Wind Turbine Noise Performance Test

Westwind 20kW

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Westwind 20kW Wind Turbine Noise Performance Test

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Site: Bornish, South Uist, Outer Hebrides, UK

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1. Introduction

1.1 A turbine noise performance test has been carried out on a Westwind 20 kW wind turbine at Bornish, South Uist, Outer Hebrides United Kingdom.

1.2 The turbine has a hub height of 15 m and a rotor with a diameter of 10.4 m. It has a rated power of 20 kW, which is achieved at a wind speed of 13m/s at hub height.

1.3 The purpose of this test was to assess the noise performance characteristics of the wind turbine over the range of normal operational wind speeds. The test consisted of measurements of the sound pressure level and tonal characteristics, from which the apparent sound power level of the turbine was determined.

1.4 This noise test was conducted in accordance with the BWEA Small Wind Turbine Performance and Safety Standard (February 2008) which is based on BS EN 61400-11 (2003) with modifications to take account of the specific characteristics of small wind turbines.

1.5 The test took place over a period of 5 days under wind speed conditions varying from 5 m/s to 12 m/s., at hub height, between 1 and 5 September 2011.

2. Turbine Specification

2.1 The wind turbine is a three-bladed, autofurl, upwind turbine. A summary of the turbine's specification, as supplied by the manufacturer, is shown in Table 1 below.

Parameter	Value/Feature
Manufacturer	Westwind Wind Turbines Ltd.
Model Number	Westwind 20 kW
Serial No.	030211PMDK260V
Hub Height	15 m
Rotor Diameter	10.4 m
Rated Power	20 kW (Peak power at 13-14 m/s)
Tower Type	self-supporting monopole
Number of Blades	3
Cut-in Wind Speed	3 m/s
Cut-out Wind Speed	-

Table 1: Turbine Specifications

2. Measurement

Site Layout and Measurement Position

2.1 The site layout is shown in Appendix A and is in an isolated position some 800 from the A865 road running from north to south of South Uist and 1.7 km from the western coast. The land consists of open, generally flat heather/grass land and larger areas of water. There are no hedges or trees in the vicinity of the site. The closest structure is a 2 storey dwelling situated 70 m to the north of the turbine location. There are no other turbines within 150 m of the test turbine. The site is normally used for cattle grazing but at the time of the test, no animals were present on the site. The A865 is a very lightly trafficked road and there are no other appreciable sources of noise in the vicinity other than that of birds. Sound from wave motion on the sea can be audible at times at the site, depending on weather conditions and wave action, but during the period of testing, sea conditions were generally calm.

2.2 All acoustic measurements were conducted in accordance with IEC 61400-11:2003. The BWEA have also published a standard that addresses noise assessment of small wind turbines and the acoustic measurement technique specified therein is largely based on the IEC standard. The output data are presented in the format required by the BWEA standard.

2.3 The microphone was located downwind of the turbine mast at ground level on a 1 m diameter plywood board at a distance of 19.8 m horizontally from the mast centre. The measurement position was 1.1 m above the base of the mast. The microphone was placed on a 1 m diameter plywood sheet pointing towards the mast and covered with a 90 mm diameter hemispherical wind shield. All measurements were made within an arc of +/- 60° of the downwind direction, as is allowed by the BWEA Standard to allow for frequent yawing of small turbines.

2.4 Acoustic and wind data as recorded both whilst the turbine was operating and with the turbine switched off, in order to record background noise data. Background measurements were made immediately before or after turbine operation on each occasion. Acoustic measurements were taken as 30 second L_{eq} A-weighted readings. BWEA requires that at least 100 wind/noise data pairs of turbine noise should be collected. The total number of data pairs collected was 168. All measurements were recorded with 1/3 octave band data for the purpose of assessing tonality. Wind velocity was measured at 1 second intervals, using an anemometer on a pole, at the same height as the turbine and 2.5 diameters upwind of the predominant wind direction. Wind measurements were subsequently averaged to 30 second intervals and synchronised with acoustic measurements.

3. Instrumentation

3.1 Noise measurements were carried out using the following :

- Larson Davis Type 824 Class 1 Sound Level Meter (Serial No. 824A1305)
- (UKAS Calibration Date 01/02/2011)
- Cirrus Type CR511E Class 1 Sound Level calibrator (Serial No. 039819)
- (Calibration Date 31/01/2011)
- 3 m microphone cable
- Vector Wind Instrument anemometer, (Serial no. 7964-C687) (Calibration dates 8 March 2010)

3.2 The sound level meter was programmed to log data at 30 second intervals, recording $L_{Aeq,1min}$ and 1/3 octave frequency data for each interval. The sound level meter clock was synchronised with the wind speed data logger before the start of measurements.

3.3 The sound level meter was field calibrated immediately prior to each set of measurements and at the end of a measurement run. The drift in the meter reading was found to be less than 0.1 dB on all occasions.

4. Results

Measured Noise Levels

4.1 $L_{Aeq,30\ sec.}$, measurements of turbine noise were plotted against simultaneous wind speed. Although it may be necessary to filter out extraneous noises during a measurement session, the isolation of the location helped to ensure that only turbine or wind noise was being recorded. It was not found necessary to exclude measurement periods from the overall log of measurements.

4.2 In Figure 1 & 2 below, the acoustic data is presented as a function of hub height wind speed. Data are presented for both the combined turbine & background noise and the background noise cases. A linear regression was undertaken for both the operational and background data to determine the sound pressure level versus wind speed.

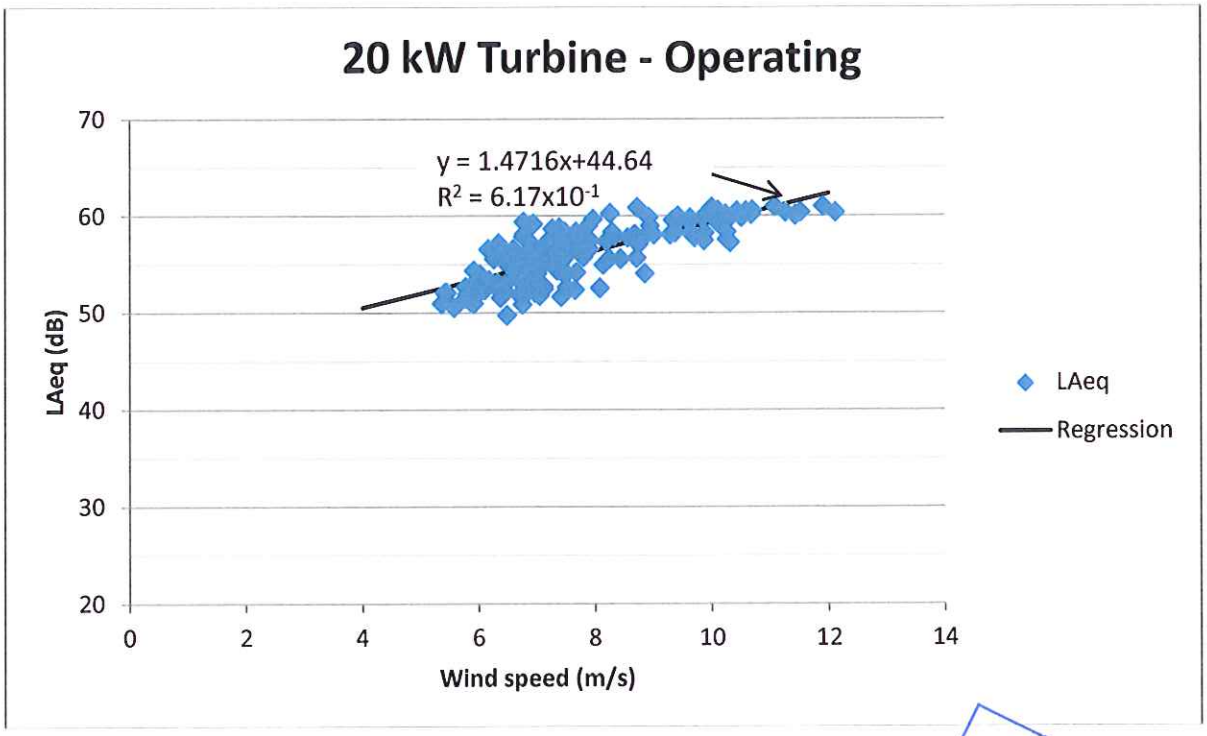


Figure 1: Turbine Operating Noise Analysis

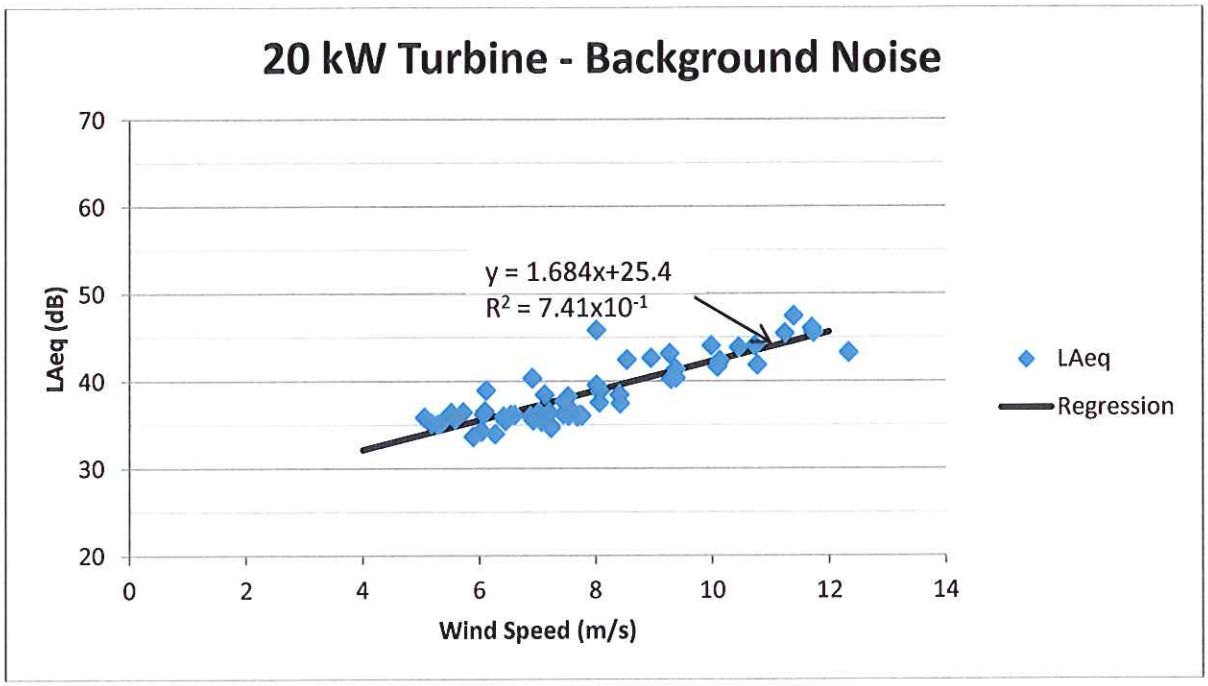


Figure 2: Background Noise Analysis

4.3 In Figure 3, the A-weighted sound pressure level of the wind turbine is adjusted to account for background noise and presented as a function of wind speed.

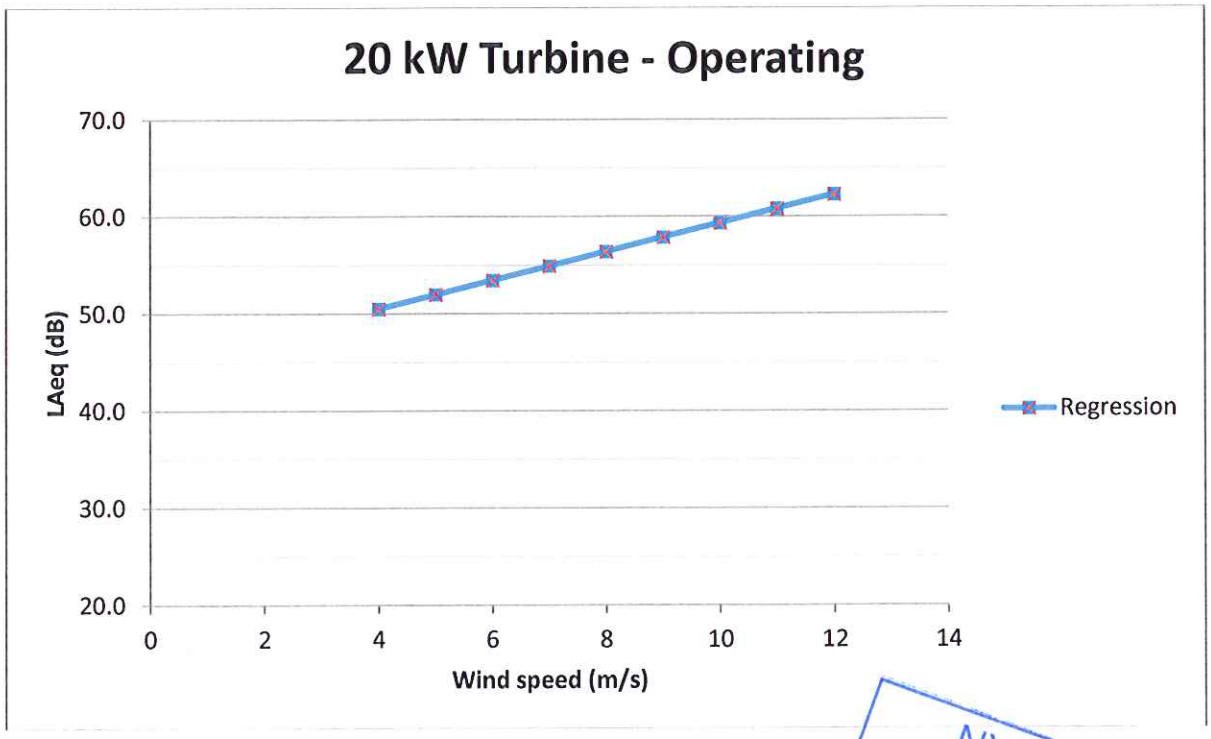


Figure 3: Operational Turbine Noise Slant Analysis

4.5 Calculation of Sound Power Level

4.5.1 The methodology prescribed by BWEA was used to calculate the apparent sound power level of the turbine under test. The Apparent Sound Power Level at wind speed 8 m/s was determined using the prescribed equation from BS EN 61400-11: -

$$L_{WA,k} = L_{Aeq,c,k} - 6 + 10\lg\left[\frac{4\pi R_1^2}{S_0}\right] \quad (9)$$

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 in Figure 4; and

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

4.5.2 The apparent sound power levels at other integer wind speeds between 4 m/s and 12 m/s was then calculated using the **Wind Speed Dependence, S_{dB}**, being the slope of the linear regression line of sound pressure level versus hub height wind speed. The apparent sound power levels over that range of wind speeds is shown in Figure 4 and Table 2 below. Regression analysis showed the Wind Speed Dependance, S_{dB} to be 1.47 dB/ ms^{-1}.

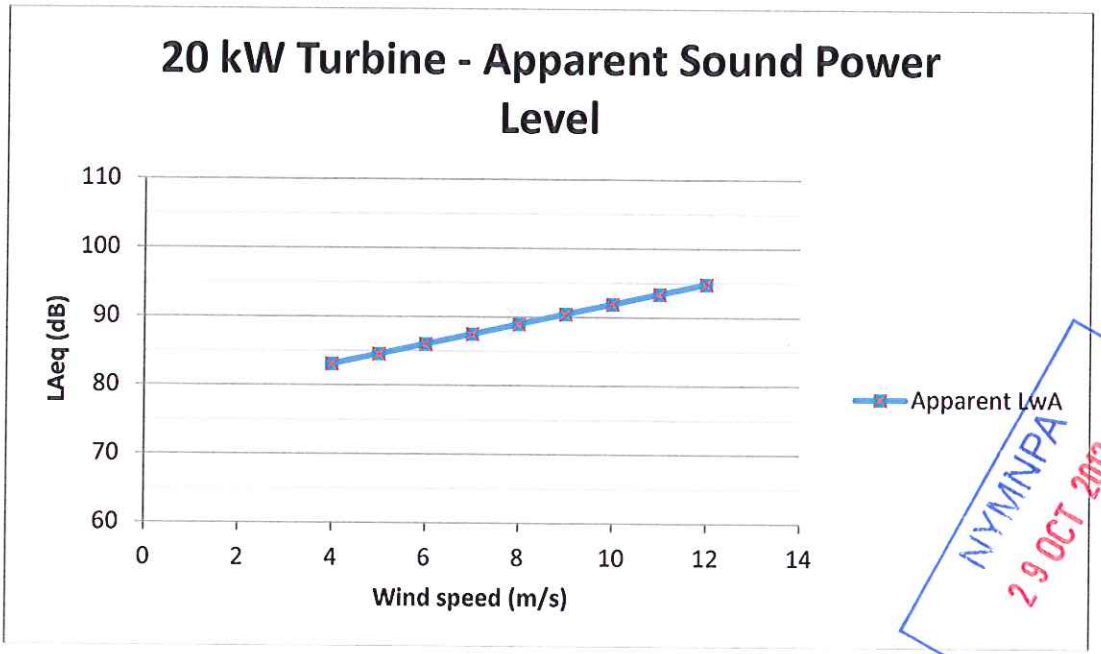


Figure 4: Apparent Sound Power Level versus Wind Speed

Wind speed (m/s)	4	5	6	7	8	9	10	11	12
Apparent Sound Power Level (dB(A))	83.1	84.6	86.1	87.5	89	90.5	91.9	93.4	94.9

Table2: Apparent Sound Power Level

5. Tonality

5.1 Tonality was assessed by the method of ISO 1996-2: 2007 Annex D as allowed by BWEA using 1/3 octave band spectra recorded for wind speeds of 8 m/s. Recorded spectra for wind speeds between 8.0 and 8.3 m/s were averaged and the frequency spectrum was found to be as shown in Figure 5 below:

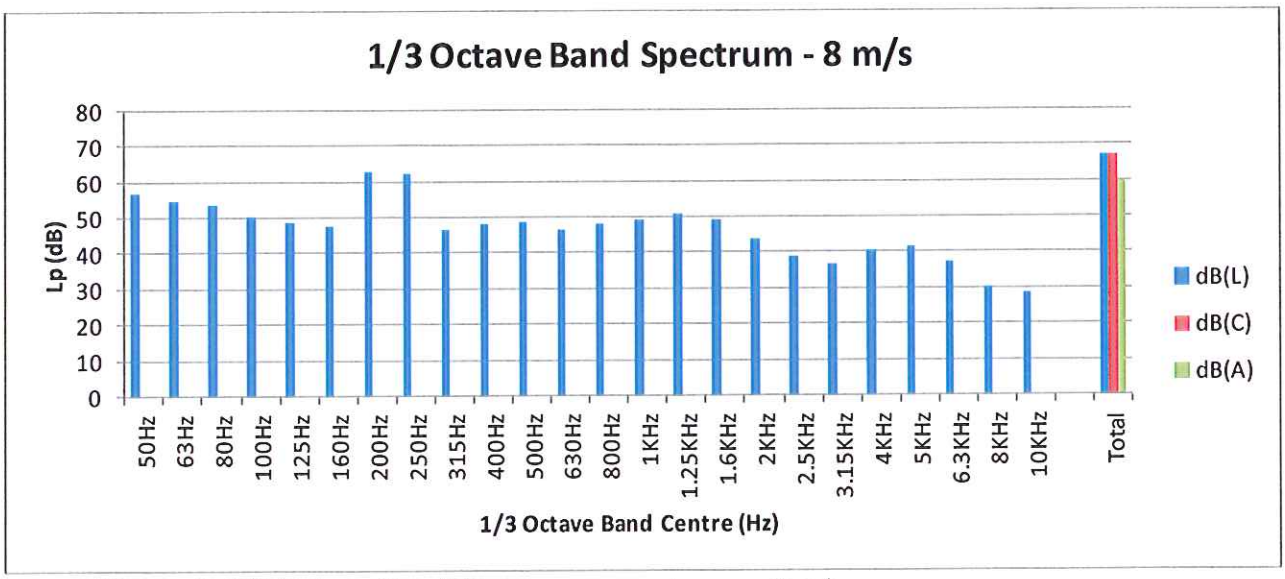


Figure 5: 1/3 Octave Band Frequency spectrum – 8 m/s

Frequency	50	63	80	100	125	160	200	250	315	400	500	630
dB(L)	57	54.6	53.5	50	48.6	47.6	62.7	62.1	46.3	48.1	48.7	46.5
dB(C)	55.7	53.8	53	49.7	48.4	47.5	62.7	62.1	46.3	48.1	48.7	46.5
dB(A)	26.8	28.4	31	30.9	32.5	34.2	51.8	53.5	39.7	43.3	45.5	44.6
Frequency	**800**	**1K**	**1.25K**	**1.6K**	**2K**	**2.5K**	**3.15K**	**4K**	**5K**	**6.3K**	**8K**	**Overall**
dB(L)	47.8	49.2	50.6	49.4	43.6	38.6	36.6	40.5	41.3	37.3	30.2	67.3
dB(C)	47.8	49.2	50.6	49.3	43.4	38.3	36.1	39.7	40	35.3	27.2	67.1
dB(A)	47	49.2	51.2	50.4	44.8	39.9	37.8	41.5	41.8	37.2	29.1	59.7

Table3: 1/3 Octave Band Frequency spectrum – 8 m/s

In addition, the spectra at the lowest and highest measured wind speeds are recorded in Figures 6 and 7 below.

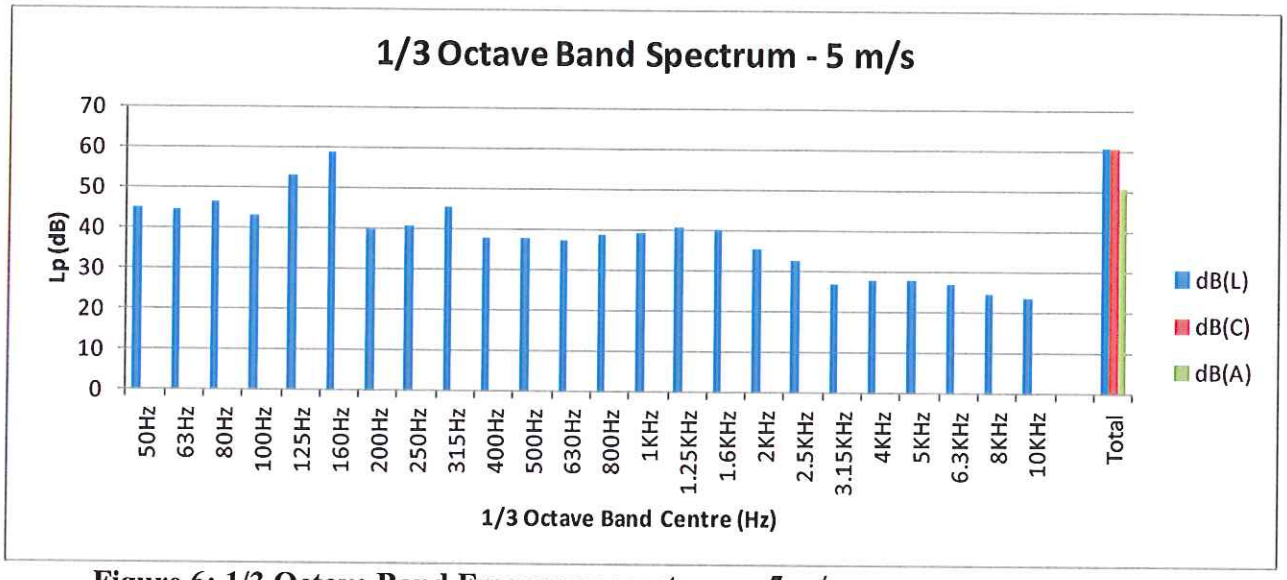


Figure 6: 1/3 Octave Band Frequency spectrum – 5 m/s

Frequency	50	63	80	100	125	160	200	250	315	400	500	630
dB(L)	44.7	44.2	46.4	43.2	52.9	58.8	39.8	40.6	45.6	37.6	37.7	37.4
dB(C)	43.4	43.4	45.9	42.9	52.7	58.7	39.8	40.6	45.6	37.6	37.7	37.4
dB(A)	14.5	18	23.9	24.1	36.8	45.4	28.9	32	39	32.8	34.5	35.5

Frequency	800	1K	1.25K	1.6K	2K	2.5K	3.15K	4K	5K	6.3K	8K	Overall
dB(L)	38.6	39.3	40.8	40.1	35.6	32.4	27	27.7	27.9	27	24.6	60.8
dB(C)	38.6	39.3	40.8	40	35.4	32.1	26.5	26.9	26.6	25	21.6	60.6
dB(A)	37.8	39.3	41.4	41.1	36.8	33.7	28.2	28.7	28.4	26.9	23.5	50.4

Table4: 1/3 Octave Band Frequency spectrum – 5 m/s

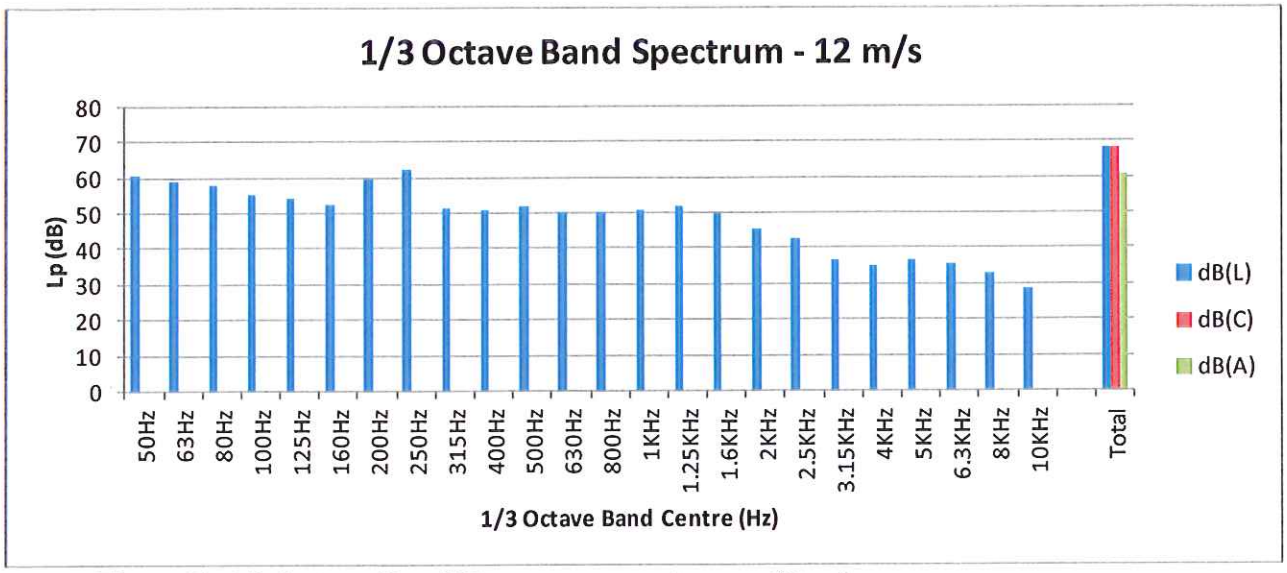


Figure 7: 1/3 Octave Band Frequency spectrum – 12 m/s

Frequency	50	63	80	100	125	160	200	250	315	400	500	630
dB(L)	60.3	58.8	58	55.1	54.2	52.5	59.7	62.2	51.4	50.8	51.8	50.1
dB(C)	59	58	57.5	54.8	54	52.4	59.7	62.2	51.4	50.8	51.8	50.1
dB(A)	30.1	32.6	35.5	36	38.1	39.1	48.8	53.6	44.8	46	48.6	48.2
Frequency	800	1K	1.25K	1.6K	2K	2.5K	3.15K	4K	5K	6.3K	8K	Overall
dB(L)	50.2	51	51.8	49.8	45.5	42.6	36.4	34.9	36.9	35.8	33.1	68.4
dB(C)	50.2	51	51.8	49.7	45.3	42.3	35.9	34.1	35.6	33.8	30.1	68.0
dB(A)	49.4	51	52.4	50.8	46.7	43.9	37.6	35.9	37.4	35.7	32	60.6

Table5: 1/3 Octave Band Frequency spectrum – 5 m/s

5.2 The ISO indicates that the turbine 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).

5.3 It is apparent then that between the range of wind speeds measured (5 – 12 m/s), the spectra would not be considered to be tonal, in that in the appropriate spectrum, the band sound pressure level of any individual band does not exceed the level of its adjacent bands by more than the values noted in 5.2 above.

6. Uncertainty

6.1 Annex D of BS EN 61400-11 specifies a procedure for assessing uncertainties, namely Type A uncertainties (U_A), relating to the statistical analysis of the measurement data set and type B uncertainties (U_B) relating to the measurement equipment and procedures. The total uncertainty (UC) is evaluated from the square root of the sum of the squares of each individual component.

6.2 The standard uncertainty of the apparent sound power is calculated in Table 3 using Equation D.1 in Annex D of the standard. The total uncertainty of the measured L_{WA} calculated from all uncertainties, as given in Table 2, is ± 2.4 dB for the Reference Position.

Calculation of Type A uncertainty	
Standard Error of L_{WA} measurements (U_A)	0.09
Calculation of Type B uncertainty	
Calibration	0.2
Instrument	0.2
Board	0.3
Distance	0.1
Impedance	0.1
Turbulence	0.4
Direction	0.2
Wind speed, measured	0.9
Total U_B uncertainty	2.4
Total U_C uncertainty	2.4

Table 3: Uncertainty Assessment

7. Declared Results

7.1 BWEA indicates that the **Declared Apparent Emission Sound Power Level ($L_{Wd,8m/s}$)** shall be determined, using the equation :-

$$L_{Wd,8m/s} = L_{W,8m/s} + 1.645\sigma$$

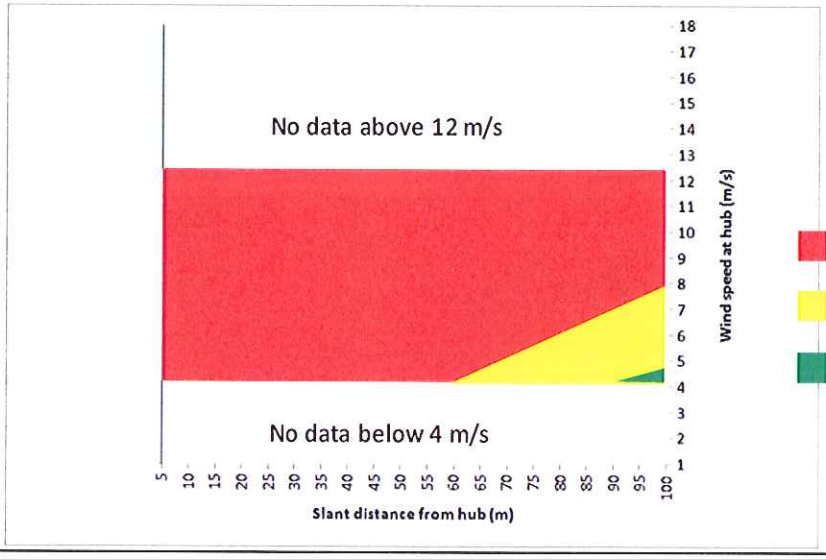
7.2 This equates to a 95% confidence level that the noise will be below this value at the reference wind speed. In this case, σ represents the total uncertainty U_C.

7.3 As required by BWEA, the following data is declared with respect to the tests conducted in relation to the Westwind 20 kW wind turbine.

Apparent Emission Sound Power Level ($L_{W,8m/s}$)	89 dB(A)
Declared Apparent Emission Sound Power Level)$L_{Wd,8m/s}$	93 dB(A)
Measurement uncertainties (U_c)	2.4 dB(A)
Wind Speed Dependence, S_{dB}	1.47 dB/ms^{-1}
Tonal Penalty	0 dB
Immission Sound Pressure Level at 60 m $L_{p,60m}$	49.5 dB(A)
Immission Sound Pressure Level at 60 m $L_{p,25m}$	57 dB(A)

7.4 Noise Label

ACOUSTIC NOISE LEVELS				
Turbine Make	Westwind	**Model**		20kW
NOISE EMISSION LEVEL				**PENALTY**
Sound Power $L_{Wd,8m/s}$ (dB(A))	93	**Noise Slope, S_{dB} (dB/m/s)**	1.47	NO



Immission Noise Map
Including Penalty where applicable

APPENDIX 1

Photographs

Figure A1 - Measurement site

Figure A2 - Noise Measurement Setup

Figure A3 - Turbine/anemometer mast setup