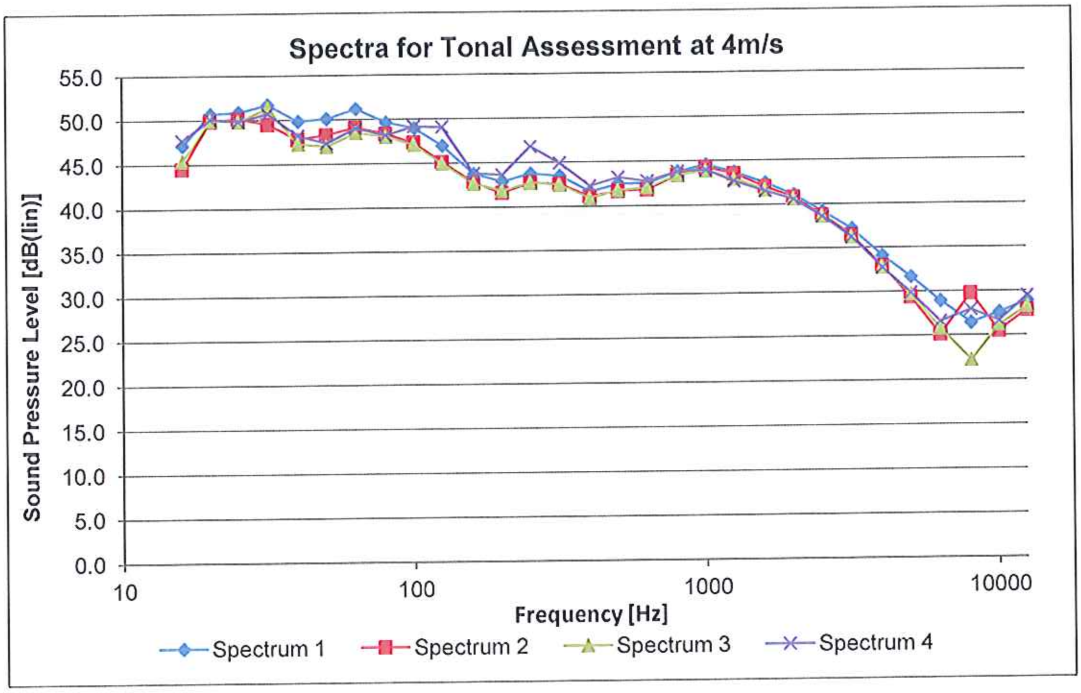


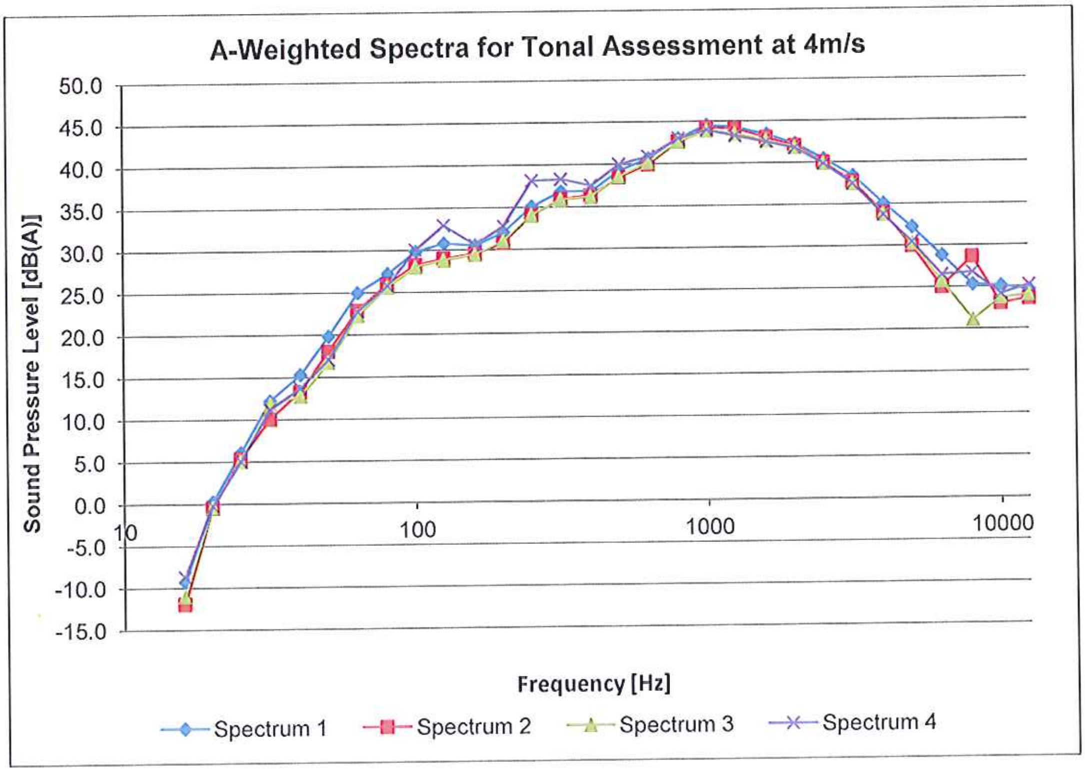

C-Weighted Spectra for Tonal Assessment at 8m/s
Sound Pressure Level [dB(C)]
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
10
100
1000
10000
Frequency [Hz]
Spectrum 1
Spectrum 2
Spectrum 3
Spectrum 4

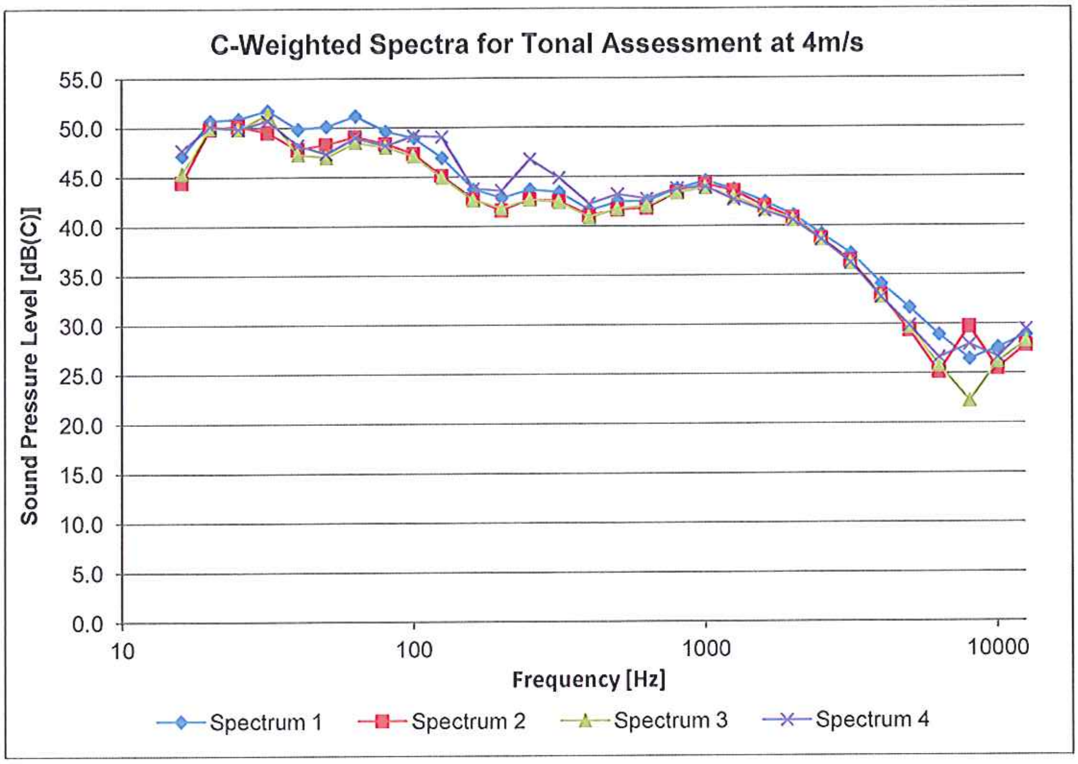

Spectra for Tonal Assessment at 6m/s
Sound Pressure Level [dB(lin)]
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
10
100
1000
10000
Frequency [Hz]
Spectrum 1
Spectrum 2
Spectrum 3
Spectrum 4


A-Weighted Spectra for Tonal Assessment at 6m/s
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
Sound Pressure Level [dB(A)]
10
100
1000
10000
Frequency [Hz]
Spectrum 1
Spectrum 2
Spectrum 3
Spectrum 4


C-Weighted Spectra for Tonal Assessment at 6m/s
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Sound Pressure Level [dB(C)]
10
100
1000
10000
Frequency [Hz]
Spectrum 1
Spectrum 2
Spectrum 3
Spectrum 4


Spectra for Tonal Assessment at 4m/s
Sound Pressure Level [dB(lin)]
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
10
100
1000
10000
Frequency [Hz]
Spectrum 1
Spectrum 2
Spectrum 3
Spectrum 4


A-Weighted Spectra for Tonal Assessment at 4m/s
Sound Pressure Level [dB(A)]
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
10
100
1000
10000
Frequency [Hz]
Spectrum 1
Spectrum 2
Spectrum 3
Spectrum 4


C-Weighted Spectra for Tonal Assessment at 4m/s
Sound Pressure Level [dB(C)]
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
10
100
1000
10000
Frequency [Hz]
Spectrum 1
Spectrum 2
Spectrum 3
Spectrum 4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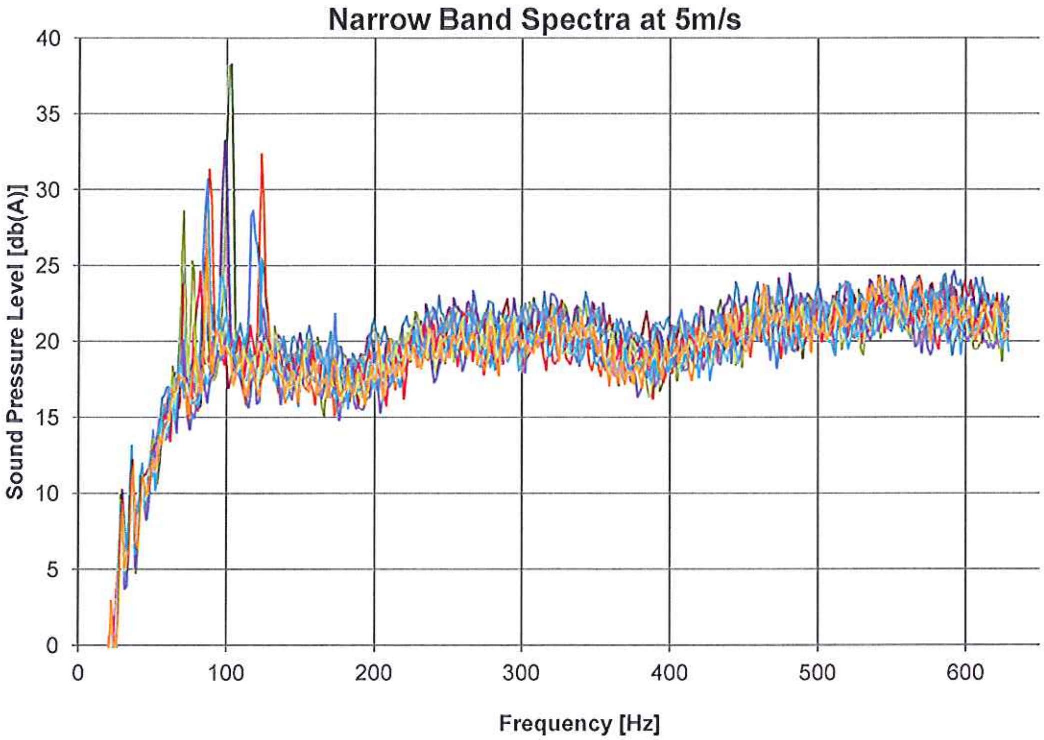
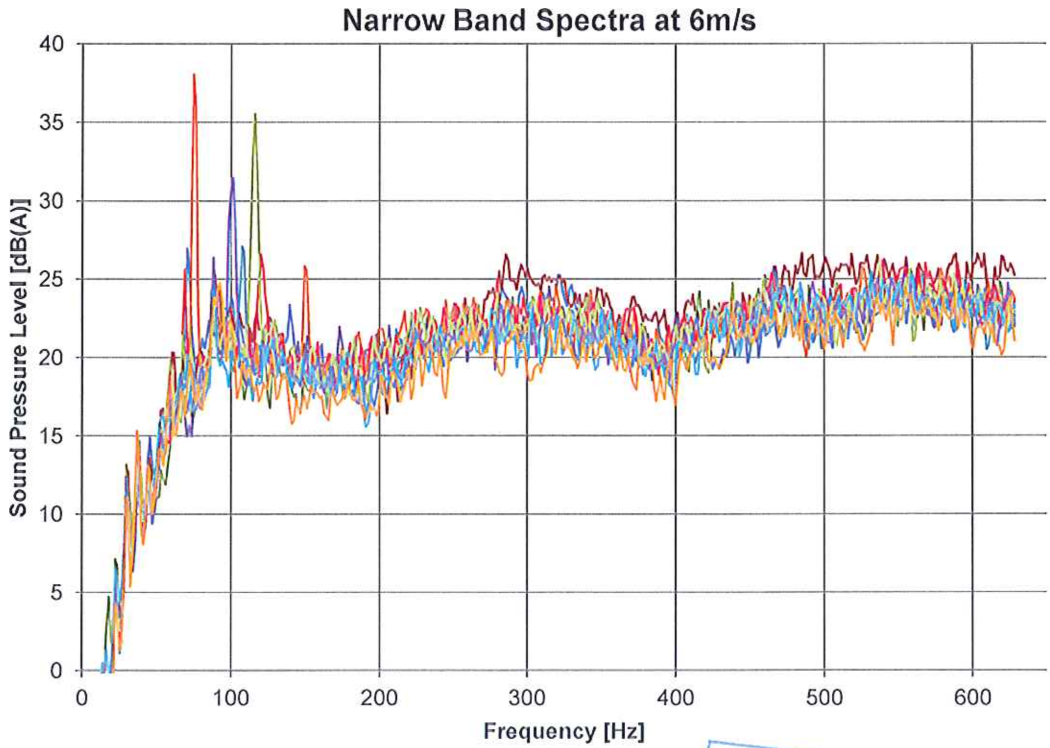
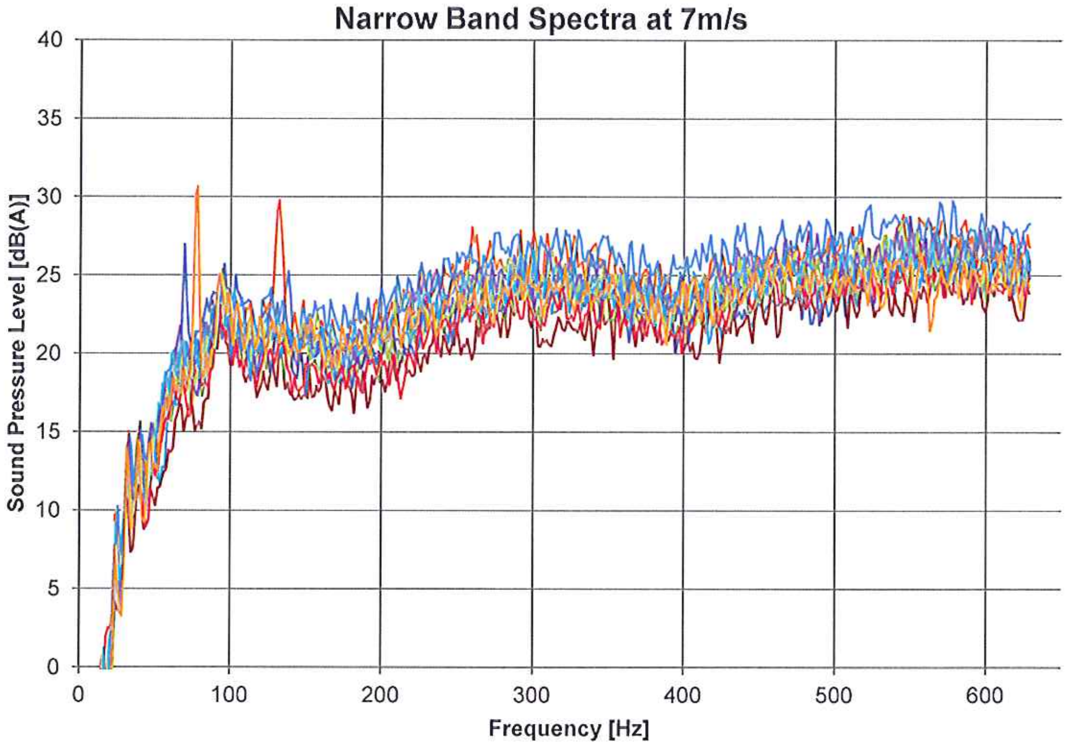
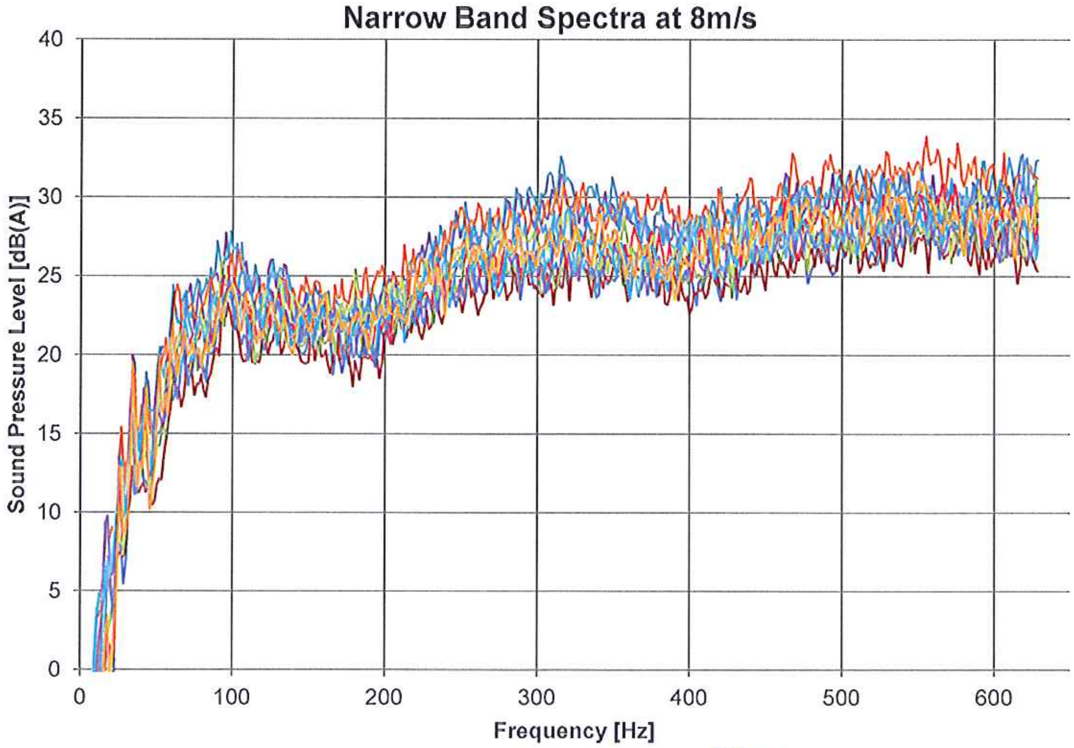
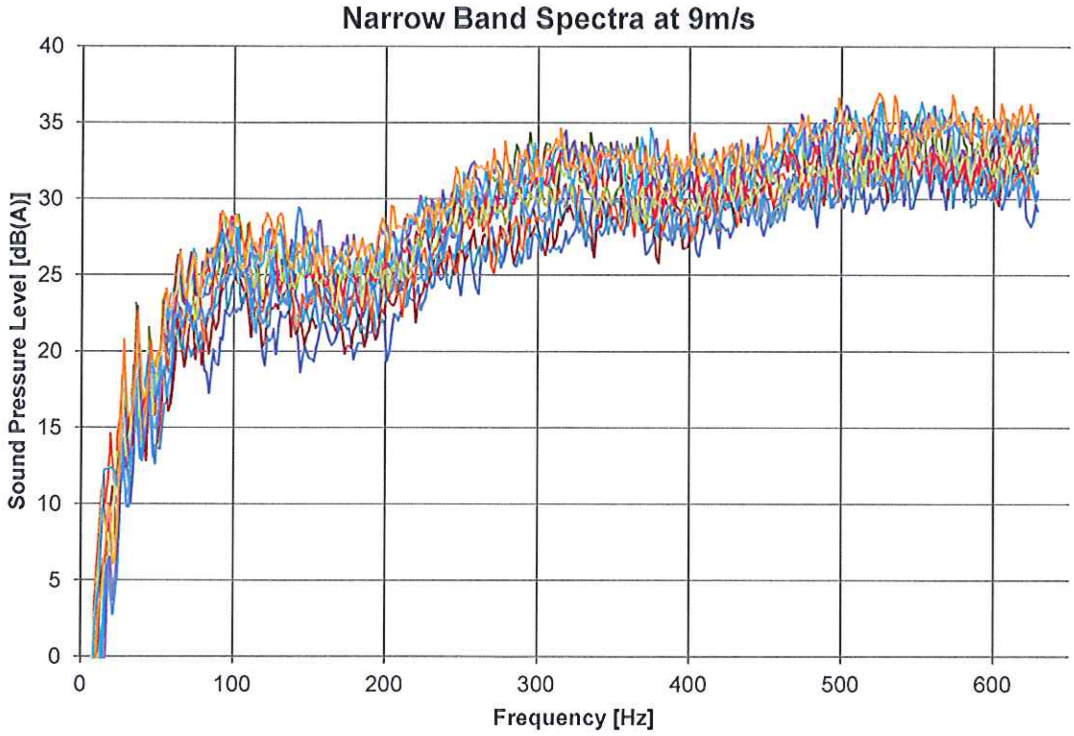
APPENDIX G: NARROW BAND DATA






Narrow Band Spectra at 7m/s
Sound Pressure Level [dB(A)]
Frequency [Hz]
0
5
10
15
20
25
30
35
40
0
100
200
300
400
500
600


Narrow Band Spectra at 8m/s
Sound Pressure Level [dB(A)]
Frequency [Hz]
0
5
10
15
20
25
30
35
40
0
100
200
300
400
500
600


Narrow Band Spectra at 9m/s
Sound Pressure Level [dB(A)]
Frequency [Hz]
0
5
10
15
20
25
30
35
40
100
200
300
400
500
600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APPENDIX H: NOISE LABEL

Acoustic Noise Levels				
Turbine Make:	Kingspan Renewables Ltd		**Model:**	KW6
Noise Emission Level				**Noise Penalty**
Sound Power $L_{Wd, 8m/s}$	88.3 dB(A)	Noise Slope S_{dB} [dB/ms^{-1}]	1.62	NO