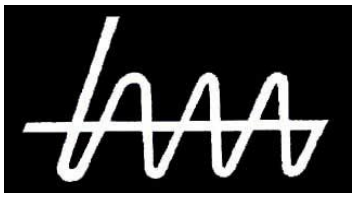
HAYES MCKENZIE

PARTNERSHIP



Prepared for:

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Bergey Excel 10, Grid-tie

Supplementary Information

Report HM: 2477/R1

8th November 2011

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BERGEY EXCEL 10 WIND TURBINE NOISE PERFORMANCE TEST

– Supplementary Information

Report	HM: 2477/R1
Version:	1.0
Date of Issue:	8th November 2011
Site:	near Bushland, Texas, USA
Measurements:	carried out by USDA-Agricultural Research Service Conservation and Production Research Laboratory (CPRL), USA
Report prepared by:	Sylvia Broneske Dipl.-Ing. MIOA Senior Consultant
Approved by:	Andy McKenzie PhD, BSc, FMIOA Principal Consultant and Director

1. INTRODUCTION

1.1 A wind turbine acoustic performance test has been carried out on a Bergey Excel 10, grid-tie wind turbine at a site near Bushland, Texas, USA by a consultant of the USDA-ARS. This has been detailed in the acoustic test report '*Noise Certification Testing of Bergey Windpower Excel Grid-tie Wind Turbine for the American Wind Energy Association (AWEA) Small Wind Certification Council*' dated 13th May 2011.

1.2 Hayes McKenzie Partnership Ltd. (HMPL) have been asked to provide supplementary information required for the UK Microgeneration Certification Scheme (MCS) for micro and small wind turbines.

1.3 A noise test carried out in accordance with the BWEA Small Wind Turbine Performance and Safety Standard (February 2008), which is based on BS EN 61400-11 (2003), allows for the specific operational characteristics of small wind turbines.

1.4 The objective of such a test is to measure the noise performance characteristics of the wind turbine. The test consists of measurements of the sound power level and tonal characteristics.

2. TURBINE SPECIFICATION

2.1 The wind turbine is a three-bladed, passive furling upwind 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	Bergey Windpower Co
Model Number	Excel 10
Type (upwind/downwind)	Upwind
Hub Height	30.5 m
Rotor Diameter	7 m
Rated Power	10 kW for grid intertie
Tower Type	Guyed lattice tower
Turbine Control (stall/pitch)	Passive furling
Rotational Speed	Variable
Number of Blades	3
Cut-in Wind Speed	2.2 m/s
Furling Wind Speed	16-18 m/s

Parameter	Value/Feature
Cut-out Wind Speed	None
Max wind speed (survival)	60 m/s

3. MEASUREMENTS

3.1 The measurements and subsequent assessment of the data were carried out by Brian Vick of the USDA-ARS, USA in accordance with the requirements of the American Wind Energy Association (AWEA). Further measurements have been done in line with the Small Wind Turbine Performance and Safety Standard issued by the former British Wind Energy Association (BWEA), now Renewable UK.

Site Layout and Measurement Position

3.2 The most recent guidance for acoustic performance testing on small wind turbines is the BWEA Small Wind Turbine Performance and Safety Standard dated February 2008 [1]. It states that acoustic noise emissions shall be measured in general accordance with BS EN 61400-11 (2003) [2] with exceptions to allow for the specific operational characteristics of small wind turbines. BS EN 61400-11:2003 including amendment A1:2006 (2006) is the latest version of [2].

3.3 [1] and [2] specify that the microphone used for the noise tests is to be mounted on a 1 m diameter ground-mounted board and facing in the direction of the wind turbine under test. The board is to be placed 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 substantially within the downwind sector (i.e. +/- 60° of the directly downwind direction) to allow for frequent yawing of small wind turbines.

3.4 According to the available measurement report [3], data has been removed from the assessment when the wind direction was more than +/- 15° and +/- 30° respectively on certain days from the downwind microphone position. The other requirements as described in paragraph 3.2 have also been complied with.

3.5 [1] requires an anemometer to measure wind speed to be placed at a distance of 2 to 4 D directly upwind of the turbine rotor, where D is the rotor diameter of the wind turbine (here D = 7 m). Wind speed values are valid as long as the anemometer position is within the upwind sector (i.e. +/- 90° of the directly upwind direction).

3.6 Synchronised wind speed and wind direction measurements were made using a mobile 10 m high mast and a permanent 30 m high mast.

3.7 Table 2 describes the measurement position. $R_{0,meas}$ is the reference distance from the microphone to the tower centre line as applied on the measurement day and R_1 is the slant distance from the measurement position to the centre of the hub where it meets the nacelle.

Table 2: Distances and Reference Values

Parameter		**Value**
Hub Height	H	30.5 m
Rotor Diameter	D	7 m
Reference Distance, calculated	$R_{0,calc}$	34 m
Reference Distance, measurement	$R_{0,meas}$	34 m
Slant Distance	R_1	45.2 m
Reference Roughness Length	z_{0ref}	0.05 m
Anemometer Height	z	10 / 30.5 m
Reference Height	h_{ref}	30.5 m (hub height)

3.8 In addition to the measurements described in [3], further acoustic performance testing took place in August 2011 (background noise) and July/August/October 2011 (combined wind turbine and background noise) for the assessment in accordance with [1].

4. RESULTS

Calculation of Sound Power Level

4.1 The methodology prescribed by [2] was used to calculate the apparent sound power level of the turbine under test with the exception of using a linear regression instead of 4th order as required by [1]. The collection, assessment of the data and calculations were carried out by USDA-ARS and are described in [3] and in the *'Standard Operating Procedure for Noise Data Collection at USDA-ARS-CPRL for Small Wind Turbines'* as supplied by Brian Vick [4]. A summary table detailing the steps is shown below in Table 3.

4.2 Each 1-minute average sound power level was calculated from the measured total noise with the respective slant distance taken into account, and plotted against the wind speed at rotor centre

height. A linear regression line was used to derive the apparent sound power level for each wind speed bin as shown in Table 3.

Table 3: Calculation of Sound Power Level (carried out by USDA-ARS)

Reference height wind speed (m/s)	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Total Noise Level (dB L_{Aeq} re 20 µPa)	39.6	41.9	44.3	46.6	49.0	51.3	53.6	56.0	58.3	60.7	63.0	65.3
Background Noise Level (dB L_{Aeq} re 20 µPa)	36.6	38.0	39.4	40.8	42.2	43.6	44.9	46.3	47.7	49.1	50.5	51.9
Difference Between Total and Background Noise (dB)	3	3.9	4.9	5.8	6.8	7.7	8.7	9.7	10.6	11.6	12.5	13.4
Background Corrected Sound Pressure Level $L_{Aeq,c,k}$ (dB L_{Aeq} re 20 µPa)	**	40.6*	43.0*	45.3*	47.9	50.5	53.0	55.5	57.9	60.3	62.7	65.1
Apparent Sound Power Level, $L_{WA,k}$ (dB L_{WA} re 1 pW)		**78.8**	**81.2**	**83.5**	**86.1**	**88.7**	**91.2**	**93.7**	**96.1**	**98.5**	**100.9**	**103.3**

* margin between equivalent continuous sound pressure level of wind turbine plus background noise and background noise alone is less than 6 dB but more than 3 dB

** margin between equivalent continuous sound pressure level of wind turbine plus background noise and background noise alone is less than 3 dB (data below 5 m/s has not been included in the table due to margin being below 3 dB)

4.3 The level difference between total noise and background is less than 3 dB at reference height wind speeds below 6 m/s and therefore no apparent sound power level shall be derived nor data points be reported according to IEC 61400-11:2003. For those wind speeds, the wind turbine noise is less than the prevailing background noise.

1/3 Octave Band Data

4.4 1/3 octave band data have been supplied by Bergey Windpower for measurements between August and October 2011. 1/3 octave band level were measured for background noise on the 15th August 2011 and for total noise (background plus wind turbine noise) on 8th and 22nd August, 12th September, 03rd and 24th October 2011.

4.5 The energy average 1/3 octave band spectra between 20 Hz and 20 kHz has been calculated by USDA-ARS for the operational turbine noise for each integer wind speed. All available samples within the integer wind bin are used to derive the average frequency spectra. Corrections have been undertaken for the average background noise spectra at each integer wind speed [5]. No correction has been applied for the insertion loss of a secondary wind shield as this information is not known.

4.6 For 1/3 octave bands where the signal-to-noise ratio between the average operational noise and average background noise is less than 6 dB but greater than or equal to 3 dB, a subtraction of 1.3 dB has been undertaken and the band is marked with '*'. For 1/3 octave bands where the signal-to-noise ratio is less than 3 dB, the band is marked with '**'.

4.7 The linear, A-weighted and C-weighted background noise corrected results for the reference wind speed 8 m/s at hub height are shown in Appendix B. The spectra of the total measured noise and background noise for 8 m/s are also shown in Appendix B.

4.8 It should be noted that the difference between total measured noise and background noise is less than 6 dB in frequency bands up to 500 Hz up to 11 m/s and at frequencies higher than 4000 Hz up to wind speeds of 8 m/s. At frequencies above 4000 Hz the signal to noise ratio improves with increasing wind speed.

4.9 For the reference spectrum at 8 m/s values of the uncorrected total noise have been displayed when the difference between total noise and background noise was less than 3 dB. The spectrum at 8 m/s is likely to be dominated by background noise, and wind turbine noise is below the background noise.

Tonality

4.10 The tonality assessment was carried out according to the method specified in ISO 1996-2: 2007 Annex D [6], as suggested in [1].

4.11 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).

4.12 For this assessment the four 1/3 octave band spectra closest to the respective integer wind speeds from 7 to 11 m/s at rotor centre height have been used. The averaging period for each spectrum was 30 sec. Charts with A-weighted 1/3 octave band spectra of the background corrected sound pressure level measured at the microphone reference point can be found in Appendix C.

4.13 Spectra for wind speeds below 7 m/s have not been analysed as the signal-to-noise ratio was so low that no statement about the wind turbine noise can be made. Spectra for wind speeds above 11 m/s have not been analysed as no background noise data are available for a background noise correction in those wind speed bins.

4.14 Based on the spectra being closest to the reference height wind speeds of 7 to 11 m/s at rotor centre height from the measurements on 22/08/2011, 03/10/2011 and 24/10/2011 respectively, the Bergey Excel 10, grid-tie wind turbine was not found to be tonal. It should be noted, that some of the analysed spectra have a high sound pressure level in the 250 Hz frequency band but this did not require a tonal penalty according to [1].

4.15 This assessment is valid for the reference point, where the noise measurement took place and describes the noise character in the proximity of the wind turbine of this site only. Background noise is fairly high compared to the wind turbine noise and therefore the signal-to-noise ratio is not high enough for an assessment in many frequency bands.

5. UNCERTAINTY

5.1 An assessment of measurement uncertainty has been carried out by USDA-ARS as described in [3] for the reference height wind speed range of 6 to 16 m/s, based on the procedure outlined in Annex D of [2], 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 taken from the [3]. The total uncertainty U_C is evaluated from the square root of the sum of the squares of each individual component.

5.2 The standard uncertainty of the apparent sound power has been calculated by USDA-ARS to be 1.85 dB for the wind speed bin of 8 m/s at rotor centre height. The total uncertainty of the measured L_{WA} calculated from all uncertainties, as given in Table 4, is ± 1.99 dB for the Reference Position.

Table 4: Calculation of Uncertainty U_C

Type A Uncertainty	
Standard Error of L_{WA} Estimate from Regression Analysis	1.85
Type B Uncertainty	
Calibration	0.23
Instrument	0.11
Board & Mounting	0.3
Distance	0.05
Impedance	0.1
Turbulence	0.4
Wind Speed Derived	0.25
Direction	0.3
Background Correction	0.2
Total	**1.99**

6. TABLES OF RESULTS

6.1 According to [1] the declared apparent emission sound power level $L_{Wd,\ 8m/s}$ is calculated using the approach of [4] for a 95% confidence level:

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

where

$L_{Wd,\ 8m/s}$ is the declared apparent sound power level at the reference wind speed 8 m/s

$L_{W,\ 8m/s}$ is the apparent sound power level at the reference wind speed 8 m/s

σ is the uncertainty of linear regression and standard deviation.

Table 5: Noise Levels of a Bergey Excel 10 Wind Turbine for a reference wind speed of 8 m/s

Parameter	**Value**
Apparent Sound Power Level $L_{W, 8m/s}$	83.5 dB(A)
Uncertainty Linear Regression and Standard Deviation σ	1.85 dB
Measurement Uncertainty U_C	1.99 dB
Declared Apparent Emission Sound Power Level $L_{Wd, 8m/s}$	86.5 dB(A)
Noise Slope S_{dB}	2.47 dB/ms^{-1}
Noise Penalty P	-

Table 6: Immission Sound Pressure Levels at given Slant Distance for a Reference Wind Speed of 8 m/s

Parameter	**Value**
Immission Sound Pressure Level at 60 m $L_{p,60m}$	43 dB(A)
Immission Sound Pressure Level at 25 m $L_{p,25m}$	51 dB(A)
Slant Distance required for 45 dB(A)	47 m
Slant Distance required for 40 dB(A)	84 m
Slant Distance required for 35 dB(A)	150 m

7. CONCLUSIONS

7.1 A noise test has been carried out, according to BWEA *Small Wind Turbine Performance and Safety Standard* on a Bergey Excel 10, grid-tie wind turbine installed at a site near Bushland, Texas/USA by USDA-ARS/USA to measure the sound power level and tonal characteristics. This acoustic performance test is described in [3] and [4].

7.2 Hayes McKenzie Partnership Ltd. have been asked to provide supplementary information for the MSC certification by carrying out additional assessments with the data collected and processed by USDA-ARS which is presented in this short report.

7.3 According to the BWEA standard for small wind turbines [1], the turbine was calculated to have an apparent sound power level of 83.5 dB(A) ± 1.99 dB at a wind speed of 8 m/s at rotor centre height, as measured at the Reference Position directly downwind of the turbine. The declared apparent emission sound power level for 8 m/s at rotor centre height was calculated to be 86.5 dB(A).

7.4 The tonal output from the Bergey Excel 10, grid-tie wind turbine has been assessed using the methodology prescribed in [1]. Based on the methodology described in [6], Annex D, no tonal characteristics were found.

REFERENCE LIST

[1] Small Wind Turbine Performance and Safety Standard
British Wind Energy Association, February 2008

[2] BS EN 61400-11 Wind turbine generator systems – Part 11: Acoustic noise measurement techniques (identical with IEC 61400-11:2002)
Standards Policy and Strategy Committee, August 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] Acoustic Test Report: Noise Certification Testing of Bergey Windpower Excel Grid-Tie Wind Turbine for the American Wind Energy Association (AWEA) Small Wind Certification Council (SWCC)
Brian Vick, USDA-ARS/United States of America, 13 May 2011

[4] Standard Operating Procedure for Noise Data Collection at USDA-ARS-CPRL for Small Wind Turbines
Brian Vick, USDA-ARS/United States of America, 3 November 2011

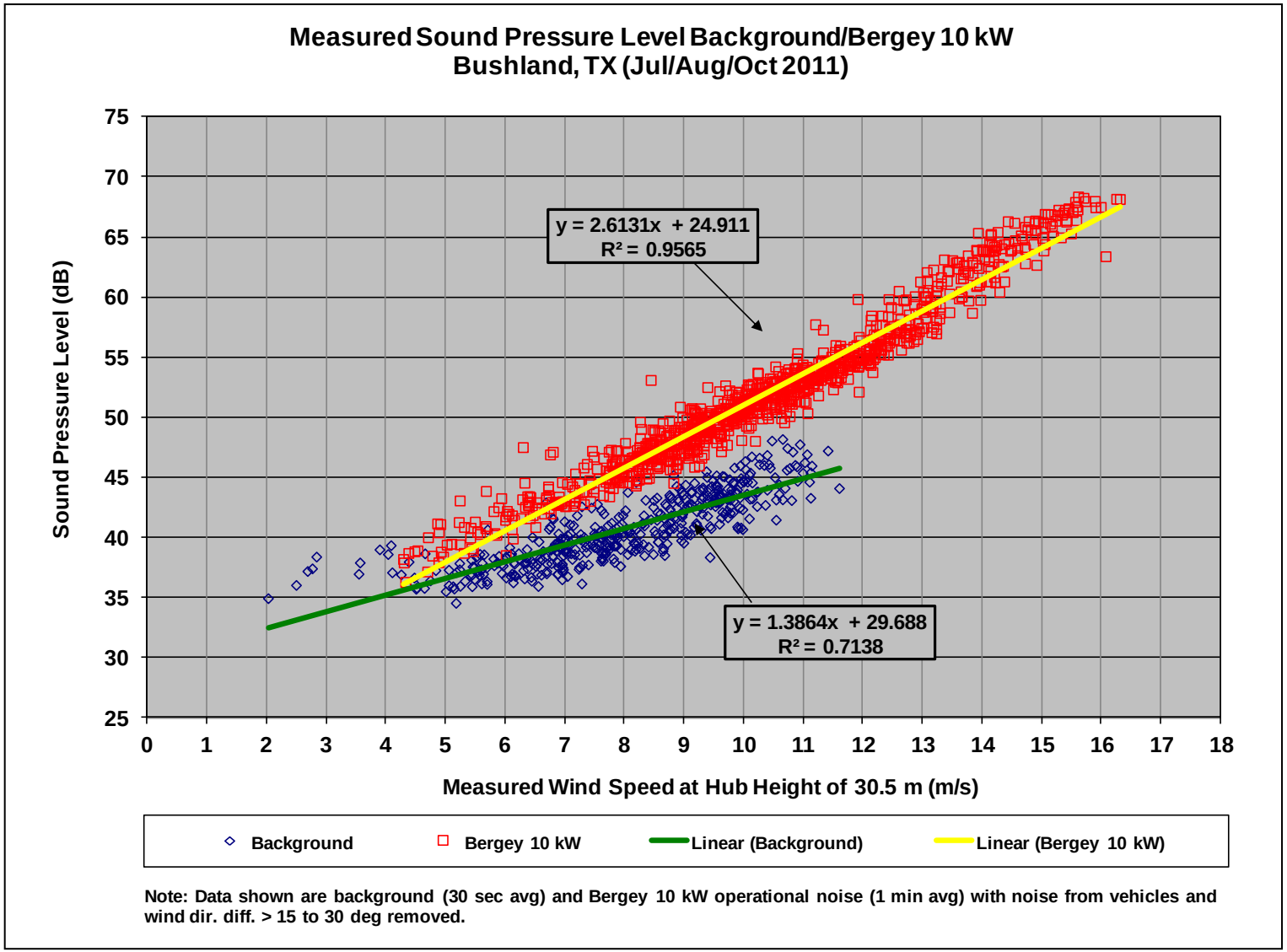
[5] Excel File: NoiseBergey3rdOctBWEArevB, received 01/11/2011
Brian Vick, USDA-ARS/United States of America, 3 November 2011

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

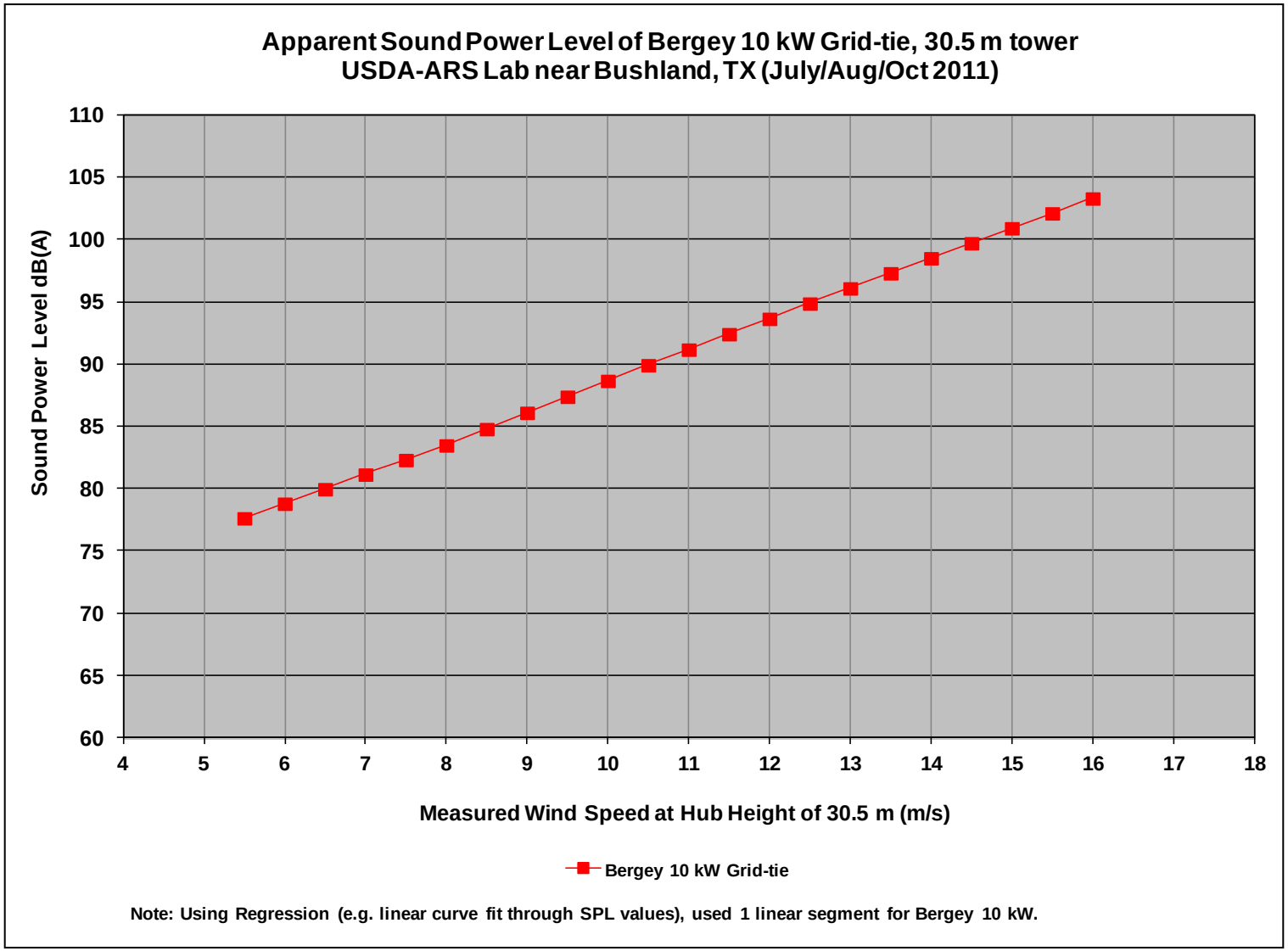
[7] IEC TS 61400-14 Wind turbines – Part 14: Declaration of apparent sound power level and tonality values
International Electrotechnical Commission, 2005

Appendix A

Noise Data for Calculation of Sound Power Level



Data and chart supplied by USDA-ARS



Data and chart supplied by USDA-ARS

Appendix B

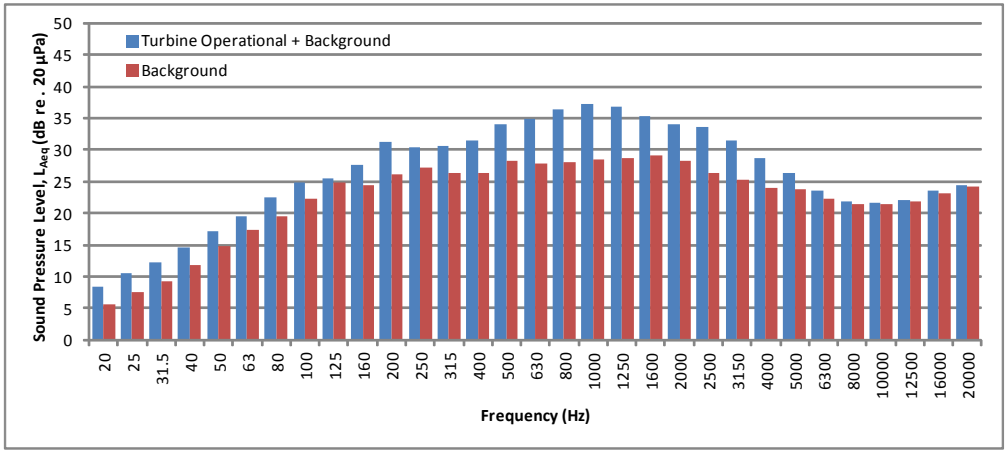
1/3 Octave Band Level

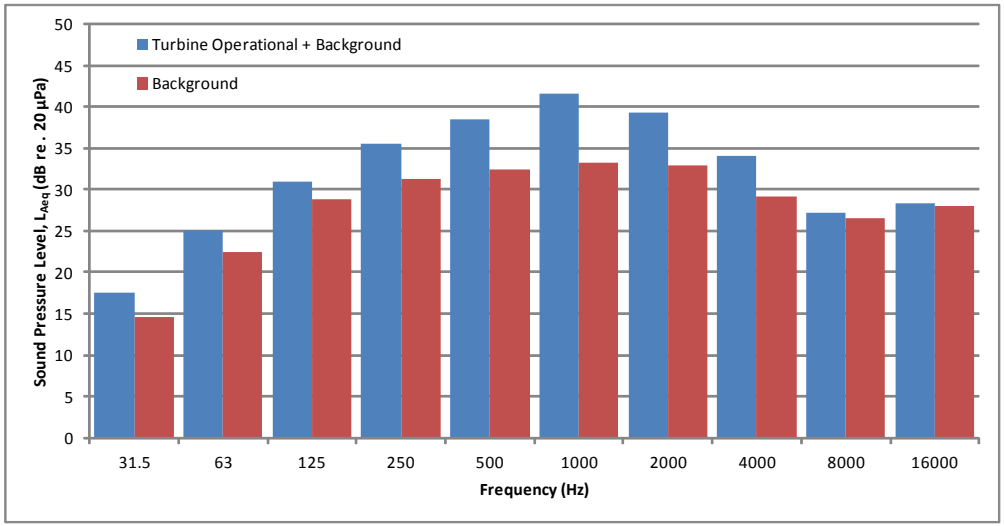
For Reference Wind Speed of 8 m/s
at Rotor Centre Height

HM: 2477

Bergey Excel 10 kW Wind Turbine
Wind Speed - 8 m/s at rotor centre height (30.5 m)
Average of all Measurement Days

	Turbine Operational + Background		Background	
Frequency (Hz)	1/3 Octave Band (dB(A))	Band (dB (A))	1/3 Octave Band (dB(A))	Band (dB (A))
20	8.4		5.6	
25	10.5	17.6	7.5	14.7
31.5	12.3		9.3	
40	14.6		11.8	
50	17.1	25.1	14.9	22.5
63	19.5		17.3	
80	22.5		19.6	
100	24.8	30.9	22.3	28.8
125	25.5		24.8	
160	27.6		24.5	
200	31.2	35.5	26.1	31.3
250	30.4		27.1	
315	30.6		26.3	
400	31.4	38.5	26.5	32.4
500	34.0		28.3	
630	35.0		27.8	
800	36.4	41.6	28.0	33.2
1000	37.2		28.6	
1250	36.9		28.8	
1600	35.4	39.2	29.1	32.9
2000	34.1		28.3	
2500	33.7		26.4	
3150	31.4	34.1	25.3	29.2
4000	28.7		24.1	
5000	26.5		23.7	
6300	23.6	27.2	22.2	26.5
8000	21.9		21.4	
10000	21.6		21.4	
12500	22.2	28.3	21.8	28.0
16000	23.5		23.2	
20000	24.5		24.2	
Overall	45.9		40.0	



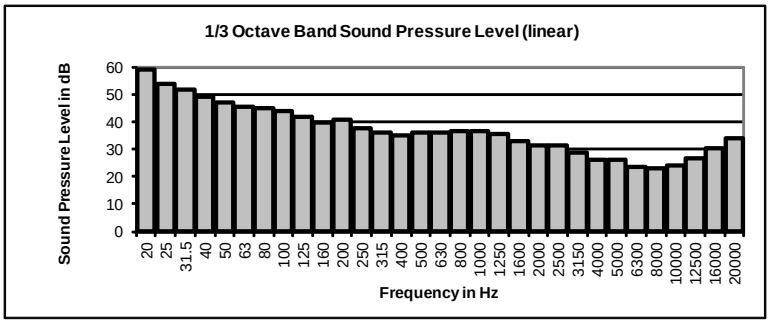


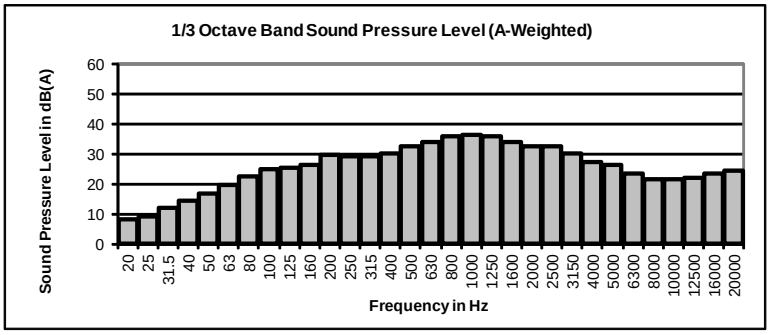
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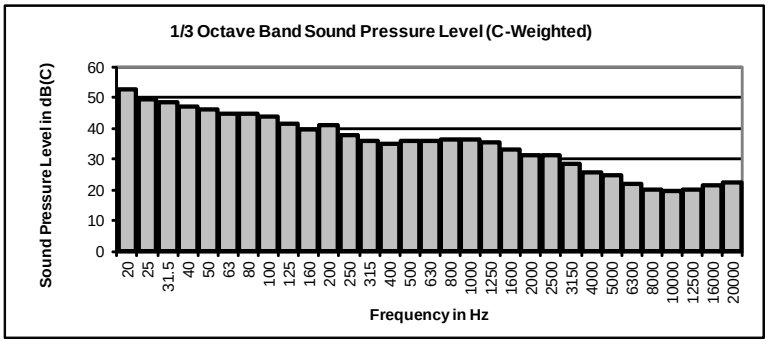
HM: 2477

Bergey Excel 10 kW Wind Turbine
Wind Speed - 8 m/s at rotor centre height (30.5 m)
1/3 Octave Band Sound Pressure Levels (Average of all Measurement Days)

f (Hz)	$L_{eq,1/3\ Octave}$ (dB(lin))	$L_{eq,1/3\ Octave}$ (dB(A))	Octave (dB(C))
20	58.9	8.4**	52.7
25	53.9	9.2*	49.5
31.5	51.7	12.3**	48.7
40	49.2	14.6**	47.2
50	47.3	17.1**	46.0
63	45.7	19.5**	44.9
80	45.0	22.5**	44.5
100	43.9	24.8**	43.6
125	41.6	25.5**	41.4
160	39.7	26.3*	39.6
200	40.8	29.9*	40.8
250	37.7	29.1*	37.7
315	35.9	29.3*	35.9
400	34.9	30.1*	34.9
500	35.9	32.7*	35.9
630	35.9	34.0	35.9
800	36.6	35.8	36.6
1000	36.5	36.5	36.5
1250	35.5	36.1	35.5
1600	33.2	34.2	33.1
2000	31.6	32.8*	31.4
2500	31.5	32.8	31.2
3150	29.0	30.2	28.5
4000	26.4	27.4*	25.6
5000	26.0	26.5**	24.7
6300	23.7	23.6**	21.7
8000	23.0	21.9**	20.0
10000	24.1	21.6**	19.7
12500	26.5	22.2**	20.3
16000	30.1	23.5**	21.6
20000	33.8	24.5**	22.6







* margin between equivalent continuous sound pressure level of wind turbine plus background noise and background noise alone is less than 6 dB but more than 3 dB

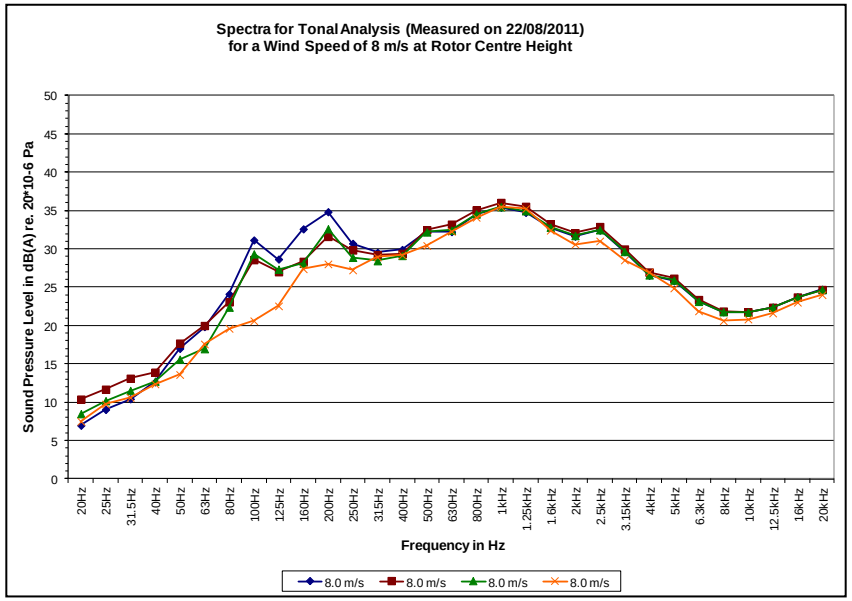
** margin between equivalent continuous sound pressure level of wind turbine plus background noise and background noise alone is less than 3 dB (data of the total noise has been displayed in the spectra)

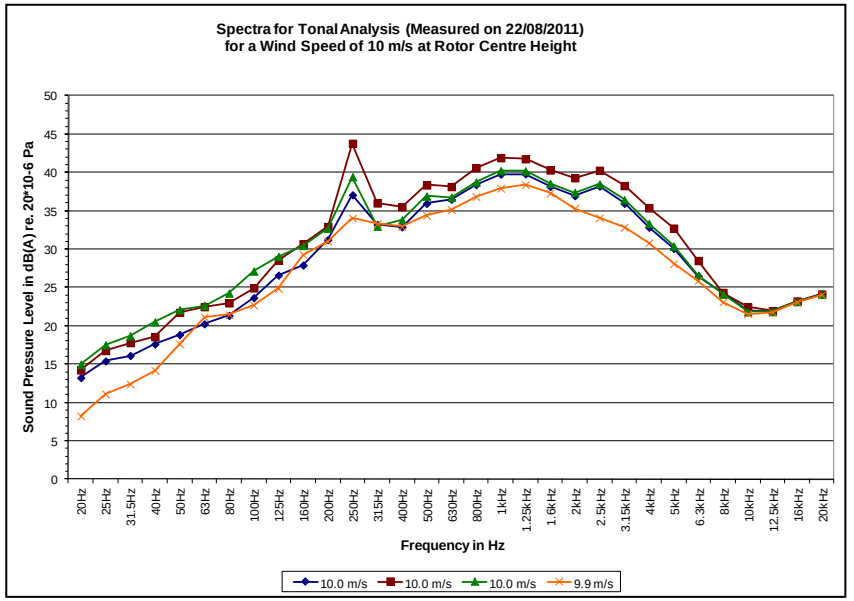
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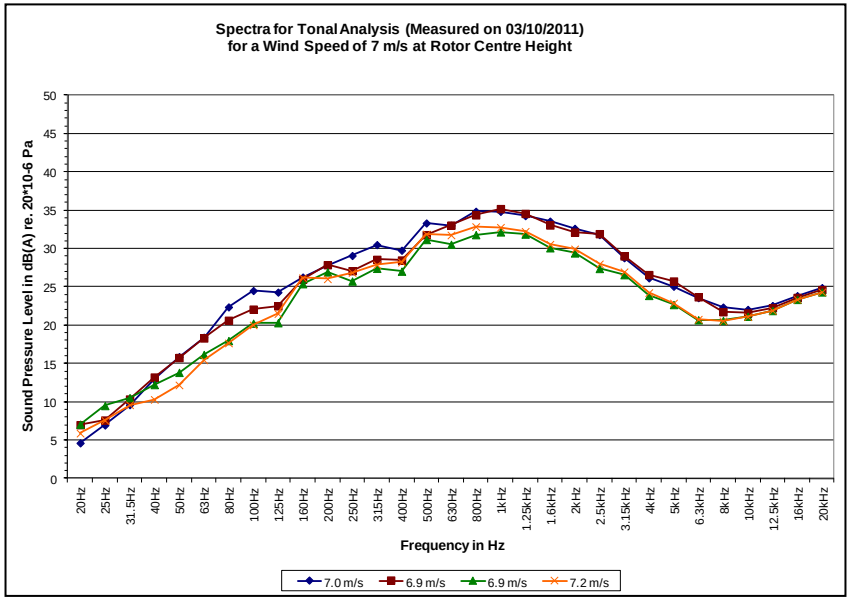
Appendix C

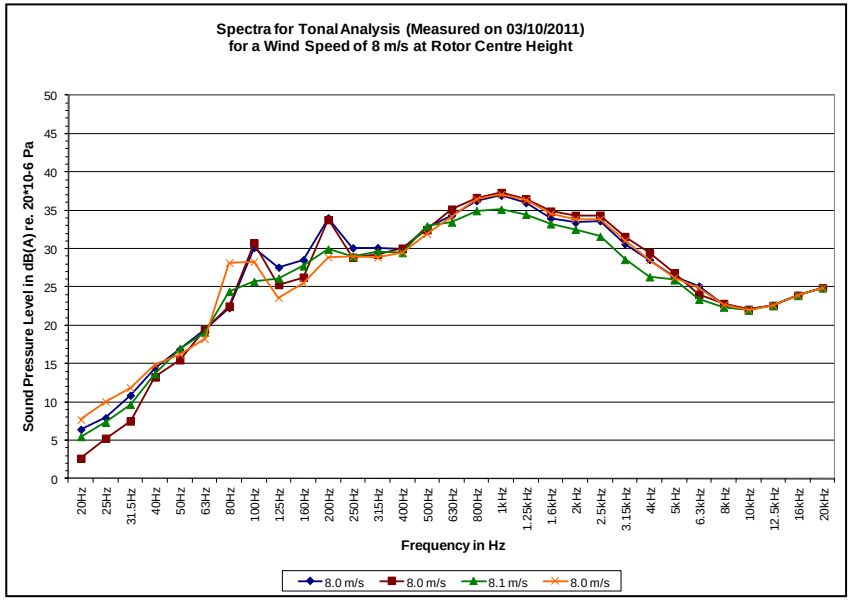
Spectra for Tonality Assessment

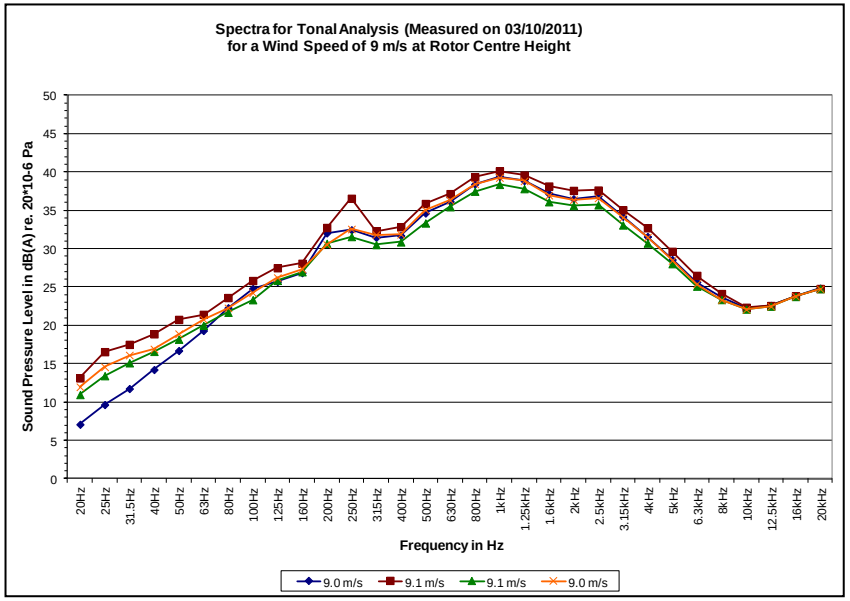
For Reference Wind Speeds of 7 to11 m/s
at Rotor Centre Height

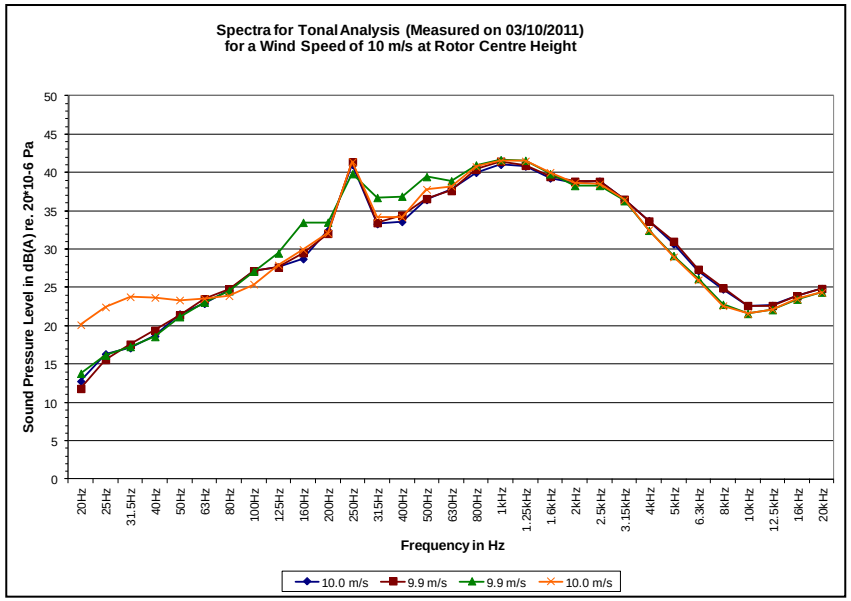

Spectra for Tonal Analysis (Measured on 22/08/2011)
for a Wind Speed of 8 m/s at Rotor Centre Height
Sound Pressure Level in dB(A) re. 20*10-6 Pa
Frequency in Hz
8.0 m/s
8.0 m/s
8.0 m/s
8.0 m/s

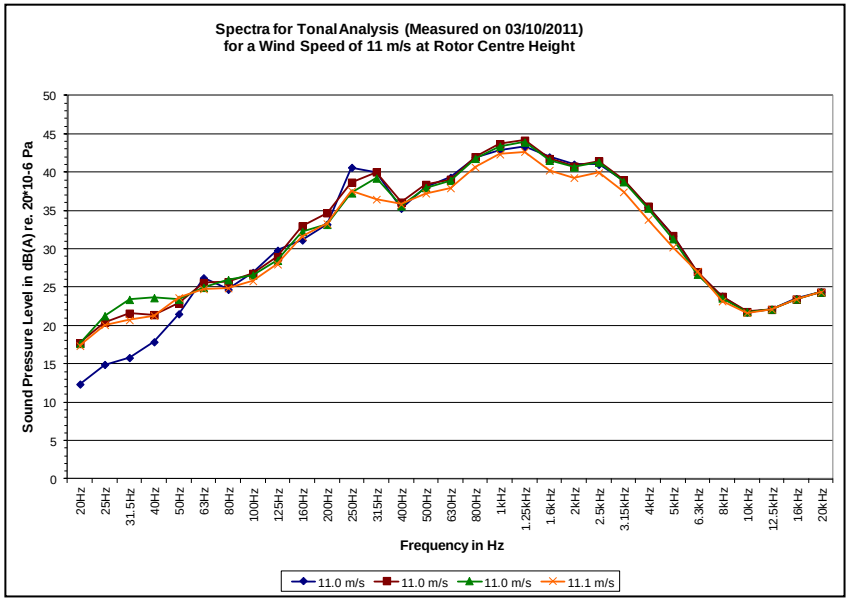

Spectra for Tonal Analysis (Measured on 22/08/2011)
for a Wind Speed of 10 m/s at Rotor Centre Height
Sound Pressure Level in dB(A) re. 20*10-6 Pa
Frequency in Hz
10.0 m/s
10.0 m/s
10.0 m/s
9.9 m/s

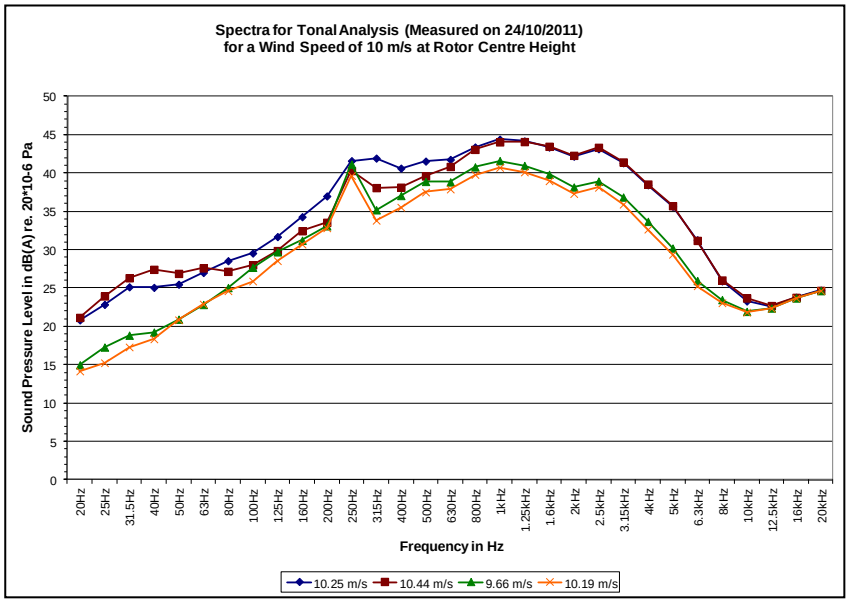

Spectra for Tonal Analysis (Measured on 03/10/2011)
for a Wind Speed of 7 m/s at Rotor Centre Height
Sound Pressure Level in dB(A) re. 20*10-6 Pa
Frequency in Hz
7.0 m/s
6.9 m/s
6.9 m/s
7.2 m/s

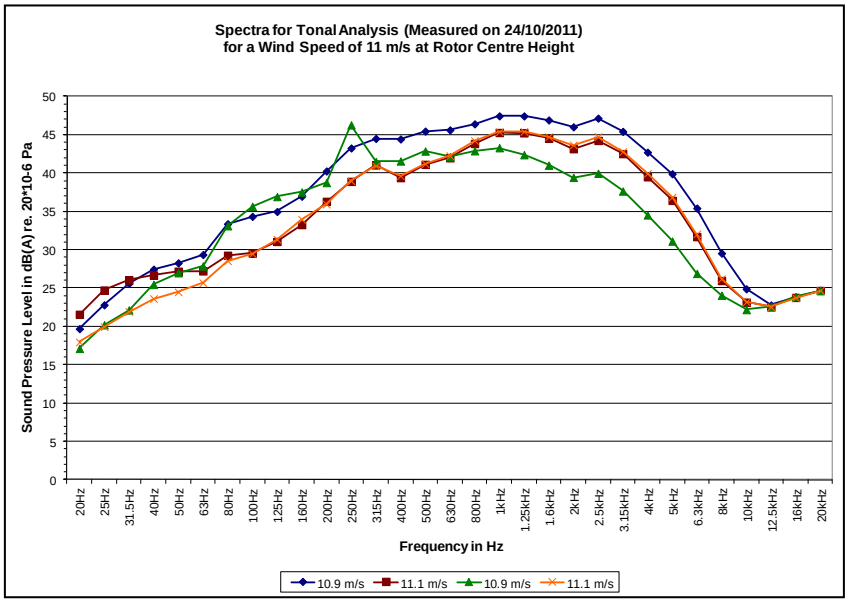

Spectra for Tonal Analysis (Measured on 03/10/2011)
for a Wind Speed of 8 m/s at Rotor Centre Height
Sound Pressure Level in dB(A) re. 20*10-6 Pa
Frequency in Hz
8.0 m/s
8.0 m/s
8.1 m/s
8.0 m/s


Spectra for Tonal Analysis (Measured on 03/10/2011)
for a Wind Speed of 9 m/s at Rotor Centre Height
Sound Pressure Level in dB(A) re. 20*10-6 Pa
Frequency in Hz
9.0 m/s
9.1 m/s
9.1 m/s
9.0 m/s


Spectra for Tonal Analysis (Measured on 03/10/2011)
for a Wind Speed of 10 m/s at Rotor Centre Height
Sound Pressure Level in dB(A) re. 20*10-6 Pa
Frequency in Hz
10.0 m/s
9.9 m/s
9.9 m/s
10.0 m/s


Spectra for Tonal Analysis (Measured on 03/10/2011)
for a Wind Speed of 11 m/s at Rotor Centre Height
Sound Pressure Level in dB(A) re. 20*10-6 Pa
Frequency in Hz
11.0 m/s
11.0 m/s
11.0 m/s
11.1 m/s





Note: Data measured and provided by USDA-ARS

Appendix D

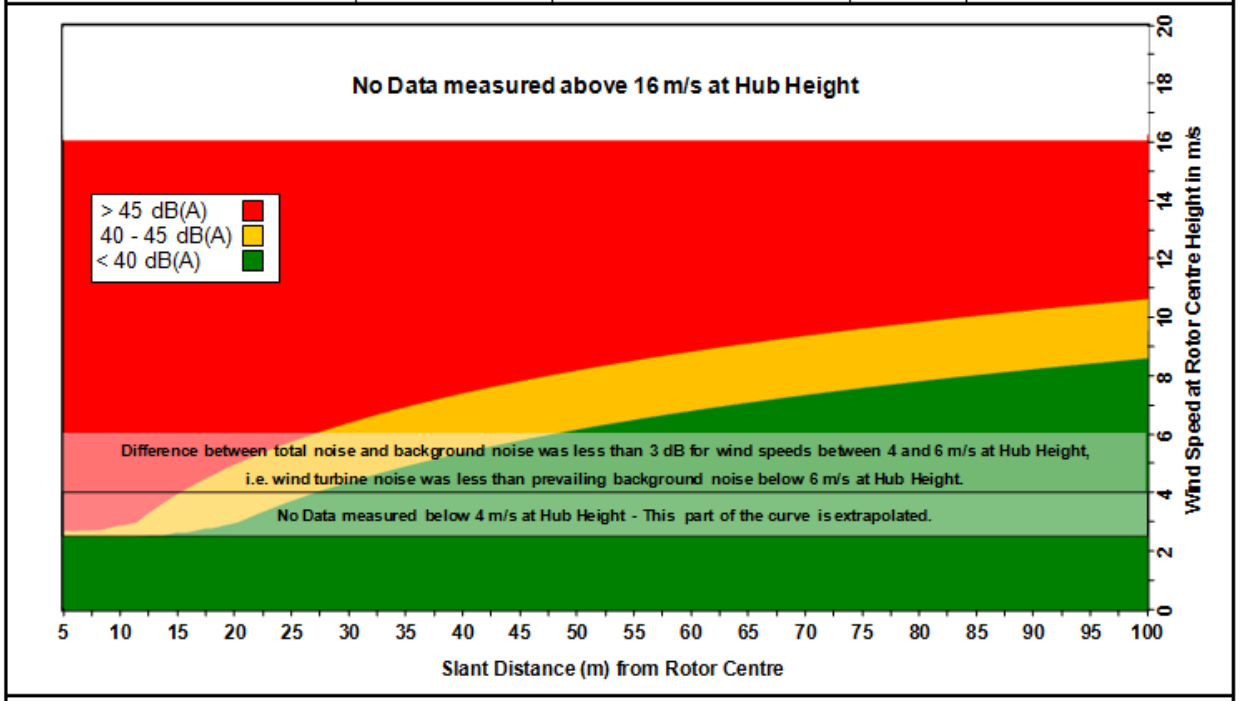
Noise Label

For Reference Wind Speed of 8 m/s
at Rotor Centre Height

Acoustic Noise Levels

Turbine Make:	Bergey Windpower Co.	Model:	Excel 10, Grid-Tie

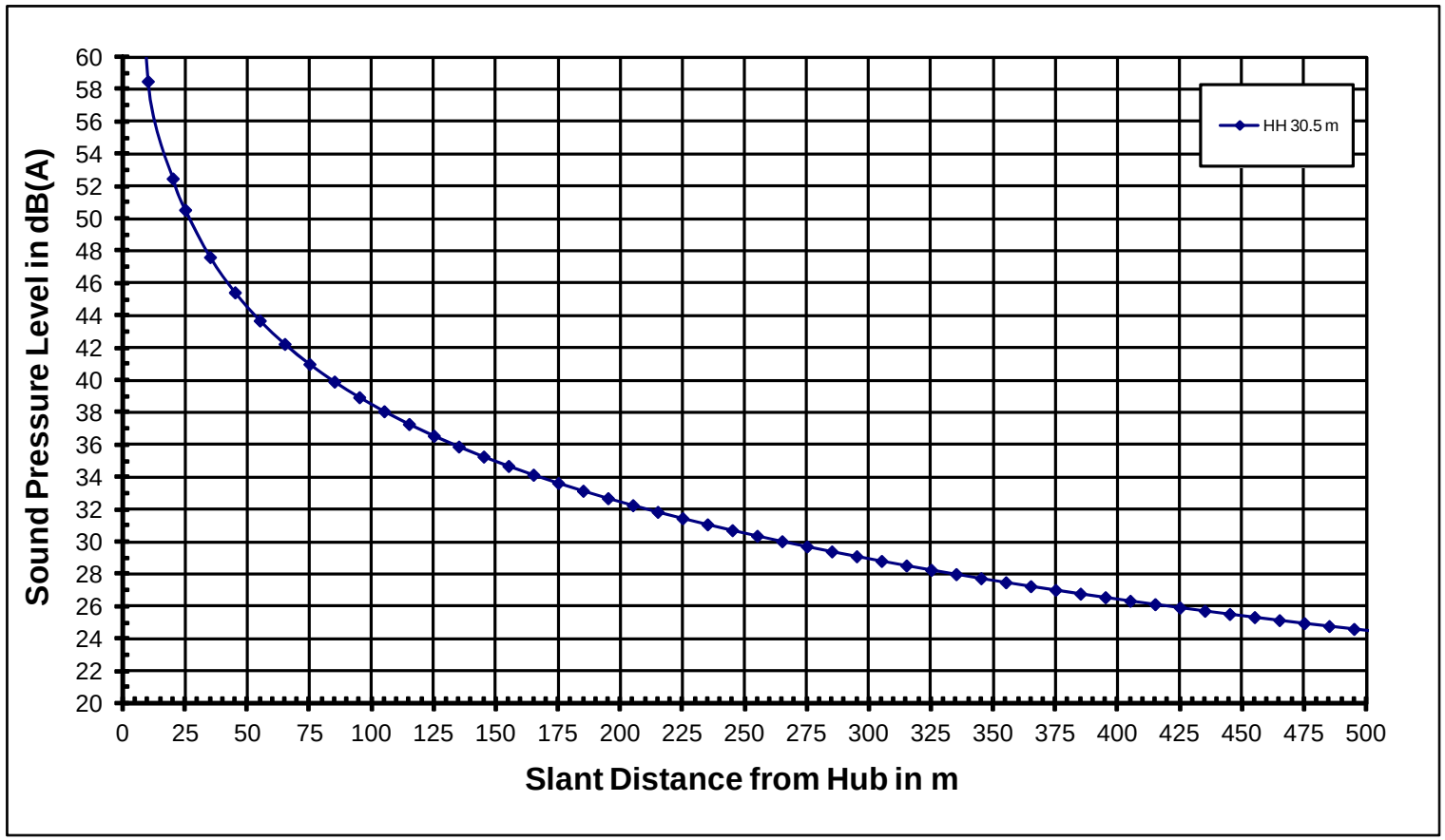
NOISE EMISSION LEVEL				NOISE PENALTY
Sound Power $L_{Wd,8m/s}$	86.5 dB(A)	Noise Slope, S_{dB} (dB/m/s)	2.47	NO



Acoustic Performance Testing by:
USDA-ARS / USA
July/August/October 2011

Noise Label issued by:
Hayes McKenzie Partnership Ltd. / UK
October 2011

Sound Pressure Level (according to BWEA Small Wind Turbine Performance and Safety Standard) of a Bergey Excel 10, Grid-tie with 30.5 m Hub Height depending on Slant Distance (Reference: 8 m/s at Rotor Centre Height)



Declared Sound Power Level $L_{Wd,8m/s}$: 86.5 dB(A)
Noise slope, S_{dB} : 2.47 dB/m/s
Noise Penalty : No

$L_{p,60m}$: 43 dB(A)
$L_{p,25m}$: 51 dB(A)