Green Cat Renewables

FINAVON HILL ESTATE WIND TURBINE

Cumulative Noise Assessment

December 2014

Green Cat Renewables Ltd

Noise Assessment
Prepared for:
Mr. J Sanderson (Finavon Estate) & Construction Partner Kilmac Construction Ltd

Prepared By:
Brian Sawers

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Edinburgh Office
Midlothian Innovation Centre
Roslin
EH25 9RE
Tel: 0131 440 8350

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Checked By: Brian Sawers	Date: 12/12/14
Approved By: Graham Donnachie	Date: 17/12/14

Table of Contents

1 Introduction

This report considers the potential cumulative noise impacts associated with the development of the proposed Finavon Hill Estate Wind Turbine at the request of Angus Council to accompany the Noise Impact Assessment previously submitted (planning application ref: 14/00827/FULL).

The assessment considers potential cumulative noise from the nearby development of Carsegownie (planning application ref: 13/00130/FULL).

2 Terminology

The symbols used for noise levels in this report are:

- L_{WA} is the A-weighted sound power level, a measure of the total sound energy emitted by a source of noise;
- $L_{A,eq}$is the A-weighted equivalent continuous sound pressure level, which is a measure of the total ambient noise at a given place at a given time; and
- $L_{A90,10min}$ is the A-weighted sound pressure level exceeded for 90 per cent of the time in the averaging time period specified, in this case 10 minutes, and is the normal index used for background noise level measurements.

The wind speeds referred to in this report are:

- v_{10} are standardised wind speeds at 10m height above ground level and used to determine the correlation between wind speed and noise levels.

3 Guidance

Guidance for assessing operational noise from wind farms is given in:

- 'ETSU-R-97: the Assessment and Rating of Noise from Wind Farms (1997), The Department of Trade and Industry (usually referred to as the Noise Working Group Recommendations); and
- 'A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise', May 2013, IOA.

4 Methodology

4.1 Assessment Criteria

The ETSU-R-97 guidelines indicate that for single turbines or turbines located far from the nearest properties, a simplified approach can be taken. If it can be demonstrated that the noise

levels due to the turbine would not exceed 35dB(A) $L_{A90,10min}$ at the nearest sensitive receptors at v_{10} wind speeds of up to 10ms^{-1}, then that in itself would provide sufficient protection of amenity for those receptors.

4.2 Cumulative Assessment Criteria

The IOA good practice guide requires that cumulative developments consider consented levels and not predicted wind turbine noise levels. The nearest property to the cumulative development is selected as the "controlling property", as defined in page 26 of the IOA good practice guide. This means that when a turbine is operating at its limit at the controlling property, it cannot operate at its noise limit at a property further away without exceeding the noise limit at the controlling property.

When considering cumulative impact from two or more developments at a given property the IOA Good Practice Guide states: '*If the proposed wind farm produces noise levels within 10dB of any existing wind farm/s at the same location, then a cumulative noise impact assessment is necessary.*'[1]

4.3 Choice of Propagation Model

The International Standard ISO 9613, 'Acoustics – Attenuation of Sound During Propagation Outdoors - Part 2', noise propagation model has been used for the turbine noise calculations. L_{Aeq} noise propagation was modelled using WindFarm v4.2.1.7 by ReSoft. L_{A90} levels were derived by subtracting two decibels from the L_{Aeq} values as per the ETSU-R-97 guidance.

The input parameters shown in **Table 4.1** have been used and are consistent with the IOA good practice guidance.

Table 4.1 – Propagation input parameters

Atmospheric Attenuation Assumptions	
Temperature (°C)	10
Humidity (%)	70
Ground Attenuation Assumptions	
Attenuation factor, G	0.5 (semi-soft ground)
Receptor height (m)	4.0

The attenuation of noise as it travels through the air varies with frequency. The atmospheric attenuation coefficients used in the assessment, corresponding to the assumptions in **Table 4.1**, are tabulated in **Table 4.2.**

Table 4.2 – Attenuation coefficients used for the noise propagation model

Octave Band (Hz)	63	125	250	500	1000	2000	4000	8000
Attenuation Coefficient	0.0001	0.0004	0.0010	0.0019	0.0037	0.0097	0.0328	0.1170

[1] IOA Good Practice Guide, page 23

5 Baseline

5.1 Overview of Assessment Procedure

Ten noise properties have been identified as potentially sensitive to cumulative noise impact. These are shown on the map in **Figure 5.1**.

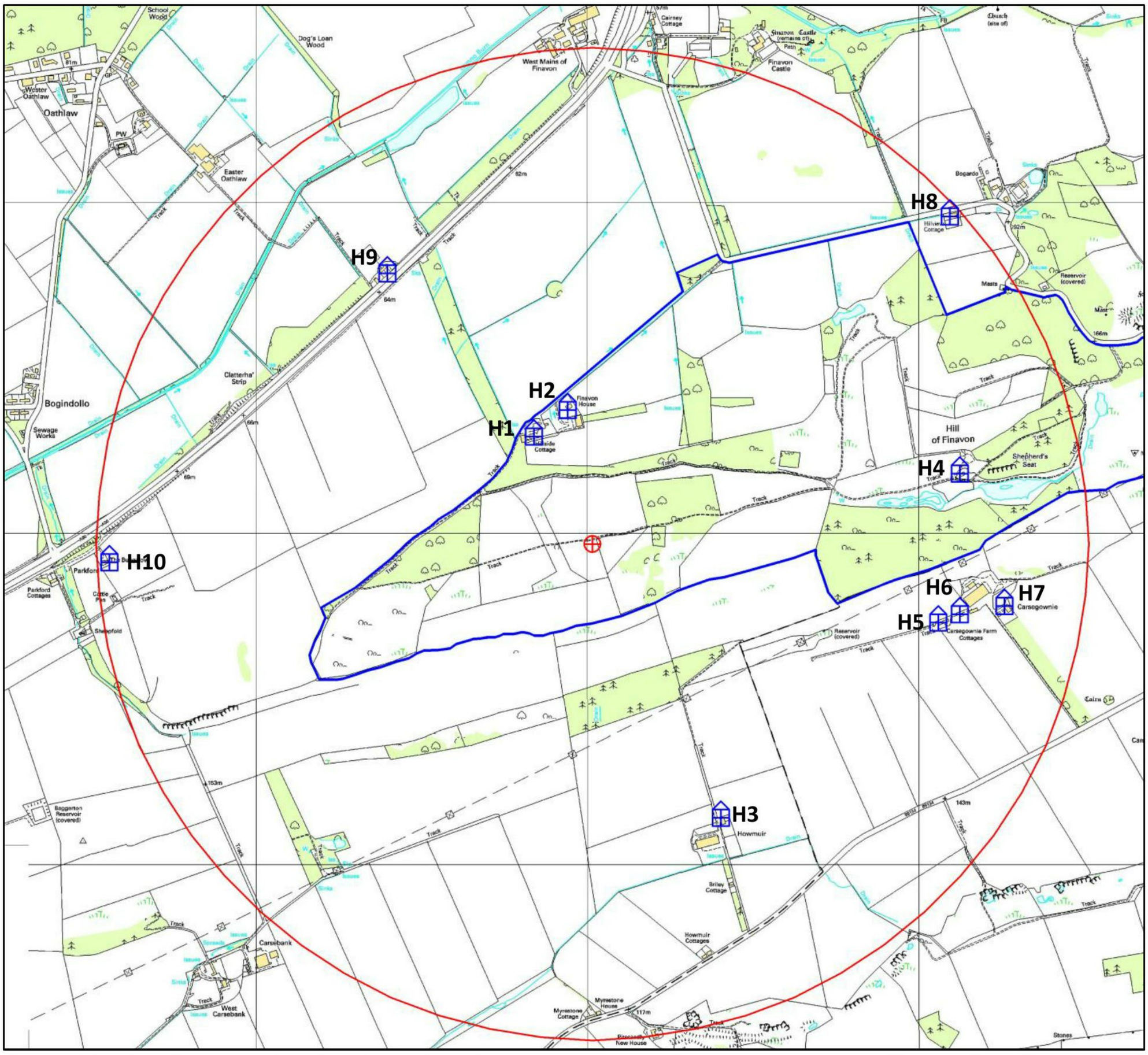


Figure 5.1 – Baseline map showing the turbine location, noise sensitive receptors and 1.5km study radius

5.2 Cumulative Baseline

The consented wind turbine at Carsegownie is located approximately 1,740m south-east from the proposed Finavon Hill Estate Wind Turbine, that could contribute to cumulative noise and increase noise levels at the assessed third party properties above 35dB(A). Details of this development are given in **Table 5.1**, and its location in relation to the proposed development at Finavon Hill Estate is shown in **Figure 5.2**.

A noise study radius of 1.5km around the proposed Finavon Hill Estate Wind Turbine has been used to identify noise sensitive receptors that may be affected by cumulative noise. This study radius has been chosen because this is approximately the distance where the predicted wind turbine noise level from the Finavon Hill turbine is 25dB(A); below this noise level, the wind turbine could not contribute to cumulative noise levels such that they would exceed a 35dB(A) noise limit.

Table 5.1 – Details of developments considered within cumulative assessment

Proposal	App. Number	Status	Turbine	Easting	Northing
Carsegownie	13/00130/FULL	Consented	1 x Endurance E3120 (50kW) 25m hub height, 19.2m rotor diameter	350656	754349

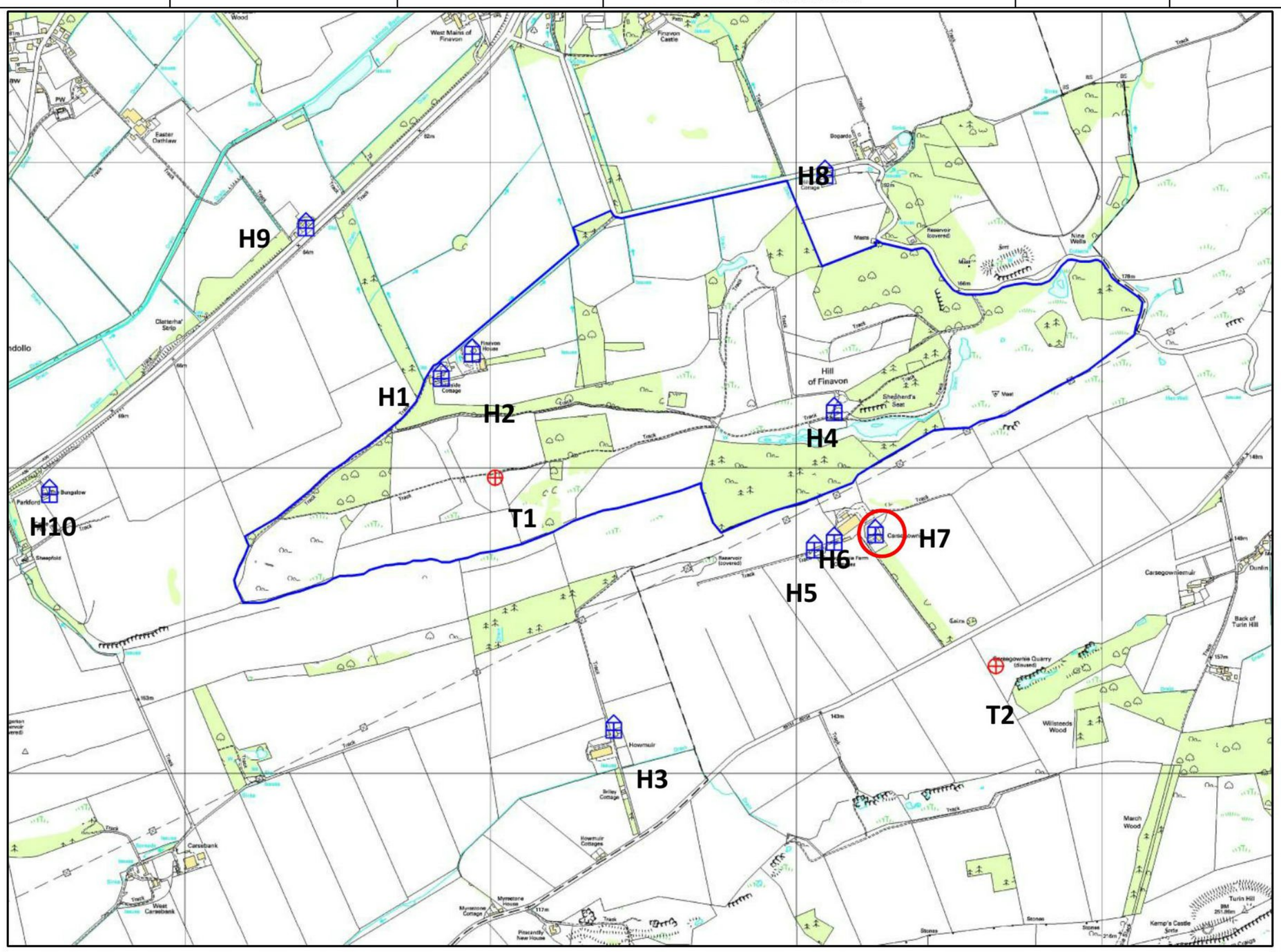


Figure 5.2 – Map showing cumulative developments, noise sensitive receptors and controlling property

T1 – Finavon Hill
T2 – Carsegownie

Noise sensitive receptor

Controlling property for Carsegownie

Land ownership boundary

Carsegownie (H7) represents the nearest non-financially involved property to the Carsegownie development and as such, has been used as the controlling property in accordance with IOA Guidance.

Planning Condition 3 states: *'At any property lawfully existing at the date of this planning permission the rating level of noise emissions, including any tonal correction from the wind turbine when measured in accordance with the guidance in "The assessment and Rating of noise from wind farms, ETSU-R-97", shall not exceed 35 dB(LA90) at wind speeds up to 10 ms^{-1} at 10m height'.*

This assessment will assume that the Carsegownie turbine is operating at 35dB(A) at Carsegownie (H7), thereby representing the maximum allowable noise levels the development can operate at. Predicted noise levels at the other properties in this assessment will be scaled accordingly.

5.3 Sound Power Levels

The measured sound power levels for the turbine models used within this assessment are given below. The IOA recommends that an uncertainty factor of 1.645 times the measured uncertainty value should be used as a clear indication that suitable uncertainties have been incorporated.

5.3.1 Finavon Hill Estate – EWT Directwind 54 (500kW)

The measured sound power levels for the EWT Directwind 54 (500kW) at a v_{10} wind speed of 10ms^{-1}, used to calculate sound pressure levels at the properties included within the assessment are presented in **Table 5.3.** The measurement uncertainty of the octave band data for the EWT DW54 (500kW) at a v_{10} wind speed of 10ms^{-1} is 0.7dB(A), resulting in an IOA recommended uncertainty factor of 1.2dB(A).

Table 5.3 – Octave band sound power levels for the EWT DW54 at v_{10} wind speed of 10ms^{-1}

Octave Band (Hz)	63	125	250	500	1000	2000	4000	8000
Sound Power Level (dB(A))	80.7	86.9	92.6	94.1	92.0	89.2	83.0	72.8
Total [dB(A)]	99.5							
Uncertainty [dB(A)]	0.7							
IOA Uncertainty [dB(A)]	1.2							

The full noise test report for the EWT Directwind 54 (500kW) used within this assessment is available in **Appendix A.**

5.3.2 Carsegownie – Endurance E3120 (50kW)

Measured sound power levels for the Endurance E3120 (50kW) are available at a v_{10} wind speed of 8ms^{-1}. Broadband sound power levels for this turbine are available for wind speeds up to 10ms^{-1}, allowing the octave band sound power levels to be scaled accordingly. Octave band sound power levels for 8ms^{-1} are shown in **Table 5.4**.

Table 5.4 – Octave band sound power levels for the Endurance E3120 at v_{10} wind speed of 8ms^{-1}

Octave Band (Hz)	63	125	250	500	1000	2000	4000	8000
Sound Power Level (dB(A))	70.3	78.7	83.7	82.6	83.9	86.6	84.5	71.5

Broadband sound power levels for the Endurance E3120 are shown in **Table 5.5**.

Table 5.5 –Broadband sound power levels for the Endurance E3120 at v_{10} wind speed of 10ms^{-1}

v_{10} wind speed (ms^{-1})	4	5	6	7	8	9	10
Sound Power Level [dB(A)]	87.3	87.6	88.1	89.0	90.6	92.4	94.3

The broadband sound power level for the E3120 is 3.7dB(A) greater at 10ms^{-1} than the sound power level at 8ms^{-1}, which is the highest wind speed in which octave band data is available from the manufacturer. As such, 3.7dB(A) has been added to the octave band data at 8ms^{-1} to scale the data to correspond with the sound power level at 10ms^{-1}, shown in **Table 5.6**.

Table 5.6 – Octave band sound power levels for the EWT DW54 at v_{10} wind speed of 10ms^{-1}

Octave Band (Hz)	63	125	250	500	1000	2000	4000	8000
Sound Power Level (dB(A))	74.0	82.4	87.4	86.3	87.6	90.3	88.2	75.2
Total [dB(A)]	95.5							
Uncertainty [dB(A)]	1.6							
IOA Uncertainty [dB(A)]	2.6							

The Endurance E3120 has an uncertainty of 1.6dB(A), resulting in an IOA recommended uncertainty factor of 2.6dB(A).

The full noise test report for the Endurance E3120 (50kW) used within this assessment is available in **Appendix A.**

6 Assessment of Predicted Impacts and Effects

6.1 Non-cumulative

The calculated $L_{A90,10min}$ levels, including a 1.2dB(A) uncertainty factor, are shown in **Table 6.1**.

Table 6.1 – Wind turbine noise levels ($L_{A90,10min}$)

ID	Property Name	Easting (to 10m)	Northing (to 10m)	Distance to Proposed turbine (to 10m)	$L_{A90,10min}$ [dB(A)]
H1	Finavon Cottage*	348840	755290	370	36.2
H2	Finavon House*	348940	755370	410	35.2
H3	Howmuir	349400	754140	910	27.2
H4	Hill of Finavon	350130	755180	1130	24.9
H5	Carsegownie Cottage 1	350060	754730	1070	25.5
H6	Carsegownie Cottage 2	350130	754760	1130	24.9
H7	Carsegownie	350260	754780	1260	23.8
H8	Hillview Cottage	350100	755960	1470	22.2
H9	Clatterha Smithy Cottages	348400	755790	1030	25.9
H10	The Bungalow	347556	754912	1460	22.2

**Indicates a receptor which has a financial interest in the proposed development*

Wind turbine noise levels at the properties within 1.5km of the proposed Finavon Hill Estate development are predicted to operate within the 35dB(A) ETSU-R-97 noise limit at all non-financially involved properties and within the 45dB(A) ETSU-R-97 noise limit at both financially involved properties. As such, when assessed on its own, noise impact from the proposed development is assessed as being acceptable.

6.2 Cumulative

Operational noise levels were predicted for all developments and then scaled to assume that the Carsegownie development is operating at the maximum allowable levels (consented levels).

Table 6.2 shows the predicted and consented levels for the Crasegownie wind turbine for all the properties considered within this assessment.

Table 6.2 – Predicted and consented noise levels for developments considered within cumulative assessment

ID	Property Name	Carsegownie $L_{A90,10min}$ [dB(A)] (Predicted)	Carsegownie $L_{A90,10min}$ [dB(A)] (Consented)
H1	Finavon Cottage*	14.1	21.6
H2	Finavon House*	14.4	21.9
H3	Howmuir	19.4	26.9
H4	Hill of Finavon	22.0	29.5
H5	Carsegownie Cottage 1	25.5	33.0
H6	Carsegownie Cottage 2	26.1	33.6
H7	Carsegownie	27.5	35.0
H8	Hillview Cottage	16.2	23.7
H9	Clatterha Smithy Cottages	11.0	18.5
H10	The Bungalow	9.0	16.5

Table 6.2 shows that noise levels from the Carsegownie wind turbine are predicted to be 27.5dB(A) at the controlling property, Carsegownie (H7). Planning Condition 3 of the Carsegownie wind turbine planning permission states that the turbine should not exceed 35dB(A) $L_{A90,10min}$ at any property. As such, 7.5dB(A) has been added to the predicted turbine noise levels at all properties to simulate the turbine operating at its maximum allowed level (consented level).

Cumulative noise calculations have been undertaken for properties where noise contributions from both developments are within 10dB(A) of each other. Only properties in which the noise levels from each turbine are within 10dB(A) of each other have been considered within the cumulative assessment.[2] This means that properties H1, H2 and H7 have not been assessed for cumulative noise. The calculated $L_{A90,10min}$ cumulative noise levels based on consented levels are shown in **Table 6.3**.

Table 6.3 – Maximum cumulative wind turbine noise levels ($L_{A90,10min}$) at properties within 1.5km study area

ID	Property Name	Finavon Hill $L_{A90,10min}$ [dB(A)]	Carsegownie $L_{A90,10min}$ [dB(A)] (Consented)	Total Cumulative $L_{A90,10min}$ [dB(A)]
H3	Howmuir	27.2	26.9	30.0
H4	Hill of Finavon	24.9	29.5	30.8
H5	Carsegownie Cottage 1	25.5	33.0	33.7
H6	Carsegownie Cottage 2	24.9	33.6	34.2
H8	Hillview Cottage	22.2	23.7	26.0
H9	Clatterha Smithy Cottages	25.9	18.5	26.7
H10	The Bungalow	22.2	16.5	23.3

[2] IOA Good Practice Guide, page 23

7 Mitigation

No mitigation is proposed as the assessment shows that the Finavon Hill Estate Wind Turbine can meet the ETSU-R-97 lower limit of 35dB(A) at all properties when considered on its own and cumulatively.

8 Summary of Predicted Impacts and Effect

Wind turbine noise calculations have been carried out to assess the significance of noise impacts on residential amenity due the proposed scheme on its own and cumulatively with the consented Carsegownie wind turbine.

It has been demonstrated that the Finavon Hill Estate Wind Turbine would meet a fixed noise limit of 35dB(A) at all non-financially involved properties and 45dB(A) at properties with a financial interest when considered on its own.

Furthermore, it has been demonstrated that the proposed scheme is not predicted to produce noise levels that could exceed ETSU-R-97 noise limits when the Finavon Hill Estate Wind Turbine is considered alongside the consented Carsegownie wind turbine operating at its maximum permitted levels.

9 Conclusion

It is concluded that this proposal can be accommodated in terms of noise both on its own and cumulatively.

Appendix A – Noise Data Sheets

HAYES MCKENZIE

PARTNERSHIP

Prepared for:

Endurance Wind Power, Inc.
#107-19052 26th Ave
Surrey, BC
Canada, V3S 3V7

Endurance E-3120 Wind Turbine Acoustic Performance Test

Report HM: 2300/R1

6th April 2011

16a The Courtyard, Dean Hill Park, West Dean, Salisbury SP5 1EY, UK
Tel. +44 (0)1794 342343, Fax +44 (0)1794 342344, hmpl@hayesmckenzie.co.uk
● Offices in Salisbury & Machynlleth ●

ENDURANCE E-3120 WIND TURBINE

ACOUSTIC PERFORMANCE TEST

Report HM : 2300/R1

6th April 2011

Final Version

Prepared by: Rob Shepherd MEng, MIOA, AMImechE
Checked by: Sylvia Broneske Dipl.-Ing. MIOA, VDI
Approved by: Andrew R McKenzie PhD, BSc, MIOA

Contents

Tables

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 50 kW, which is achieved at a wind speed of approximately 9.5 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. The turbine's specification, as required by IEC 61400-11 and 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
Serial Number	EWP-E-01-00123
Type (upwind/downwind)	Downwind, horizontal axis
Hub Height	25m
Rotor Diameter	19.2m
Tower Type	Free-standing Monopole
Turbine Control (stall/pitch)	Passive stall
Rotational Speed	Constant, 43 rpm
Rated Power	50 kW (at 9.5 m/s at rotor centre)
Cut-in Wind Speed	3.5 m/s
Cut-out Wind Speed	25 m/s
Control Software Version	PLC Phoenix Contact - PLC Code version 1.4.11
Rotor Control Devices	Full blade pitching (centrifugally activated)
Blade Type	Fibreglass / epoxy
Number of Blades	3
Gearbox Manufacturer	Flender
Gearbox Type	3 parallel stages
Generator Manufacturer	ABB
Generator Rotational Speed	1500 rpm

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. The insertion loss of the secondary wind shield is shown at Appendix C. The ground board was 20mm plywood with a diameter of 1000mm.

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), and the anemometer was moved during the survey to ensure that it was within allowable tolerances.

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 from the turbine operational data once a minute 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 would 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.

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.

[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)

Secondary Windshield – Performance detailed at Appendix C

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, and all measurements were averaged over one minute, with the exception of the air pressure which was sampled every one minute.

Non-Acoustic Data

4.5 Table 3 below details the non-acoustic data reported as required by IEC 61400-11.

Table 3 – Non-acoustic Data

Wind speed determination method	Measured 10m height
Roughness length	0.05m
Air temperature, day 1	5.9 - 9.1ºC
Air temperature, day 2	6.3 - 9.5 ºC
Atmospheric pressure, day 1	1000.0 – 1002.0 mB
Atmospheric pressure, day 2	995.6 – 999.5 mB
Wind direction range, day 1	254.4 – 332.7º
Wind direction range, day 2	238.0 – 280.7º

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 D shows the measured operational noise and measured background noise at the microphone position, plotted against the measured 10m-height wind speed. Table 4 below details the number of operational data points in each wind speed range measured over the 2 days.

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

Table 4 – 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, as it fits the data better than a 4th order regression line.

5.5 The $L_{WA.k}$ has been calculated using the formula below specified in IEC 61400-11. A correction has been applied to account for secondary wind shield, which has been calculated from the measured 1/3 octave band levels across wind speeds from 3-12 m/s.

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

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 E and in tabular form below at Table 5. Note that the results shown at Appendix E are not corrected for the presence of the secondary wind shield.

Table 5 - 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
Secondary Wind Shield Correction	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5
Apparent Sound Power Level, $L_{WA,k}$ (dB L_{WA})	**87.1**	**87.3**	**87.6**	**88.1**	**89.0**	**90.6**	**92.4**	**94.3**	**95.4**	**94.9***

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 F, which also shows the octave band levels. The data has been corrected for the insertion loss of the secondary wind shield.

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 G, 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. Note that the 6m/s background noise has been subtracted from the 7m/s spectrum as there was no background noise data for 7m/s. 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 H. Note that the data has not been A-weighted or corrected for the insertion loss of the secondary wind shield.

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 H 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 6 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 7, is ± 1.6 dB for the Reference Position.

Table 6 - Calculation of L_{WA} Uncertainty U_A

Number of Elements	191
Standard Error U_A	0.728

Table 7 - 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.

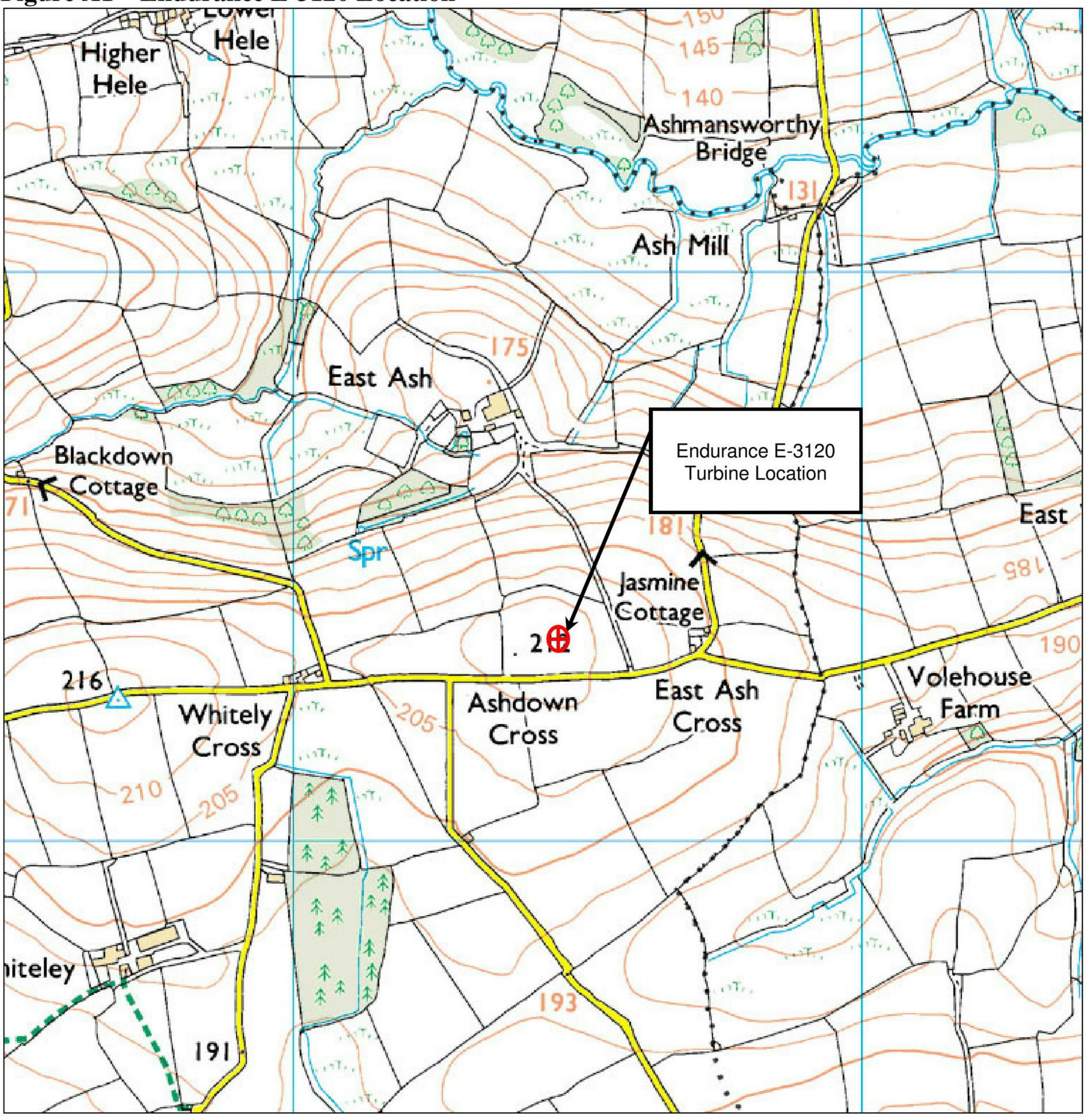
8.3 The tonal output from the Endurance E-3120 turbine has been assessed using the methodology prescribed by IEC 61400-11 for wind speeds of 6-10 m/s and has been determined to be not tonal, except at a wind speed of 6m/s where tones were identified.

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
Secondary Wind Shield Insertion Loss

The University of Salford Salford Greater Manchester M5 4WT UK www.salford.ac.uk
Telephone 0161 295 3223 Facsimile 0161 295 5575

TEST REPORT No : MI/04/04 **DATE OF ISSUE : 21 September 2004**

Measurement of the Insertion Loss of Microphone Windshields

CLIENT:	Haynes M^{c}Kenzie Partnership Lintrathen House West Dean Salisbury SP5 1JL
JOB NUMBER:	A04/65
TEST SAMPLE:	Double skin tripod mounted and secondary windshields
MANUFACTURER:	None specified
DATE RECEIVED:	1 September 2004
DATE OF TEST:	17 September 2004

Signed:[redacted]
D J M^{c}Caul
Laboratory Manager

Approved:.....[redacted]
G Kerry
Technical Manager

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2000

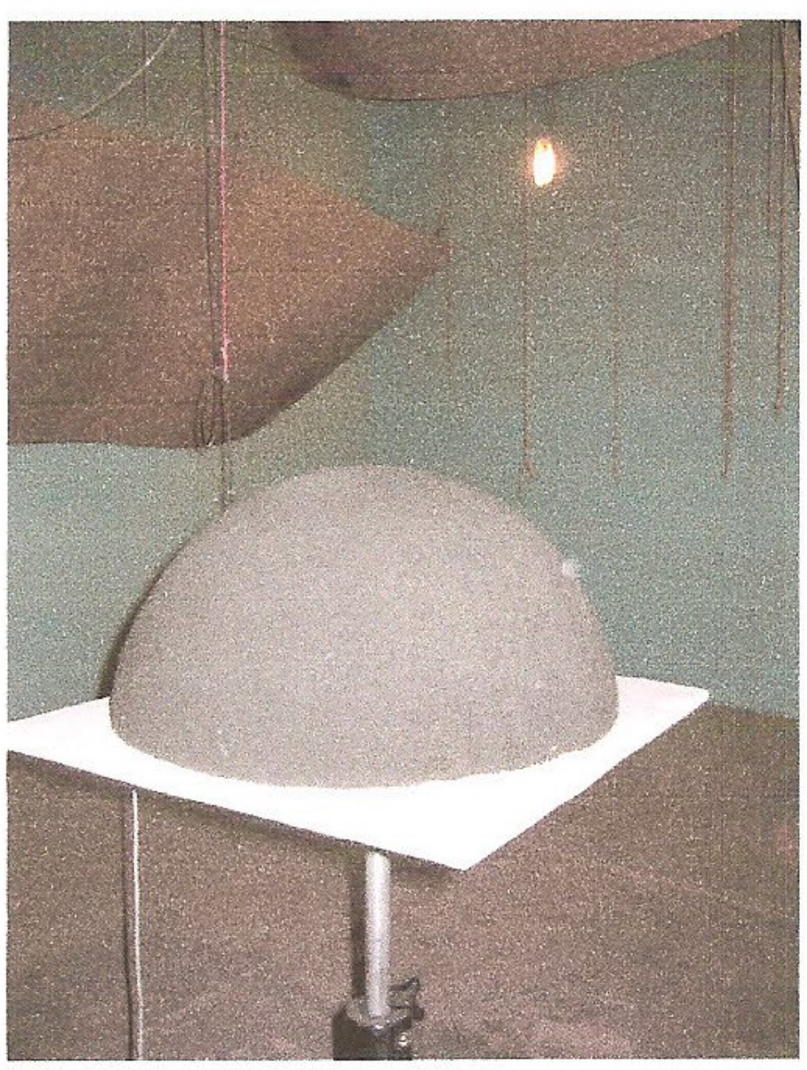
Faculty of Science, Engineering, & Environment
School of Computing, Science & Engineering

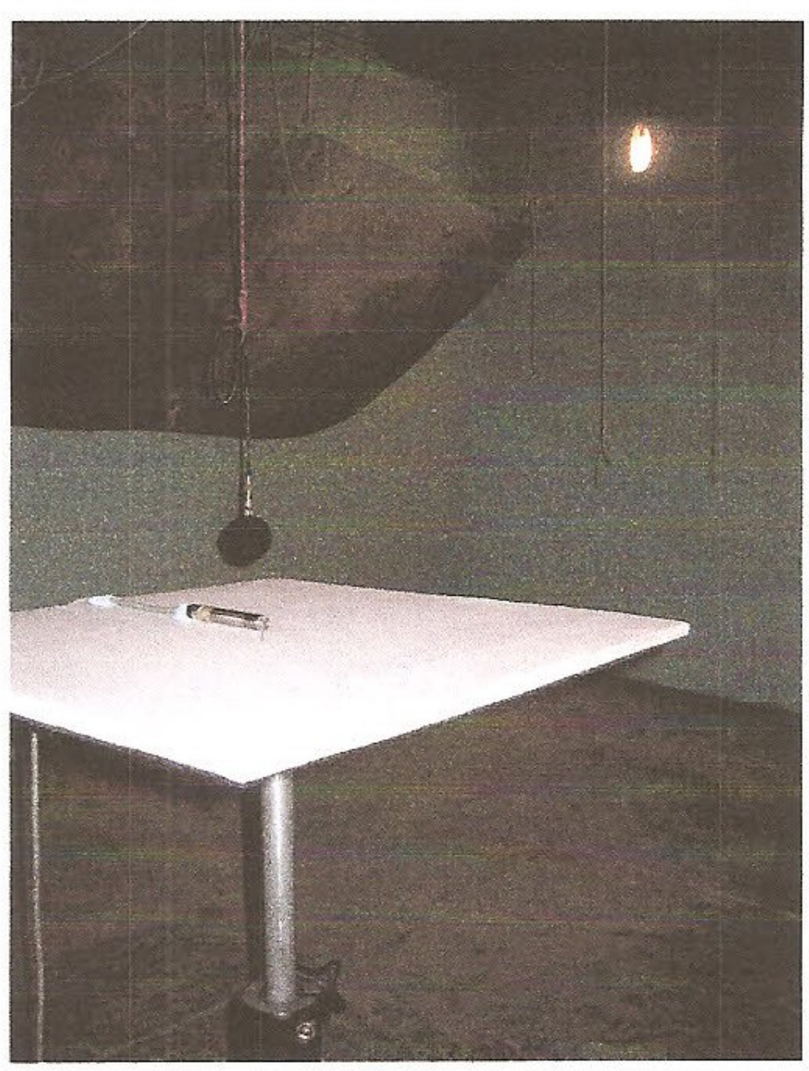
TEST SAMPLES

Description of Test Samples

Test Ref: MI/04/09/03

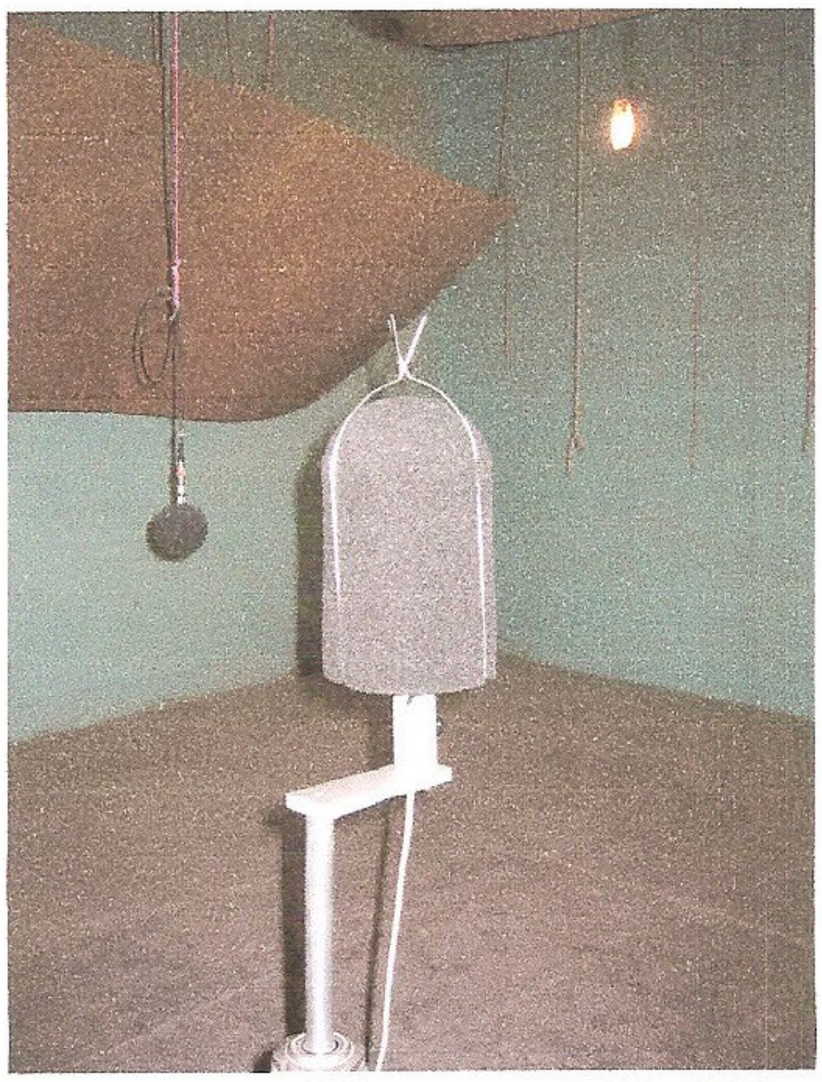
Secondary windshield, external diameter 450mm, mounted on a section of plasterboard with dimensions: 480mm x 480mm x 12.5mm and weighing 2.5kg.

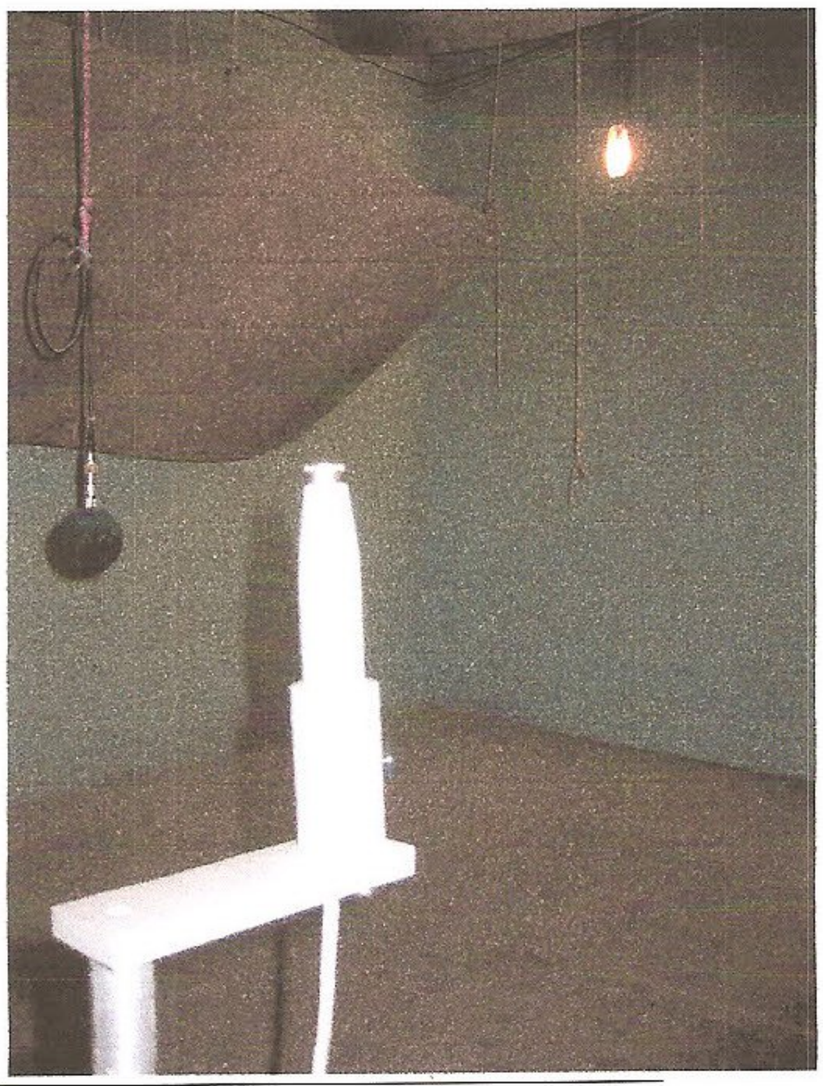




Test Ref: MI/04/09/04

Double skin tripod mounted windshield, external diameter 120mm.





DESCRIPTION OF TEST PROCEDURE

Description of Test Facility

The tests were carried out in the large reverberation room at the University of Salford. The room has been designed with hard surfaces and non-parallel walls to give long empty room reverberation times with uniform decays. It has the shape of a truncated wedge. In addition 11 plywood panels, each panel 1.22m x 2.44m, were hung in the room to improve the diffusivity of the sound field. The test sample was placed in the centre of the room and >1100mm above the floor of the room. The excitation signal comprised wide band random noise played into the room via a loudspeaker system mounted in a cabinet facing a corner. The room is 7.4m long x ~6.6m wide x 4.5m high. It has a volume of 225m^3 and a total surface area of 243m^2.

Test Procedure

Measurements were made over a frequency range of 20Hz to 20,000Hz in one-third octave bands with and without the test object in place. Measurements were carried out consecutively to avoid significant changes in relative humidity and temperature that influence air absorption at higher frequencies. The measurement period was 60 seconds. The insertion loss of the test object was determined by subtracting the level with the test object in place from the level without the test object in place:

$$\text{insertion loss} = \text{unoccluded} - \text{occluded} \qquad \text{(dB)}$$

A total of 12 measurements for each situation were taken, six each for two loudspeaker positions. These were then averaged.

3 EQUIPMENT

Item	Departmental Record No.
Norwegian Electronics 1/3 octave band real time analyser type 840 with in-built random noise generator	RTA2
Quad 510 power amplifier	PA7
Bruel &Kjaer microphone power supply type 2804	1848095
2 off broadband loudspeakers	LS3 & LS4
1 off G.R.A.S. random incidence condenser microphones type 40AP in the receiving room	M16
1 off Norsonic Multiplexer type 834A	MP2
HP Brio Pentium personal computer and related peripheral equipment (printer, plotter, monitor etc.)	COM6
Yamaha GQ1031BII graphic equalizer	GEQ1

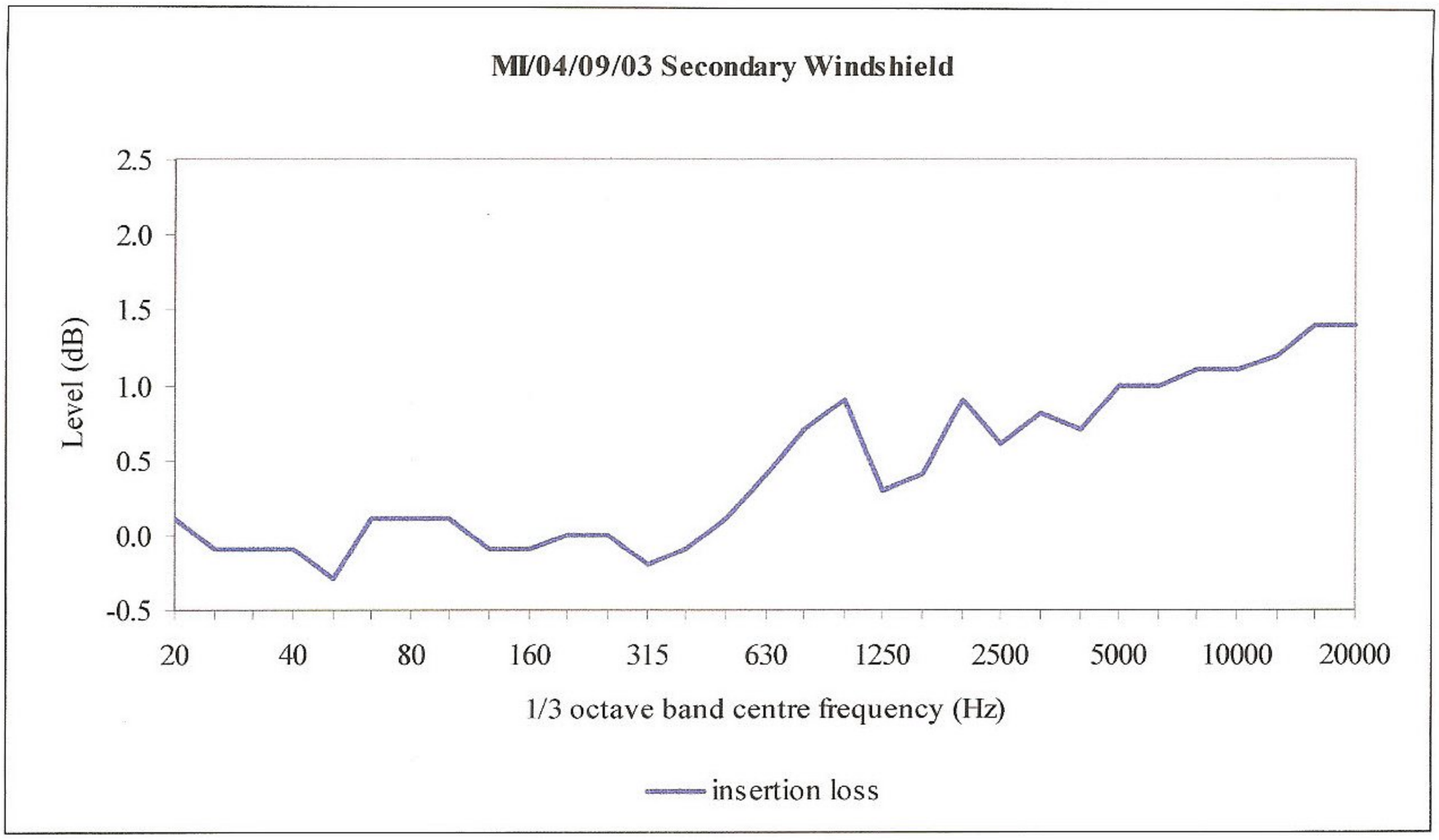
RESULTS

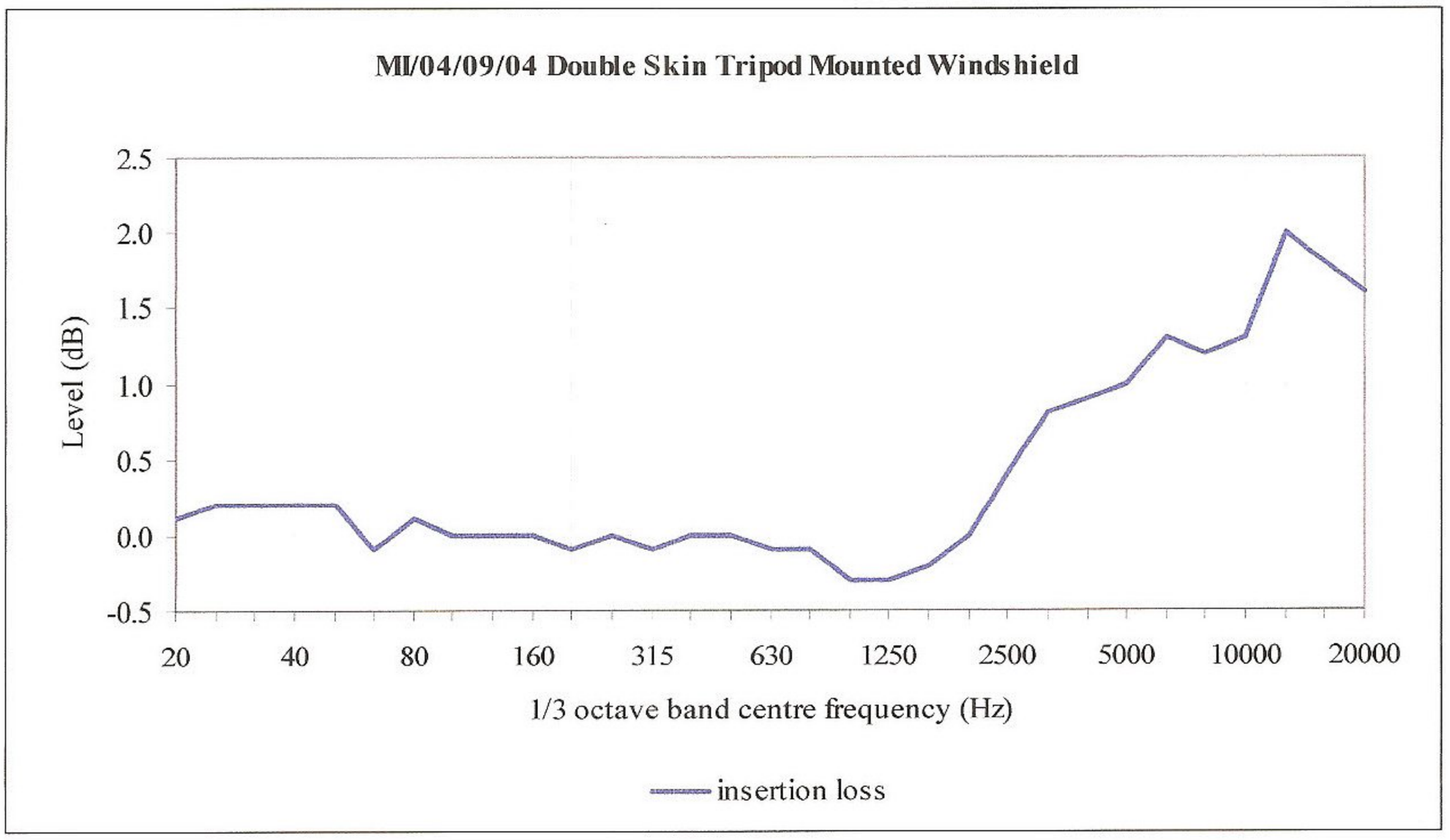
The insertion loss values at one third octave band intervals are given in the tables overleaf.

	MI/04/09/03	MI/04/09/04
Temperature in reverberation room °C:	22.5	22.6
Relative humidity in reverberation room %:	46.6	46.2

The results here presented relate only to the items tested and described in this report.

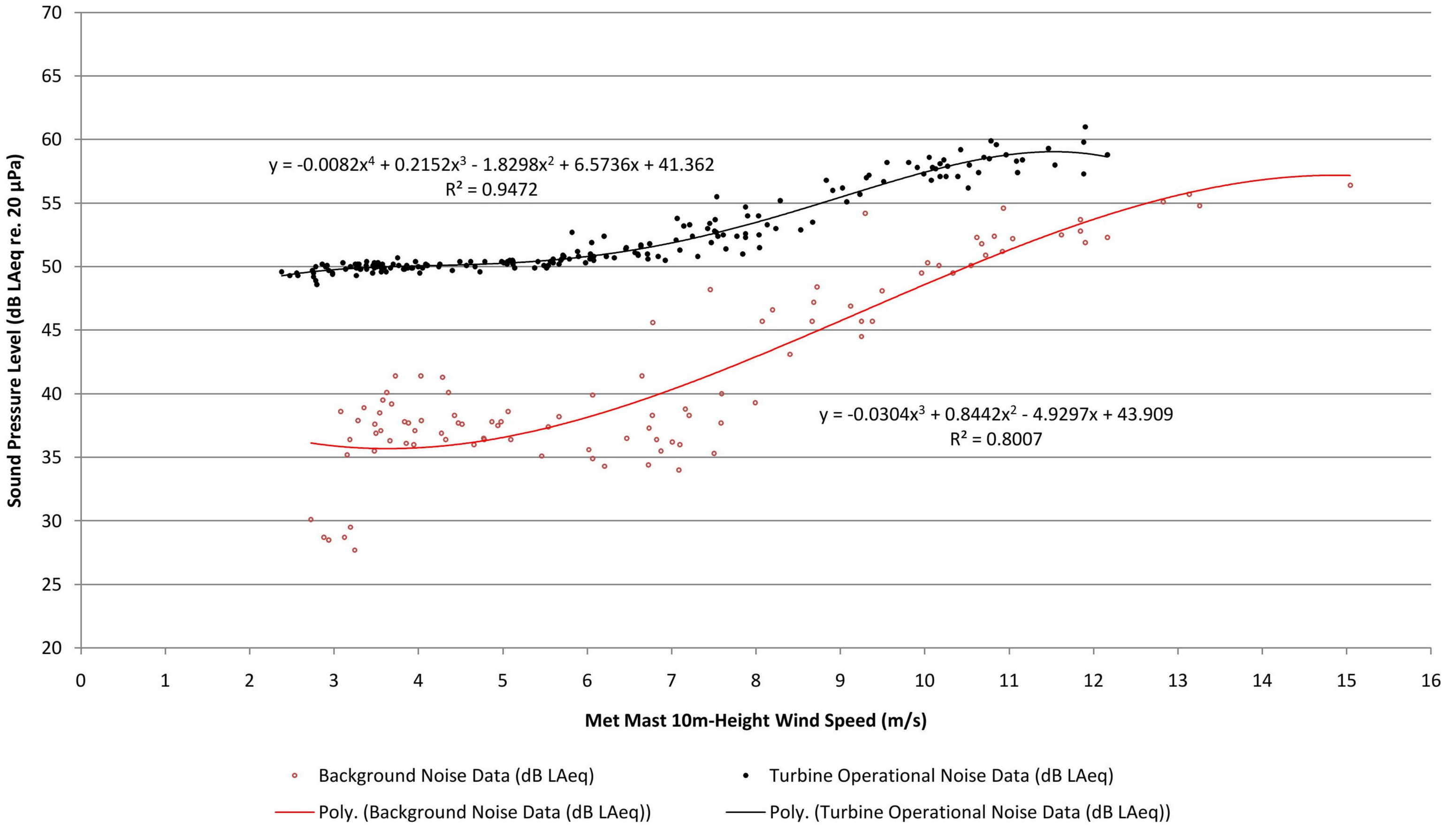
1/3		MI/04/09/03			MI/04/09/04		
OBCF (Hz)	unocc (dB)	occ (dB)	insertion loss (dB)	unocc (dB)	occ (dB)	insertion loss (dB)
20	53.6	53.5	0.1	53.1	53.0	0.1
25	60.2	60.3	-0.1	59.5	59.3	0.2
31.5	74.4	74.5	-0.1	75.1	74.9	0.2
40	79.6	79.7	-0.1	80.1	79.9	0.2
50	79.5	79.8	-0.3	79.7	79.5	0.2
63	80.8	80.7	0.1	81.2	81.3	-0.1
80	78.4	78.3	0.1	78.7	78.6	0.1
100	85.8	85.7	0.1	85.3	85.3	0.0
125	88.9	89.0	-0.1	87.7	87.7	0.0
160	86.0	86.1	-0.1	85.3	85.3	0.0
200	85.8	85.8	0.0	85.6	85.7	-0.1
250	87.7	87.7	0.0	86.3	86.3	0.0
315	88.7	88.9	-0.2	86.1	86.2	-0.1
400	89.1	89.2	-0.1	85.6	85.6	0.0
500	90.2	90.1	0.1	86.9	86.9	0.0
630	89.4	89.0	0.4	86.5	86.6	-0.1
800	88.1	87.4	0.7	85.4	85.5	-0.1
1000	88.6	87.7	0.9	85.9	86.2	-0.3
1250	88.8	88.5	0.3	86.1	86.4	-0.3
1600	88.7	88.3	0.4	86.1	86.3	-0.2
2000	89.5	88.6	0.9	86.7	86.7	0.0
2500	89.2	88.6	0.6	86.7	86.3	0.4
3150	87.9	87.1	0.8	85.9	85.1	0.8
4000	88.9	88.2	0.7	86.2	85.3	0.9
5000	89.1	88.1	1.0	86.5	85.5	1.0
6300	73.1	72.1	1.0	70.8	69.5	1.3
8000	63.1	62.0	1.1	60.9	59.7	1.2
10000	61.2	60.1	1.1	59.4	58.1	1.3
12500	59.7	58.5	1.2	58.4	56.4	2.0
16000	53.8	52.4	1.4	51.4	49.6	1.8
20000	44.4	43.0	1.4	40.3	38.7	1.6


MI/04/09/03 Secondary Windshield
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
Level (dB)
20
40
80
160
315
630
1250
2500
5000
10000
20000
1/3 octave band centre frequency (Hz)
insertion loss

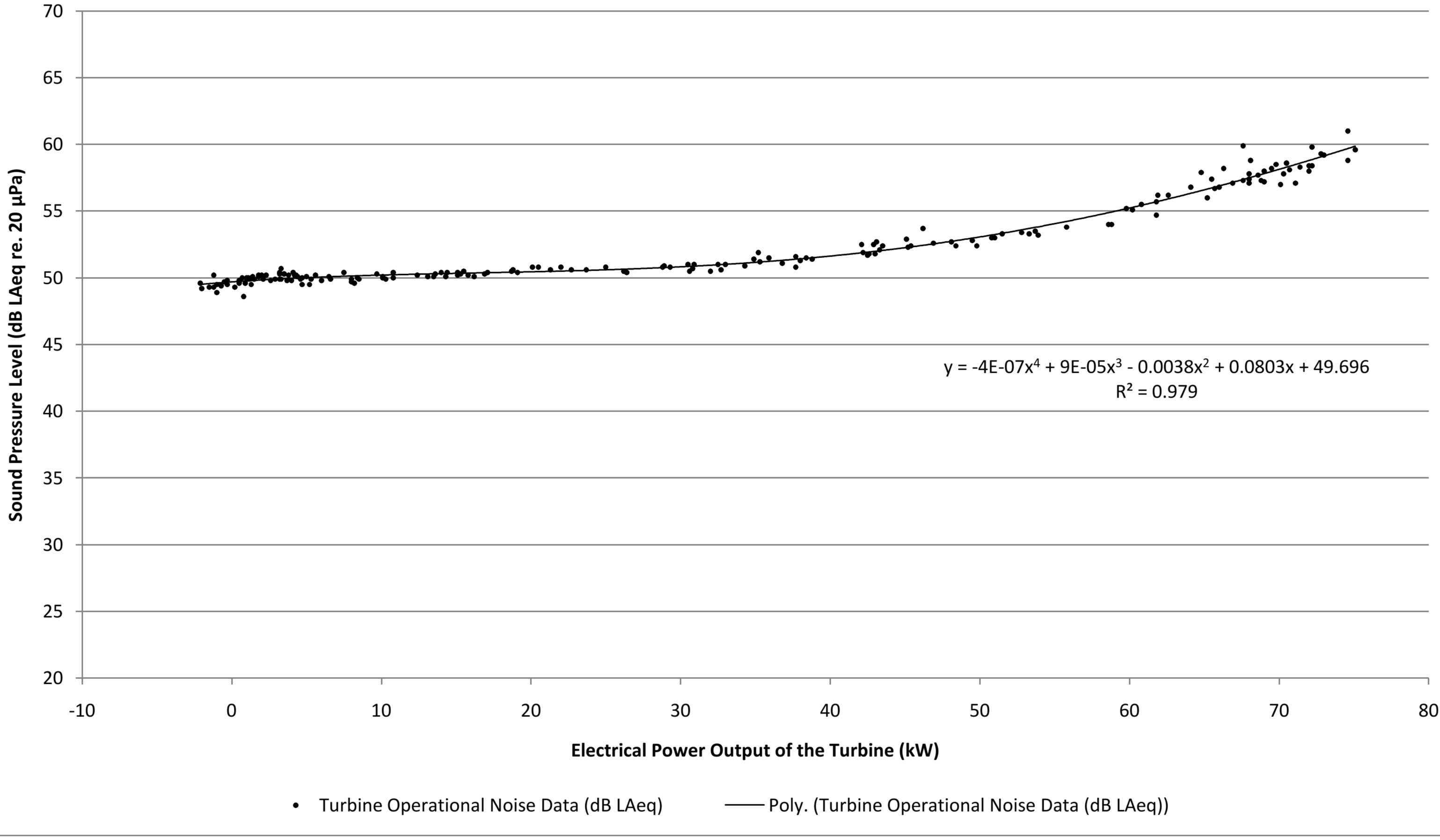

MI/04/09/04 Double Skin Tripod Mounted Windshield
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
Level (dB)
20
40
80
160
315
630
1250
2500
5000
10000
20000
1/3 octave band centre frequency (Hz)
insertion loss

Appendix D
Measured Turbine and Background Data

Endurance E-3120 - Noise Measurements
Measured Turbine and Background Noise Levels
1st and 2nd February 2011

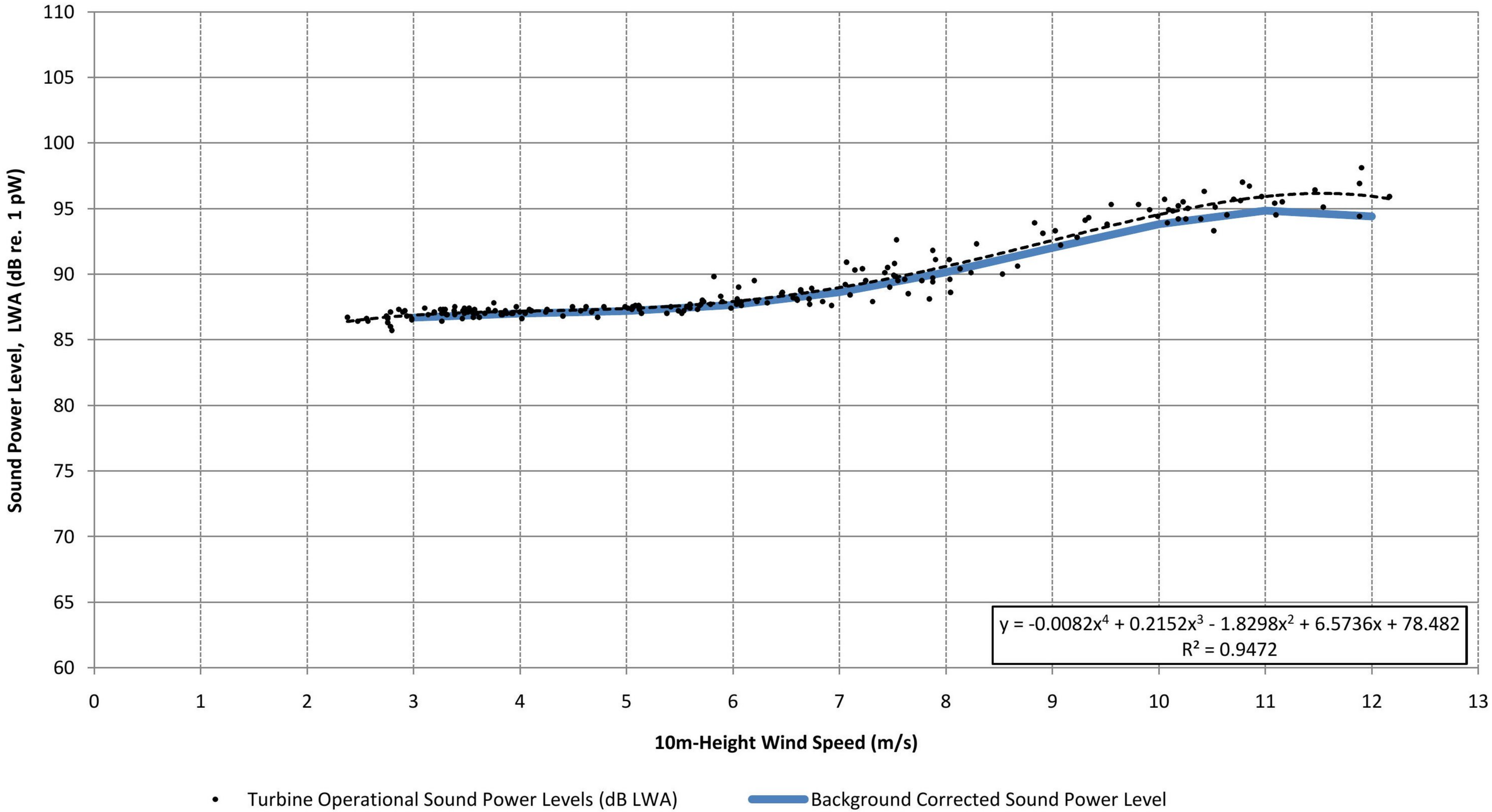


Endurance E-3120 - Noise Measurements
Measured Turbine Noise Levels Plotted against Electrical Power Output
1st and 2nd February 2011



Appendix E
Calculation of Sound Power Level

Endurance E-3120 - Noise Measurements
Calculated Sound Power Levels
1st and 2nd February 2011

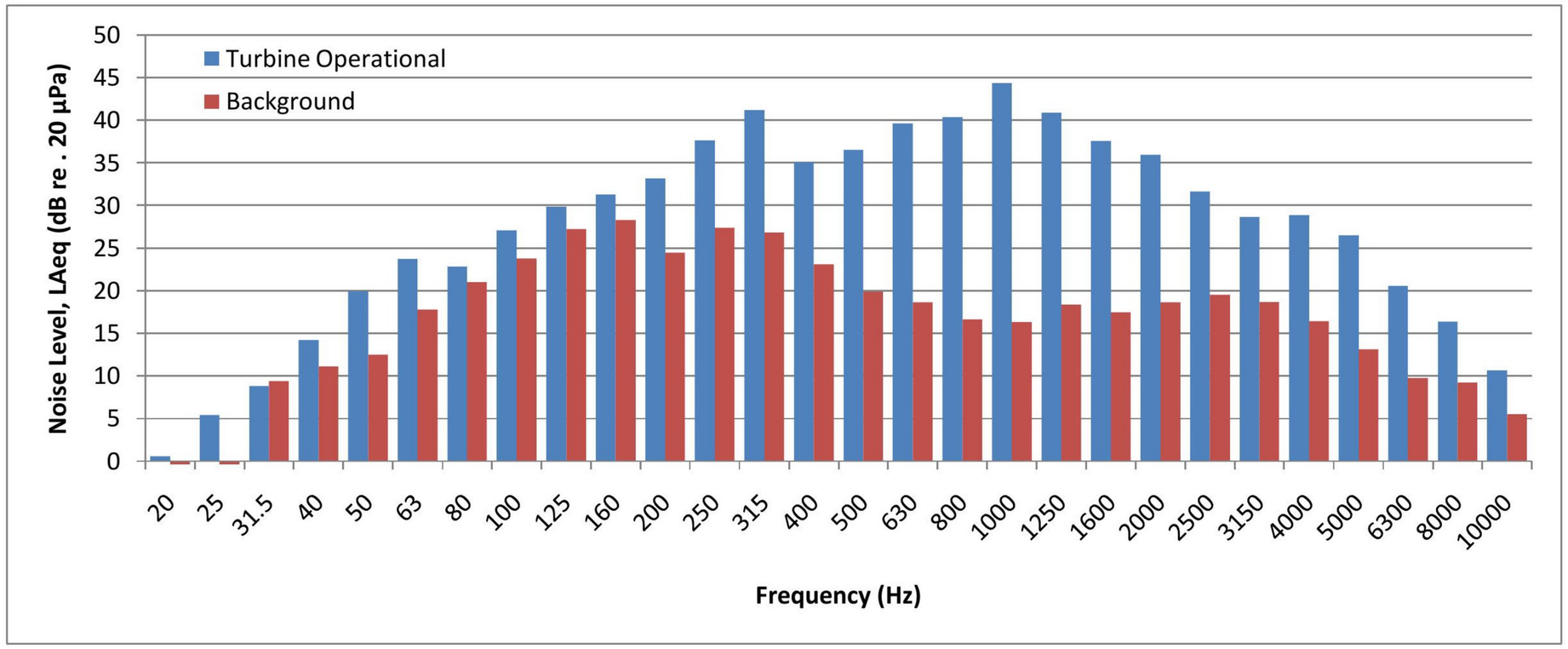


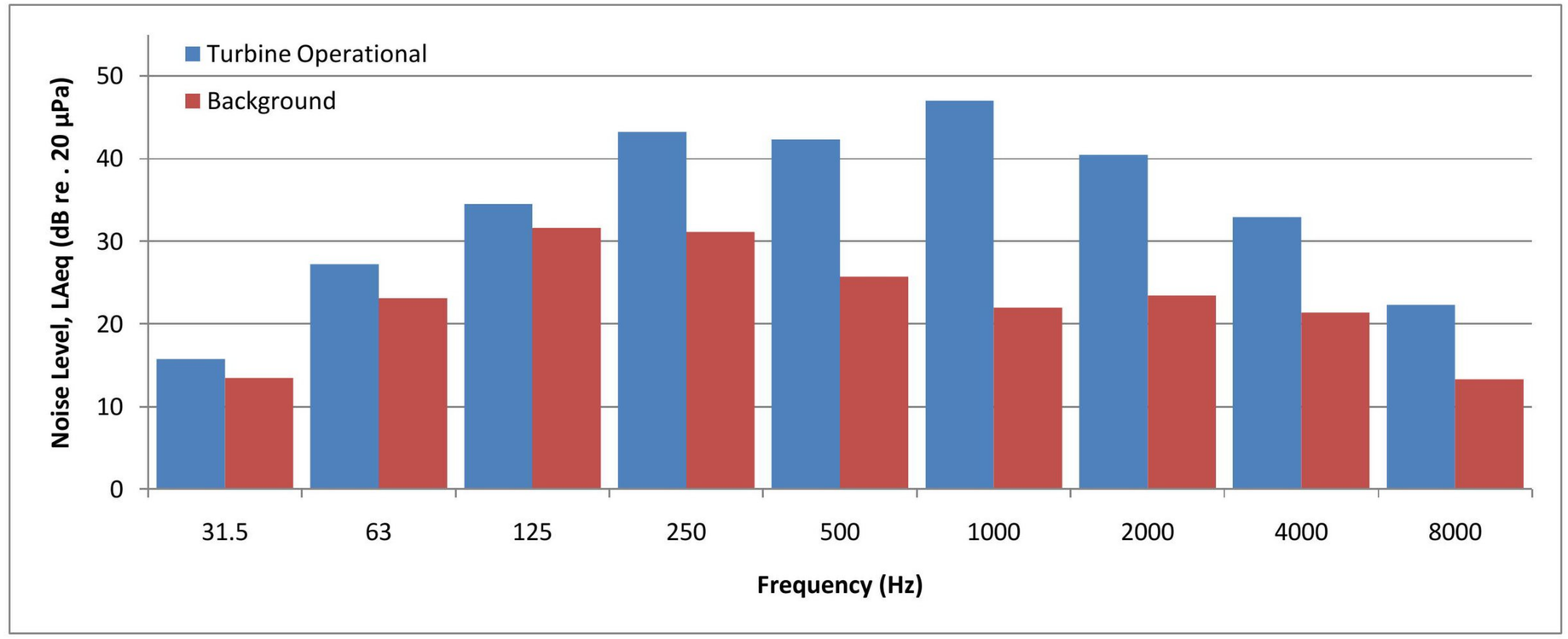
Appendix F
Measured One Third Octave Levels

HM:2300/R1

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	0.6		-10.0	
25	5.4	15.7	-2.8	13.5
31.5	8.8		9.4	
40	14.2		11.1	
50	20.0	27.2	12.5	23.1
63	23.7		17.8	
80	22.8		21.0	
100	27.1	34.5	23.8	31.6
125	29.9		27.3	
160	31.3		28.3	
200	33.2	43.2	24.5	31.2
250	37.6		27.4	
315	41.2		26.8	
400	35.1	42.3	23.1	25.7
500	36.5		19.9	
630	39.6		18.6	
800	40.3	47.0	16.6	22.0
1000	44.3		16.3	
1250	40.9		18.4	
1600	37.6	40.5	17.5	23.4
2000	36.0		18.6	
2500	31.6		19.6	
3150	28.7	32.9	18.7	21.4
4000	28.9		16.4	
5000	26.5		13.1	
6300	20.6	22.3	9.8	13.3
8000	16.4		9.2	
10000	10.7		5.5	
Overall	50.2		35.9	



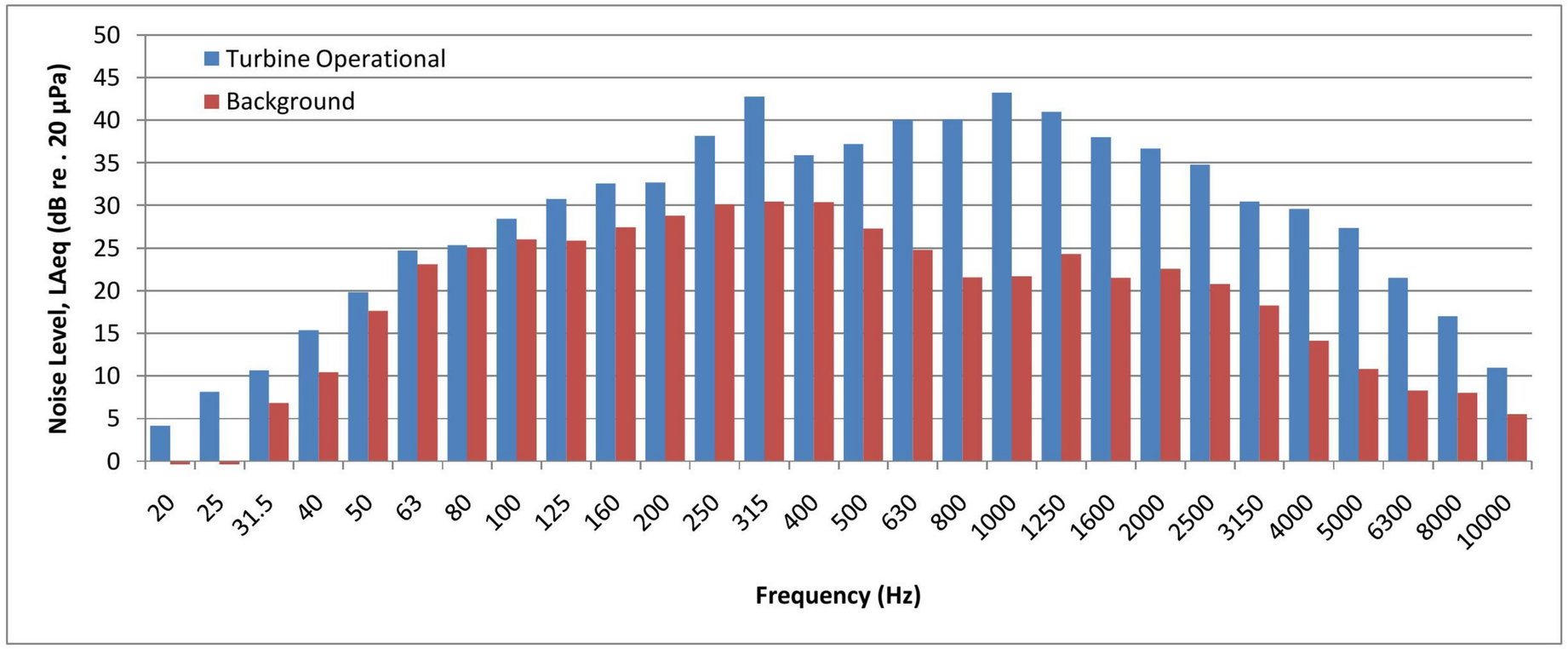


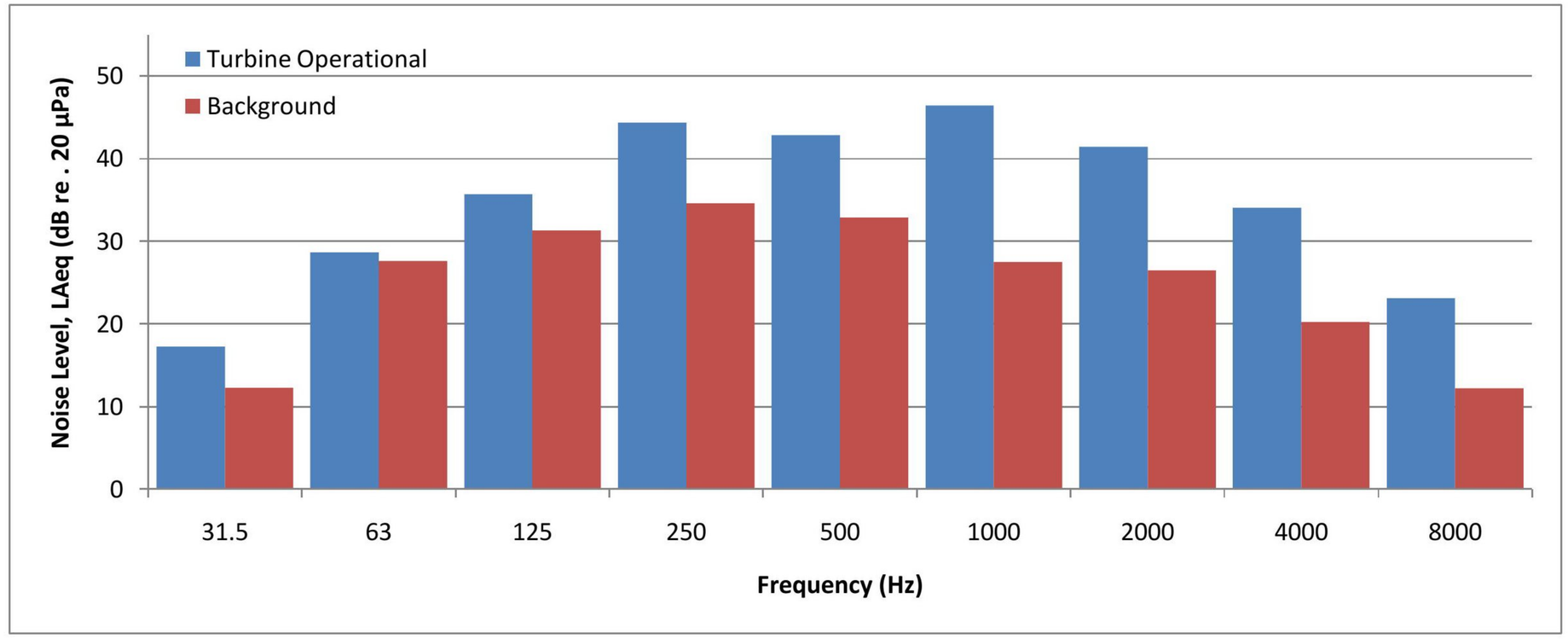
HM:2300/R1

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	4.2		-9.0	
25	8.1	17.2	-1.1	12.2
31.5	10.6		6.8	
40	15.4		10.5	
50	19.8	28.7	17.6	27.6
63	24.7		23.1	
80	25.4		25.0	
100	28.5	35.7	26.1	31.3
125	30.8		25.9	
160	32.6		27.4	
200	32.7	44.4	28.8	34.6
250	38.2		30.1	
315	42.8		30.5	
400	35.9	42.8	30.4	32.9
500	37.2		27.3	
630	40.0		24.8	
800	40.1	46.4	21.6	27.5
1000	43.3		21.7	
1250	41.0		24.3	
1600	38.0	41.5	21.5	26.5
2000	36.7		22.6	
2500	34.8		20.8	
3150	30.4	34.1	18.3	20.2
4000	29.6		14.1	
5000	27.3		10.8	
6300	21.5	23.1	8.3	12.2
8000	17.0		8.0	
10000	11.0		5.5	

Overall	50.5	39.0



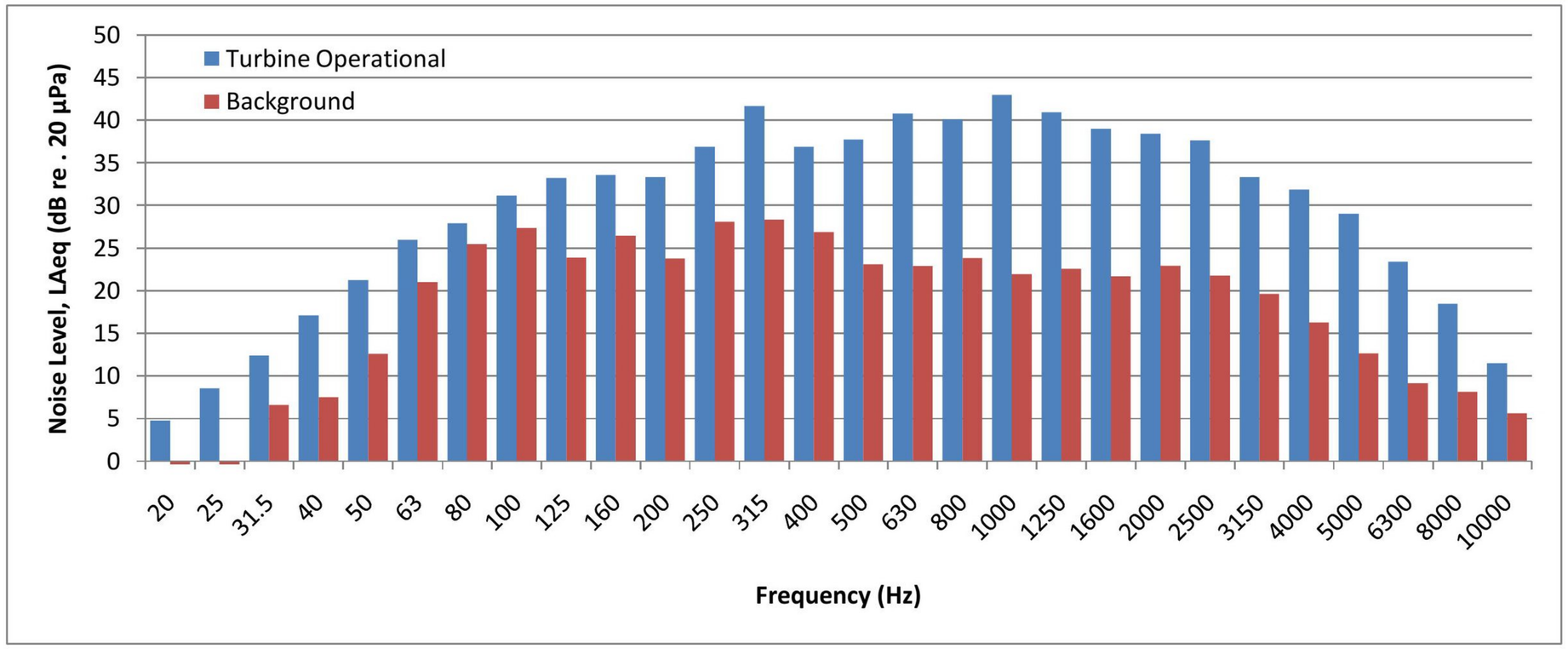


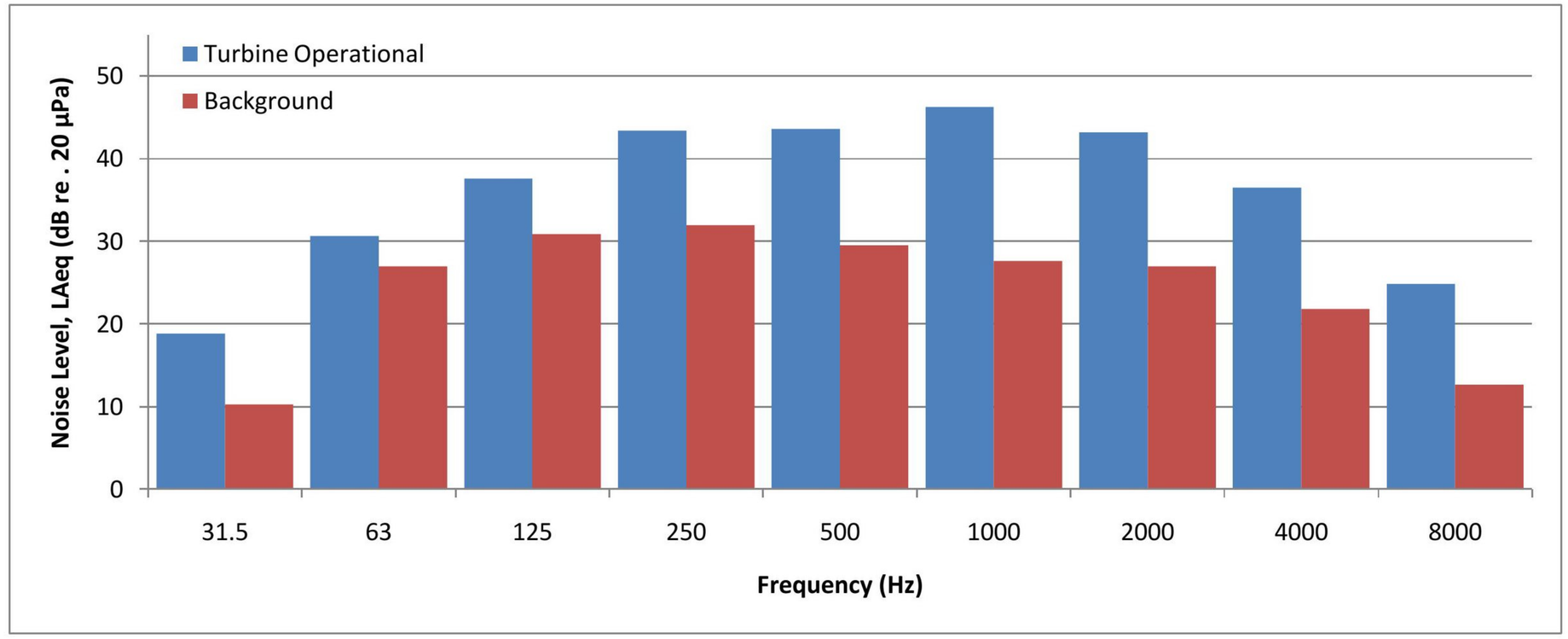
HM:2300/R1

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	4.8		-10.8	
25	8.5	18.8	-4.6	10.2
31.5	12.4		6.6	
40	17.1		7.5	
50	21.3	30.6	12.6	27.0
63	26.0		21.0	
80	27.9		25.5	
100	31.2	37.6	27.3	30.9
125	33.2		23.9	
160	33.6		26.4	
200	33.4	43.4	23.8	32.0
250	36.9		28.1	
315	41.7		28.4	
400	36.9	43.6	26.9	29.5
500	37.7		23.1	
630	40.8		22.9	
800	40.1	46.3	23.8	27.6
1000	43.0		22.0	
1250	41.0		22.6	
1600	39.0	43.2	21.7	27.0
2000	38.4		22.9	
2500	37.7		21.8	
3150	33.3	36.5	19.6	21.8
4000	31.9		16.2	
5000	29.0		12.6	
6300	23.4	24.8	9.1	12.6
8000	18.5		8.1	
10000	11.5		5.6	

Overall	50.8	37.4

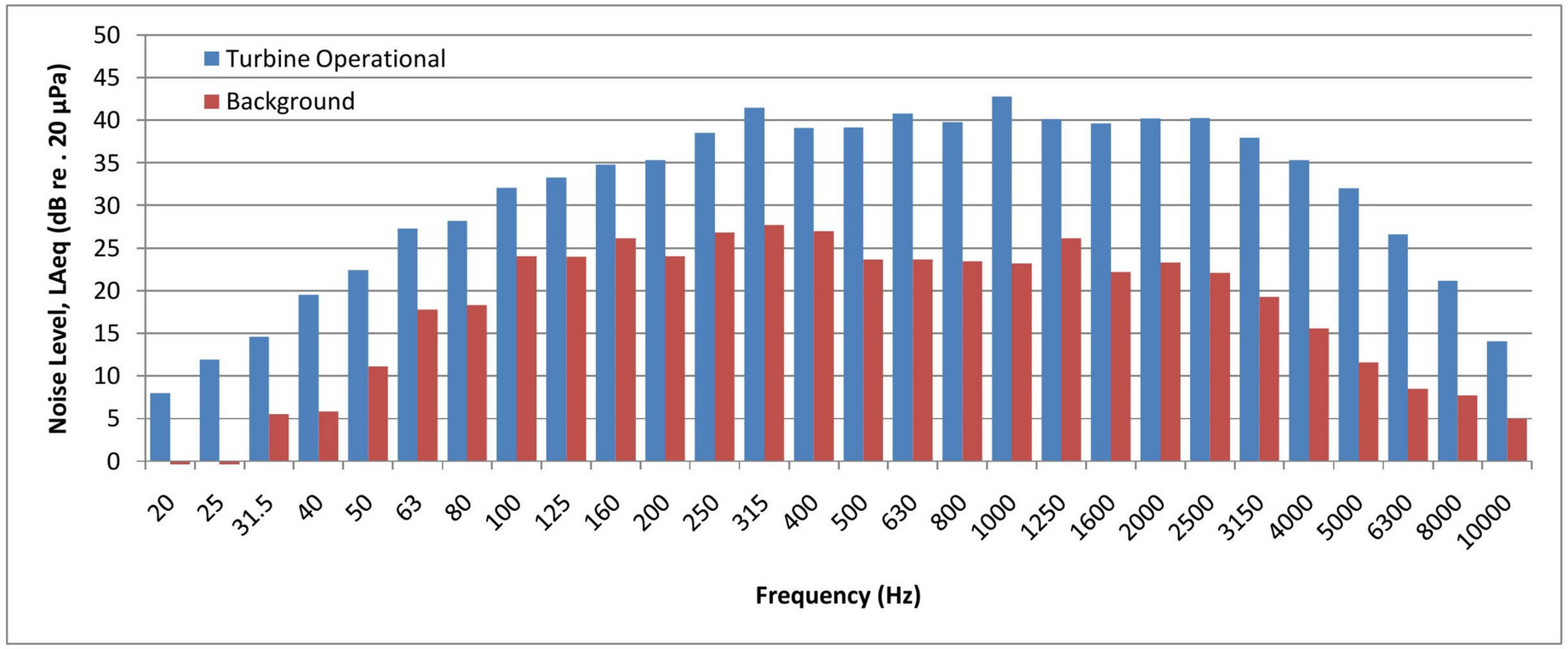


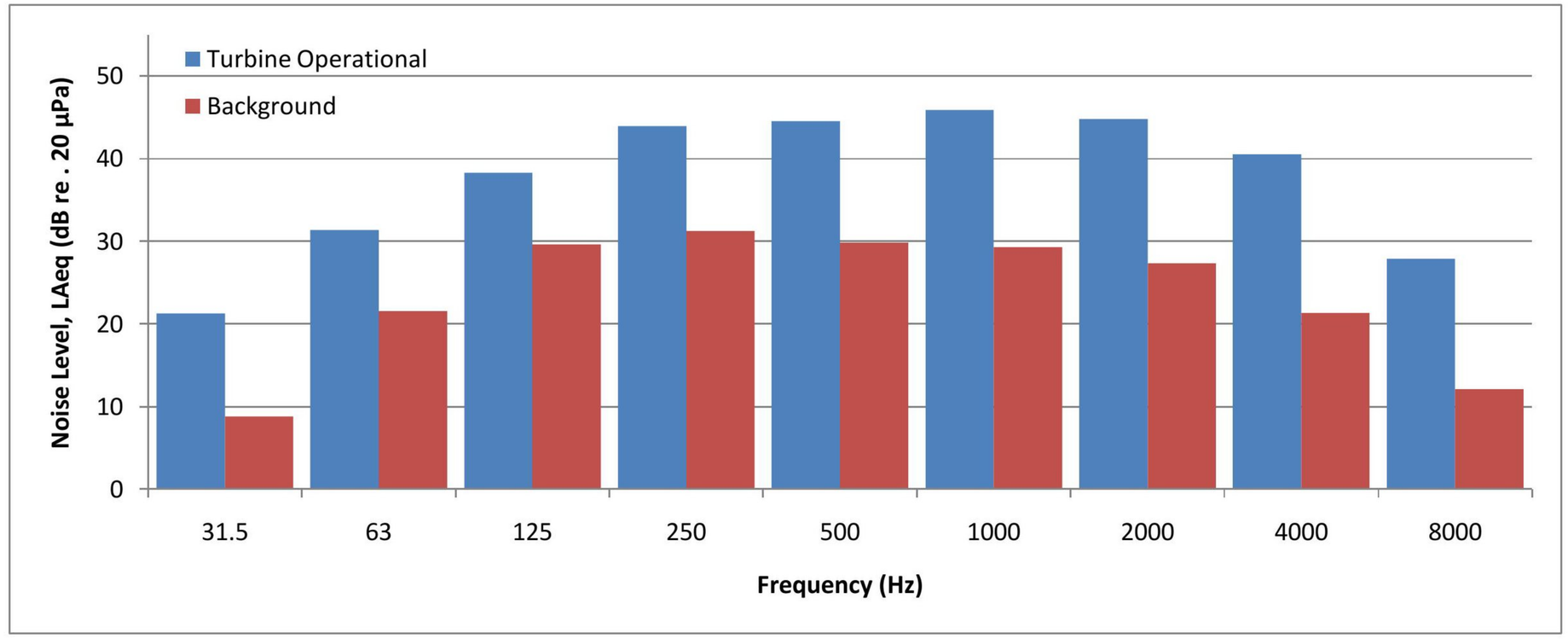


HM:2300/R1

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	8.0		-12.7	
25	11.9	21.3	-6.5	8.8
31.5	14.6		5.5	
40	19.5		5.8	
50	22.4	31.4	11.2	21.5
63	27.3		17.8	
80	28.2		18.3	
100	32.1	38.3	24.0	29.6
125	33.3		24.0	
160	34.8		26.2	
200	35.3	43.9	24.0	31.2
250	38.5		26.8	
315	41.5		27.7	
400	39.1	44.5	27.0	29.8
500	39.1		23.7	
630	40.8		23.6	
800	39.8	45.9	23.5	29.3
1000	42.8		23.2	
1250	40.1		26.2	
1600	39.7	44.8	22.2	27.3
2000	40.2		23.3	
2500	40.3		22.1	
3150	38.0	40.5	19.3	21.3
4000	35.3		15.6	
5000	32.0		11.6	
6300	26.6	27.9	8.5	12.1
8000	21.1		7.7	
10000	14.1		5.0	
Overall	51.5		36.9	





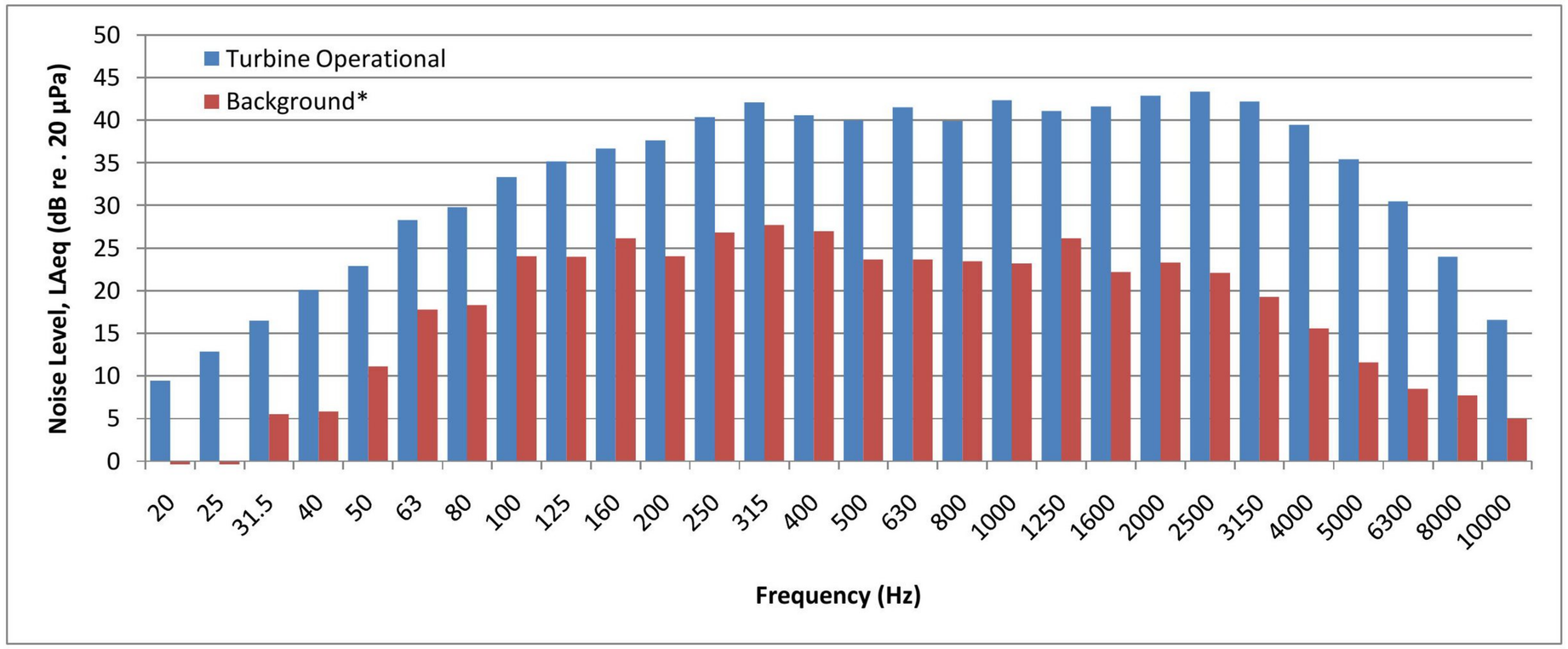
HM:2300/R1

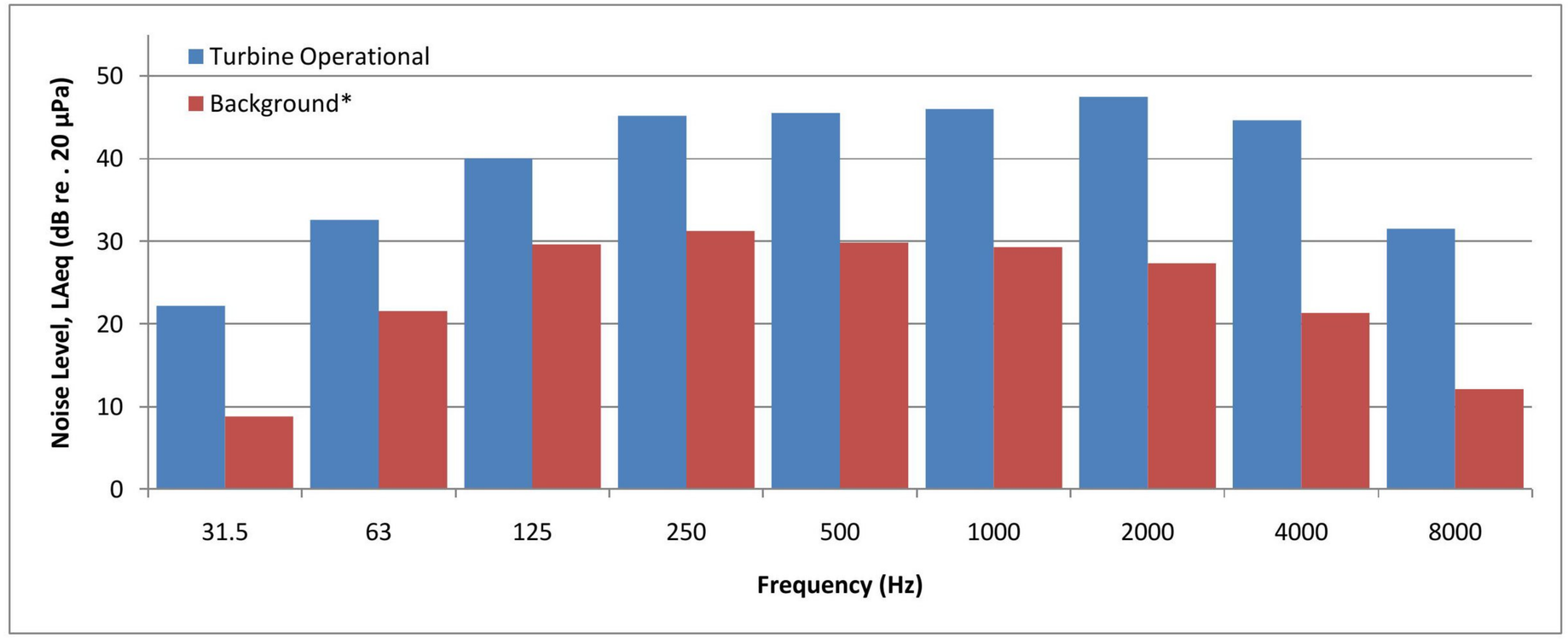
Endurance E-3120 Wind Turbine
Wind Speed - 7 m/s

	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	9.4		-12.7	
25	12.9	22.2	-6.5	8.8
31.5	16.5		5.5	
40	20.1		5.8	
50	22.9	32.6	11.2	21.5
63	28.3		17.8	
80	29.8		18.3	
100	33.3	40.0	24.0	29.6
125	35.2		24.0	
160	36.7		26.2	
200	37.7	45.2	24.0	31.2
250	40.4		26.8	
315	42.1		27.7	
400	40.6	45.5	27.0	29.8
500	40.0		23.7	
630	41.5		23.6	
800	39.9	46.0	23.5	29.3
1000	42.4		23.2	
1250	41.1		26.2	
1600	41.6	47.5	22.2	27.3
2000	42.9		23.3	
2500	43.4		22.1	
3150	42.2	44.6	19.3	21.3
4000	39.5		15.6	
5000	35.4		11.6	
6300	30.5	31.5	8.5	12.1
8000	24.0		7.7	
10000	16.6		5.0	

Overall	53.2	36.9

*Background taken from 6m/s



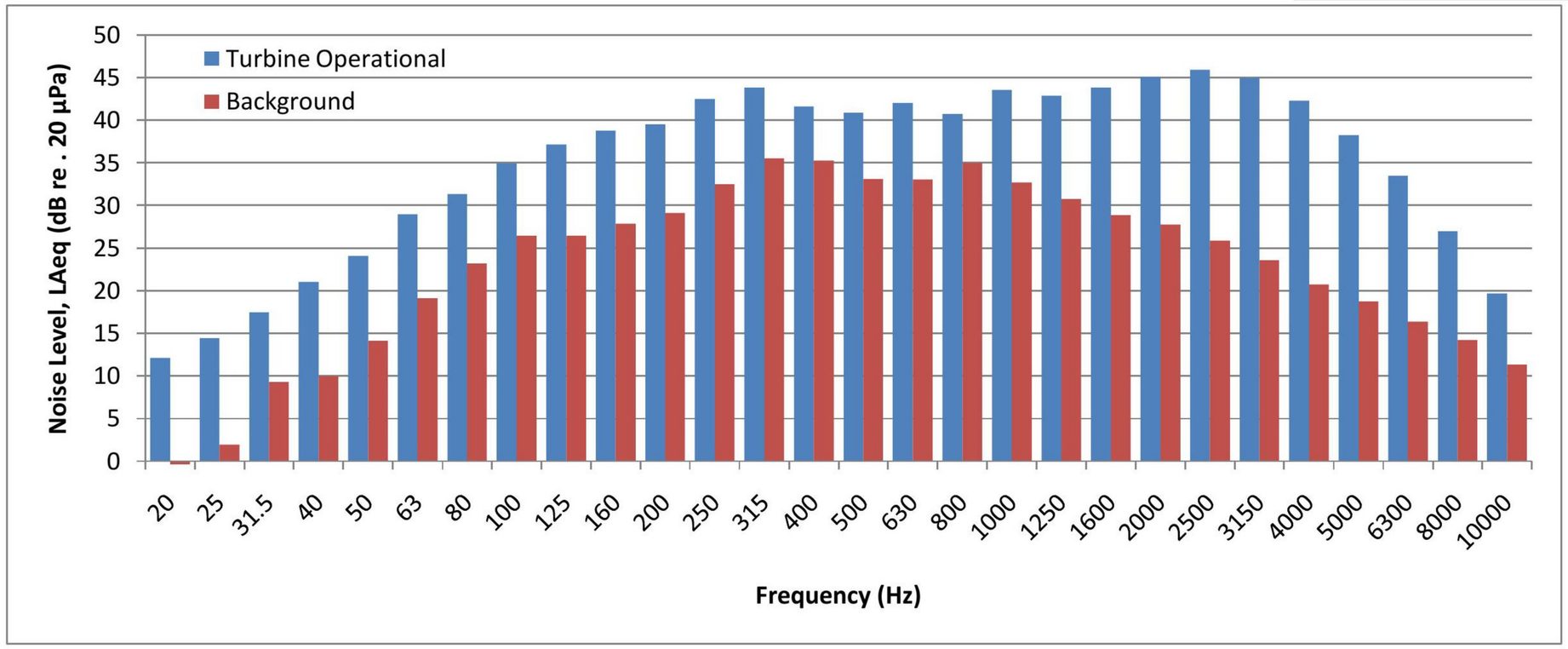


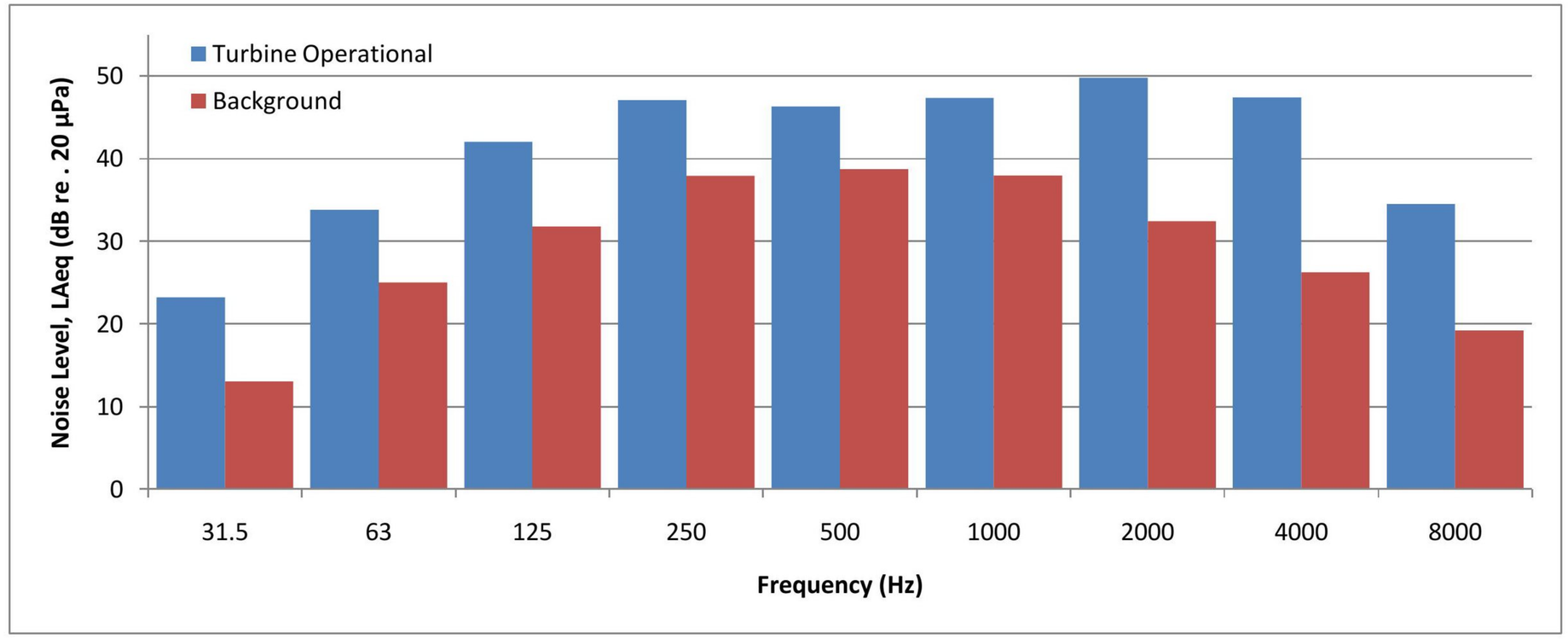
HM:2300/R1

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	12.1		-1.9	
25	14.5	23.2	2.0	13.0
31.5	17.5		9.3	
40	21.0		10.0	
50	24.1	33.8	14.1	25.0
63	29.0		19.1	
80	31.3		23.2	
100	35.0	42.0	26.5	31.8
125	37.2		26.5	
160	38.8		27.9	
200	39.5	47.1	29.2	37.9
250	42.5		32.5	
315	43.8		35.5	
400	41.6	46.3	35.3	38.7
500	40.9		33.1	
630	42.1		33.1	
800	40.7	47.3	35.0	38.0
1000	43.6		32.7	
1250	42.9		30.8	
1600	43.8	49.8	28.9	32.5
2000	45.1		27.8	
2500	45.9		25.9	
3150	45.0	47.4	23.6	26.2
4000	42.3		20.7	
5000	38.3		18.7	
6300	33.5	34.5	16.4	19.2
8000	27.0		14.2	
10000	19.7		11.3	

Overall	55.1	43.8



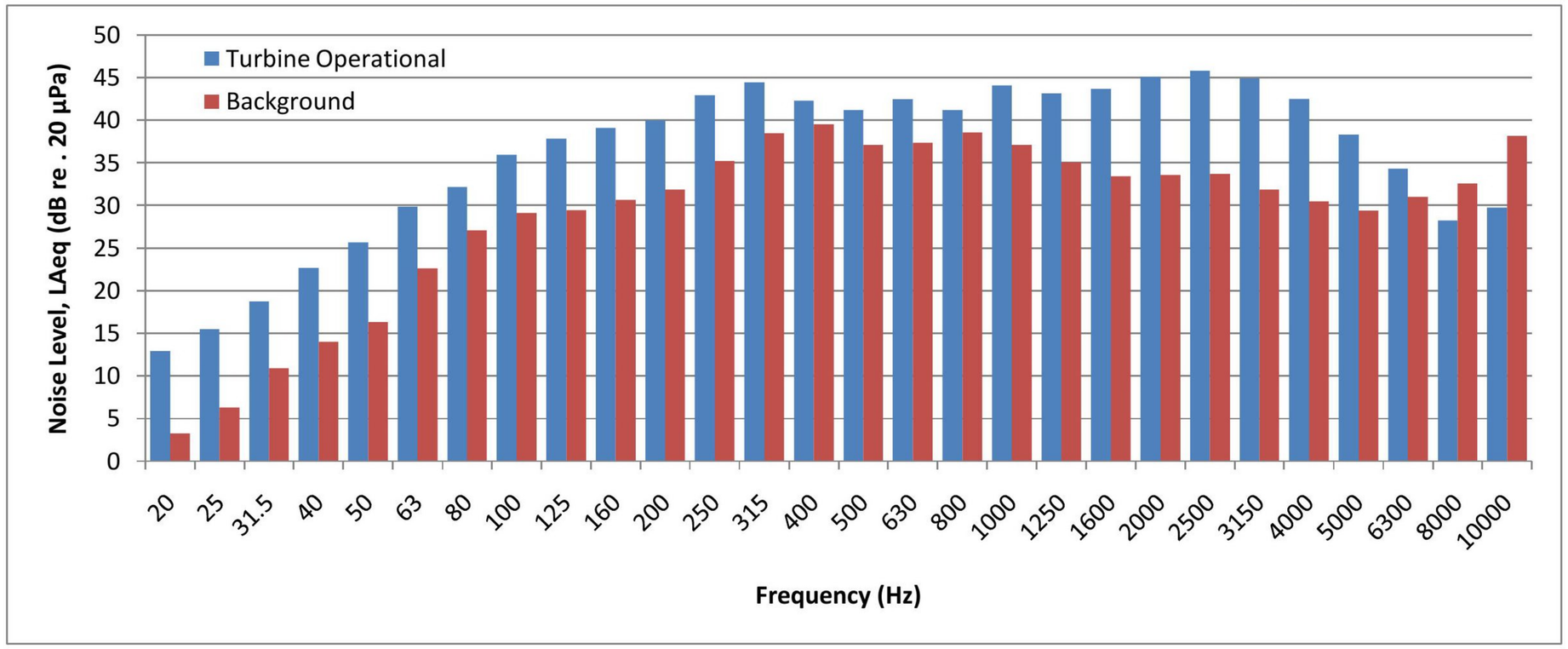


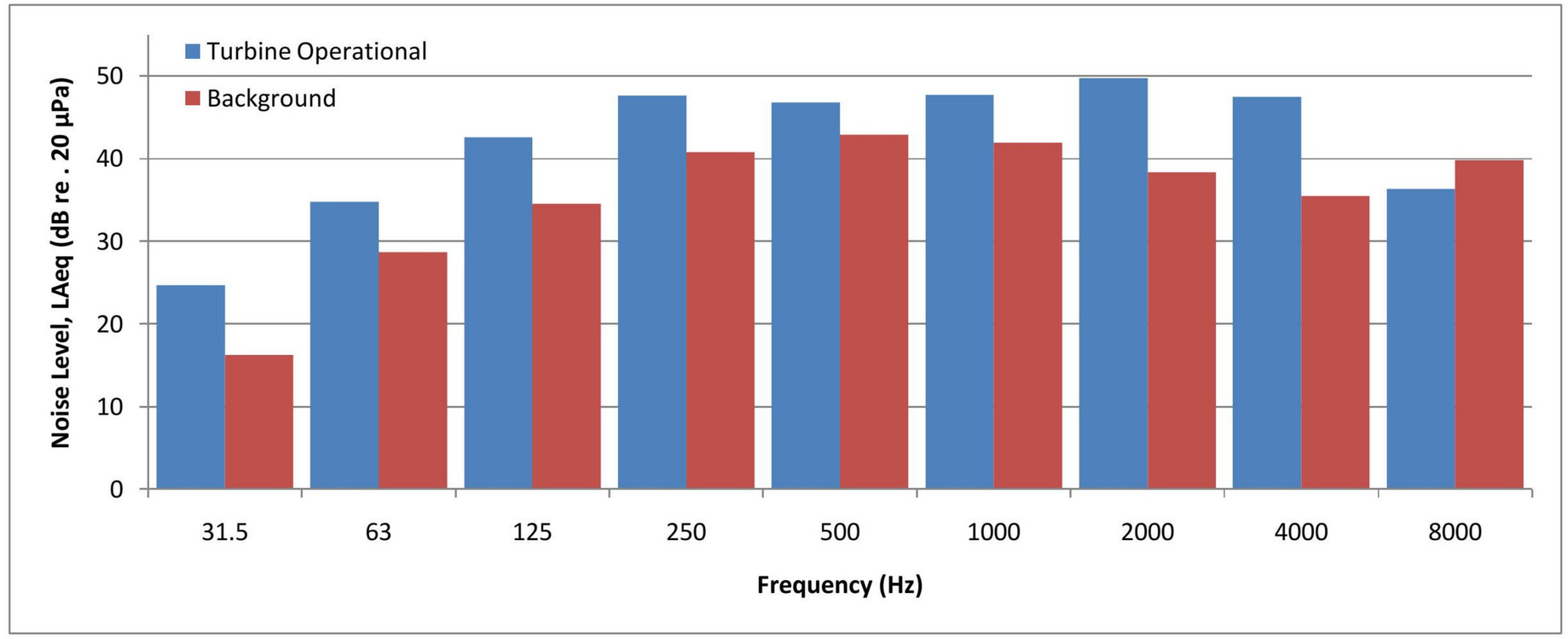
HM:2300/R1

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	12.9		3.3	
25	15.5	24.7	6.3	16.2
31.5	18.7		10.9	
40	22.7		14.0	
50	25.7	34.8	16.3	28.7
63	29.8		22.6	
80	32.2		27.1	
100	35.9	42.6	29.1	34.6
125	37.8		29.5	
160	39.1		30.6	
200	40.0	47.6	31.9	40.8
250	42.9		35.2	
315	44.5		38.5	
400	42.3	46.8	39.5	42.9
500	41.2		37.1	
630	42.5		37.4	
800	41.2	47.7	38.6	41.9
1000	44.1		37.1	
1250	43.2		35.1	
1600	43.7	49.7	33.4	38.4
2000	45.1		33.6	
2500	45.8		33.7	
3150	44.9	47.5	31.9	35.5
4000	42.5		30.5	
5000	38.3		29.4	
6300	34.3	36.4	31.0	39.8
8000	28.2		32.6	
10000	29.8		38.1	

Overall	55.3	48.5

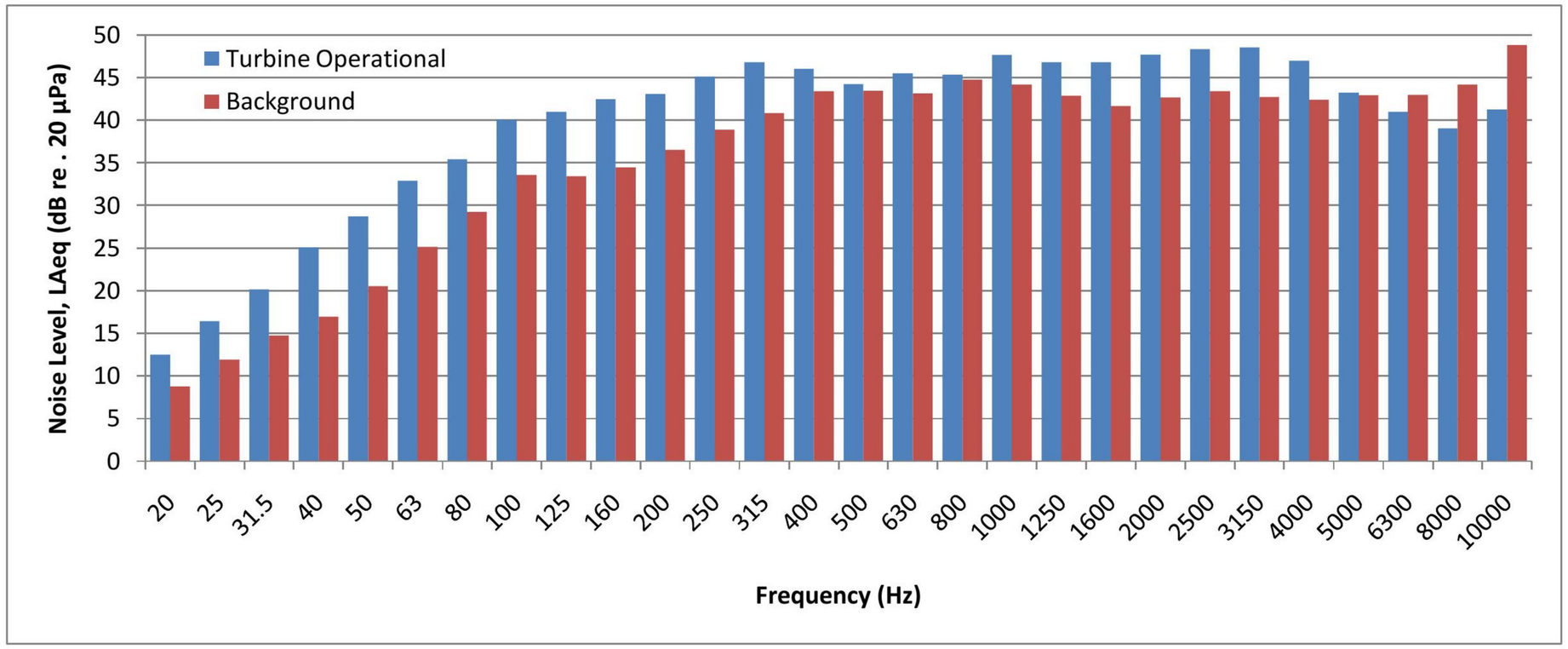


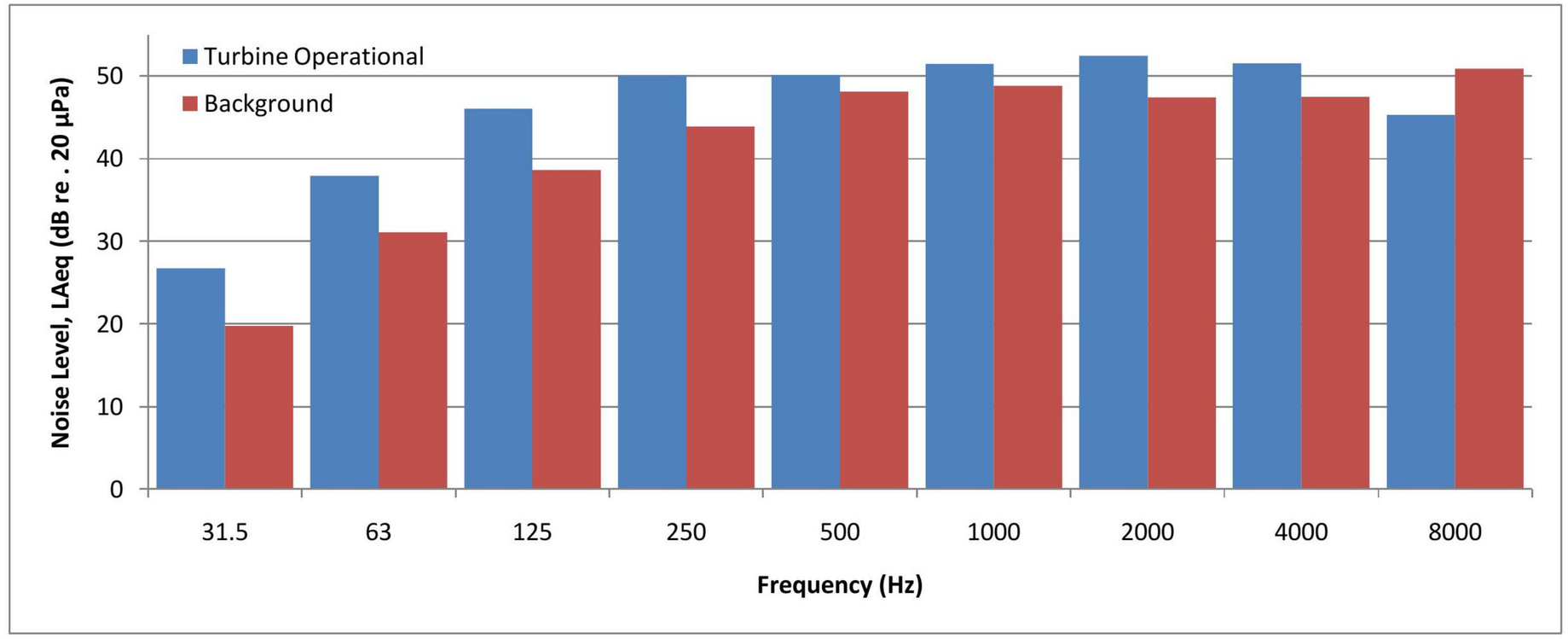


HM:2300/R1

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	12.5		8.8	
25	16.4	26.7	11.9	19.8
31.5	20.1		14.7	
40	25.1		16.9	
50	28.7	37.9	20.5	31.1
63	32.9		25.2	
80	35.4		29.3	
100	40.0	46.0	33.6	38.6
125	41.0		33.4	
160	42.4		34.5	
200	43.1	50.1	36.5	43.9
250	45.2		38.9	
315	46.8		40.9	
400	46.0	50.1	43.4	48.1
500	44.2		43.5	
630	45.5		43.2	
800	45.4	51.5	44.8	48.8
1000	47.7		44.2	
1250	46.8		42.9	
1600	46.8	52.4	41.7	47.4
2000	47.7		42.7	
2500	48.4		43.4	
3150	48.5	51.5	42.7	47.5
4000	47.0		42.4	
5000	43.2		42.9	
6300	41.0	45.3	43.0	50.9
8000	39.1		44.2	
10000	41.2		48.8	
Overall	58.7		56.1	



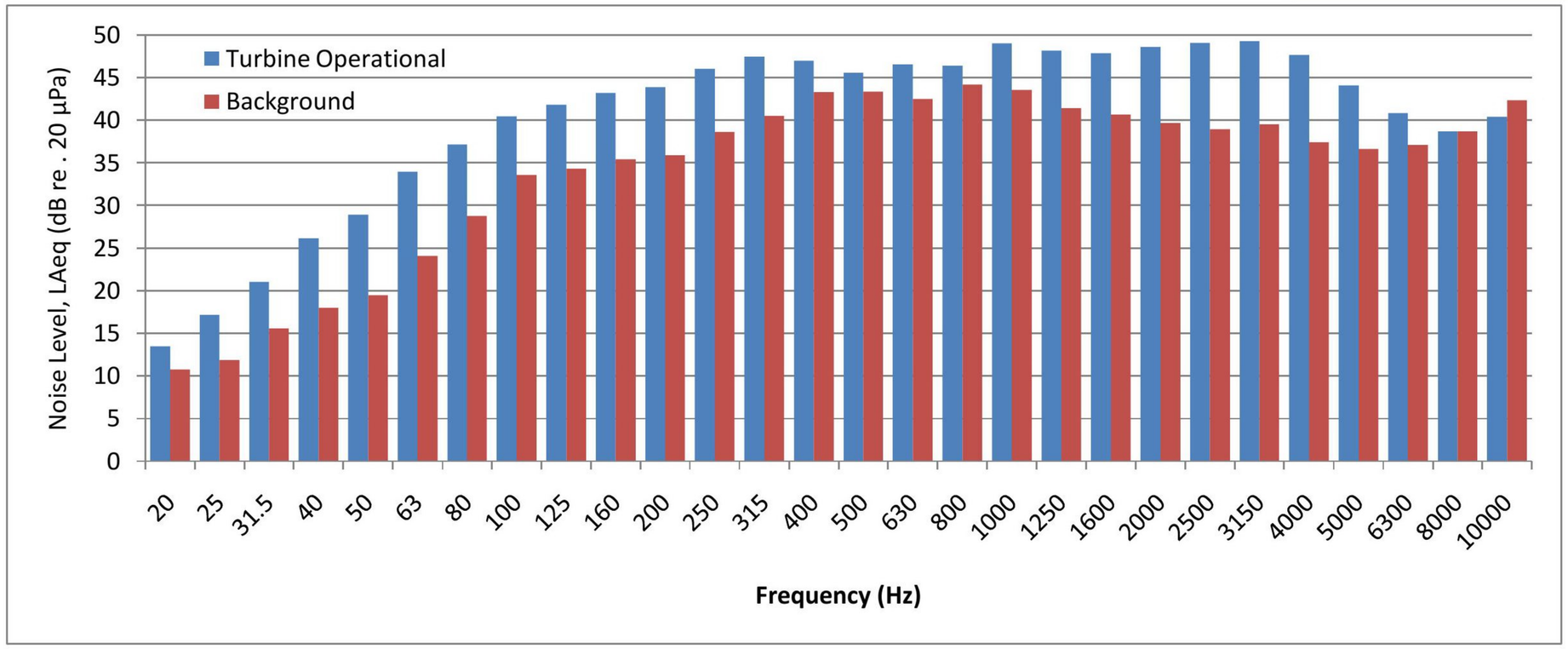


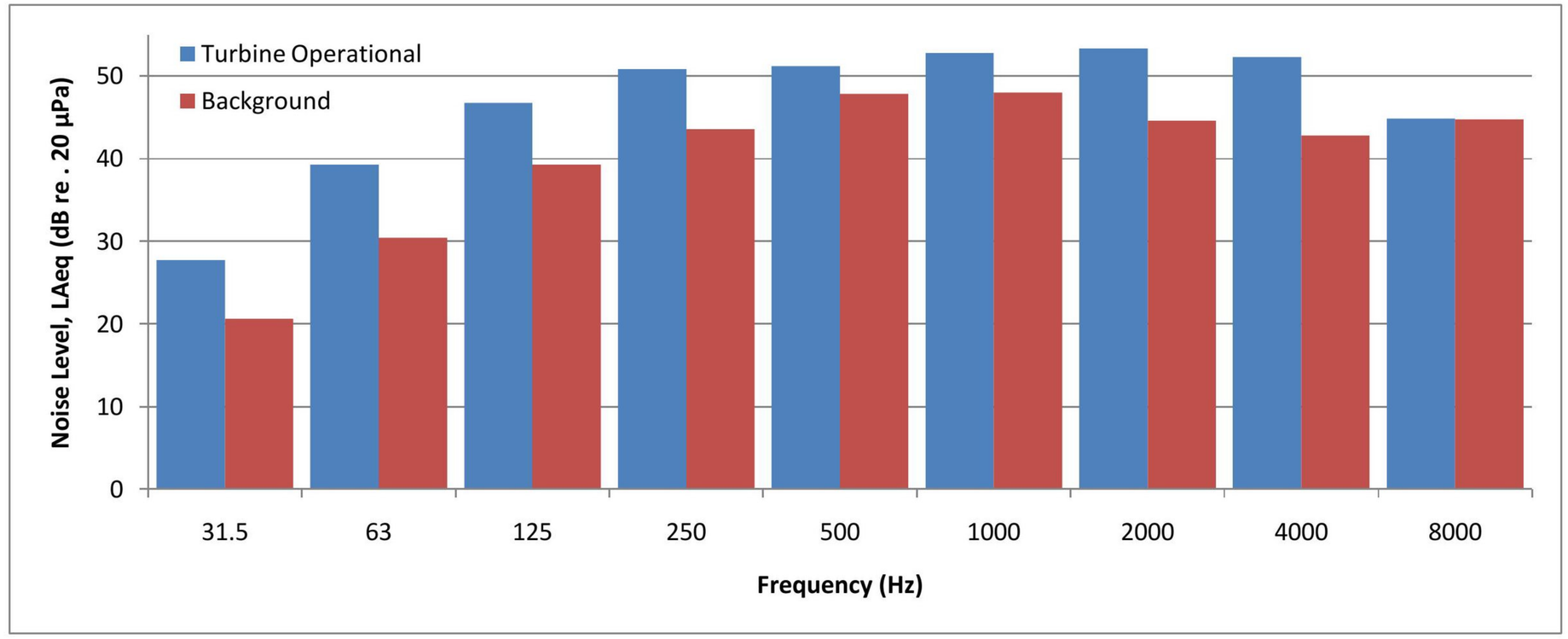
HM:2300/R1

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	13.5		10.7	
25	17.1	27.7	11.9	20.6
31.5	21.0		15.6	
40	26.1		18.0	
50	28.9	39.3	19.5	30.4
63	33.9		24.1	
80	37.2		28.8	
100	40.5	46.8	33.6	39.3
125	41.8		34.3	
160	43.2		35.4	
200	43.9	50.8	35.9	43.5
250	46.0		38.7	
315	47.5		40.5	
400	47.0	51.2	43.3	47.8
500	45.6		43.3	
630	46.5		42.5	
800	46.4	52.8	44.2	48.0
1000	49.0		43.5	
1250	48.2		41.4	
1600	47.9	53.3	40.7	44.6
2000	48.6		39.7	
2500	49.1		38.9	
3150	49.3	52.3	39.5	42.8
4000	47.7		37.4	
5000	44.1		36.6	
6300	40.8	44.8	37.1	44.7
8000	38.7		38.7	
10000	40.4		42.4	

Overall	59.6	53.7



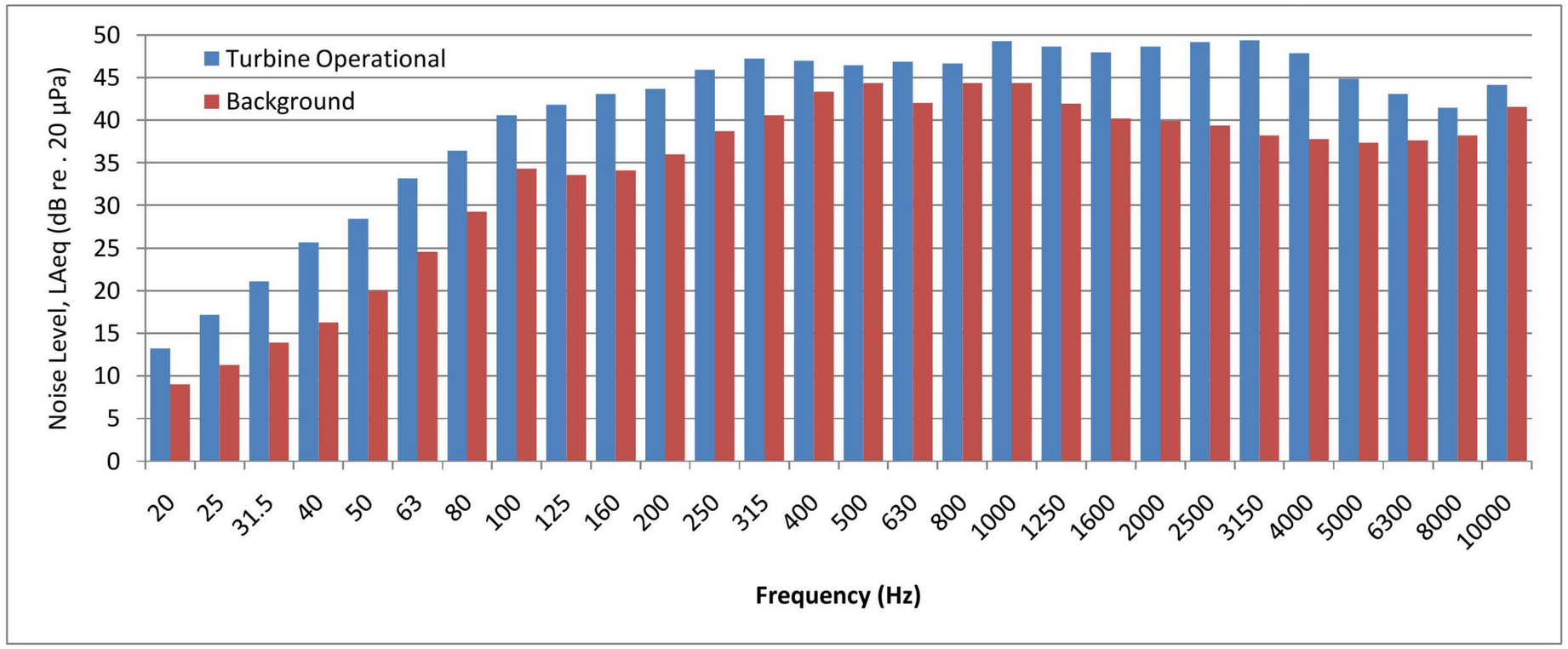


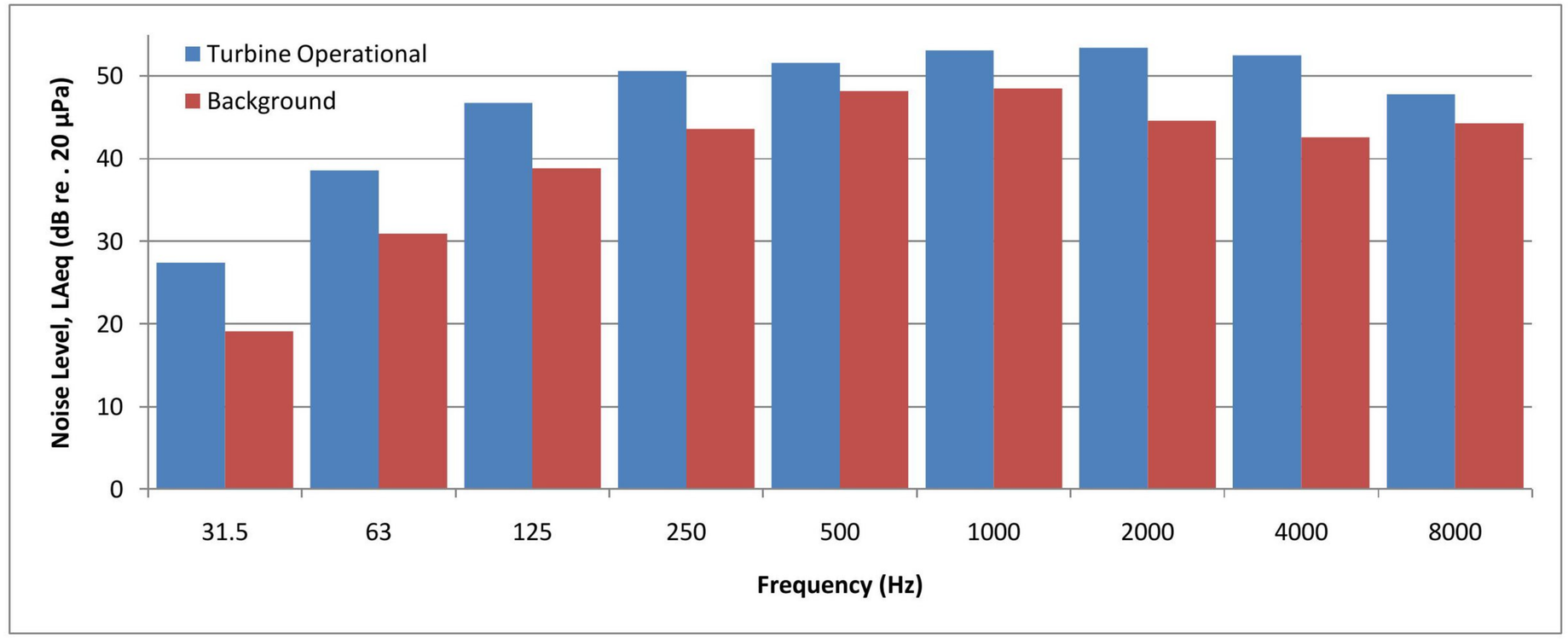
HM:2300/R1

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	13.2		9.0	
25	17.2	27.4	11.3	19.1
31.5	21.1		13.9	
40	25.7		16.3	
50	28.4	38.5	20.0	30.9
63	33.2		24.5	
80	36.4		29.3	
100	40.6	46.7	34.4	38.8
125	41.9		33.6	
160	43.1		34.1	
200	43.7	50.6	36.0	43.6
250	45.9		38.8	
315	47.3		40.6	
400	47.0	51.6	43.4	48.1
500	46.5		44.4	
630	46.9		42.0	
800	46.7	53.1	44.4	48.5
1000	49.3		44.4	
1250	48.7		42.0	
1600	48.0	53.4	40.2	44.6
2000	48.7		39.9	
2500	49.2		39.4	
3150	49.4	52.5	38.2	42.6
4000	47.9		37.8	
5000	44.9		37.4	
6300	43.1	47.8	37.6	44.3
8000	41.5		38.2	
10000	44.1		41.5	

Overall	59.9	53.8





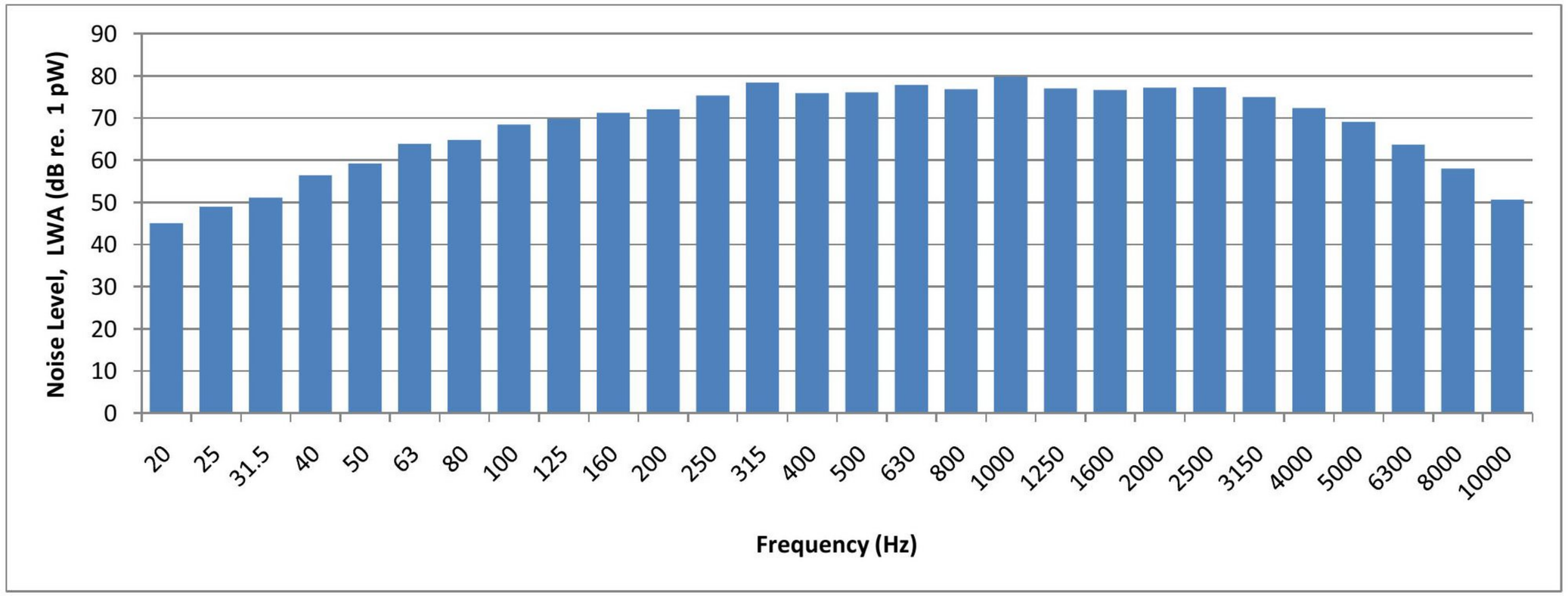
Appendix G
Background Corrected One Third Octave Sound Power Levels

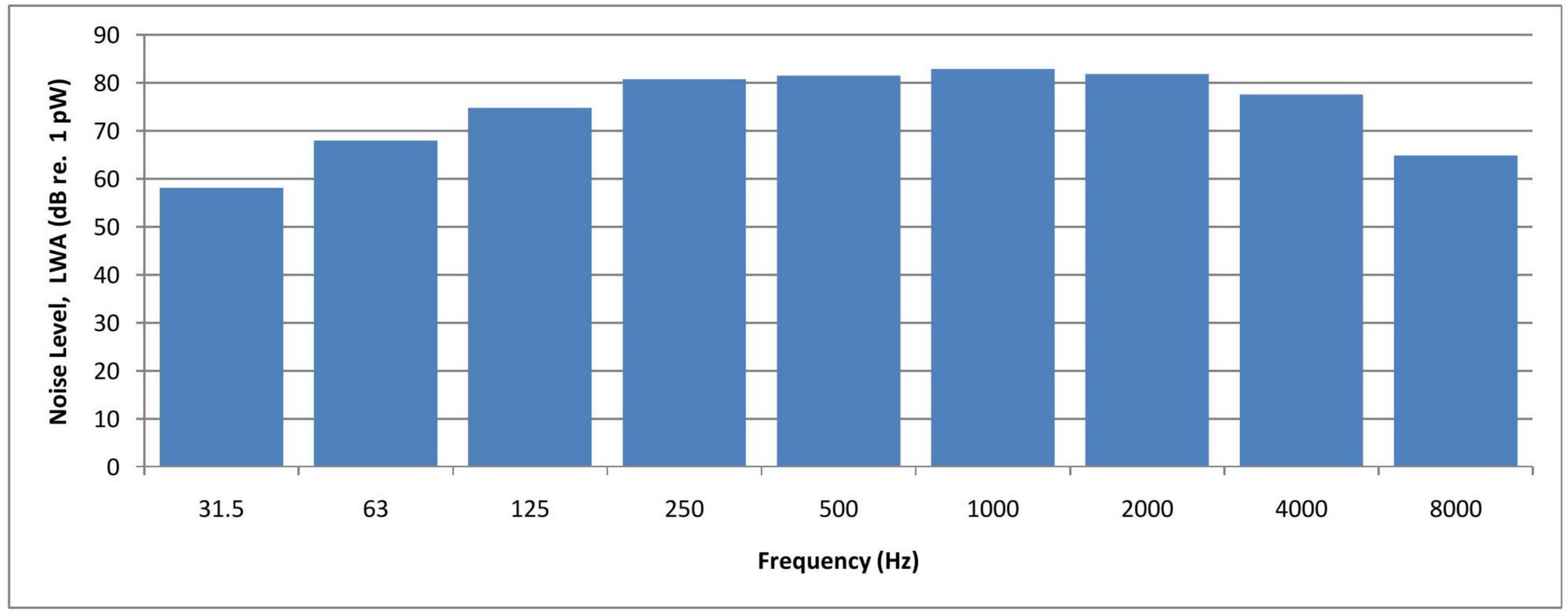
HM:2300/R1

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

Frequency (Hz)	1/3 Octave Band (dB LWA)	Octave Band (dB LWA)
20	45.1	
25	49.0	58.1
31.5	51.1	
40	56.4	
50	59.2	68.0
63	63.9	
80	64.9	
100	68.4	74.8
125	69.9	
160	71.3	
200	72.1	80.8
250	75.3	
315	78.4	
400	75.9	81.5
500	76.1	
630	77.8	
800	76.8	82.9
1000	79.8	
1250	77.1	
1600	76.7	81.9
2000	77.2	
2500	77.3	
3150	75.0	77.6
4000	72.4	
5000	69.1	
6300	63.7	64.9
8000	58.0	
10000	50.6	

Overall	88.5





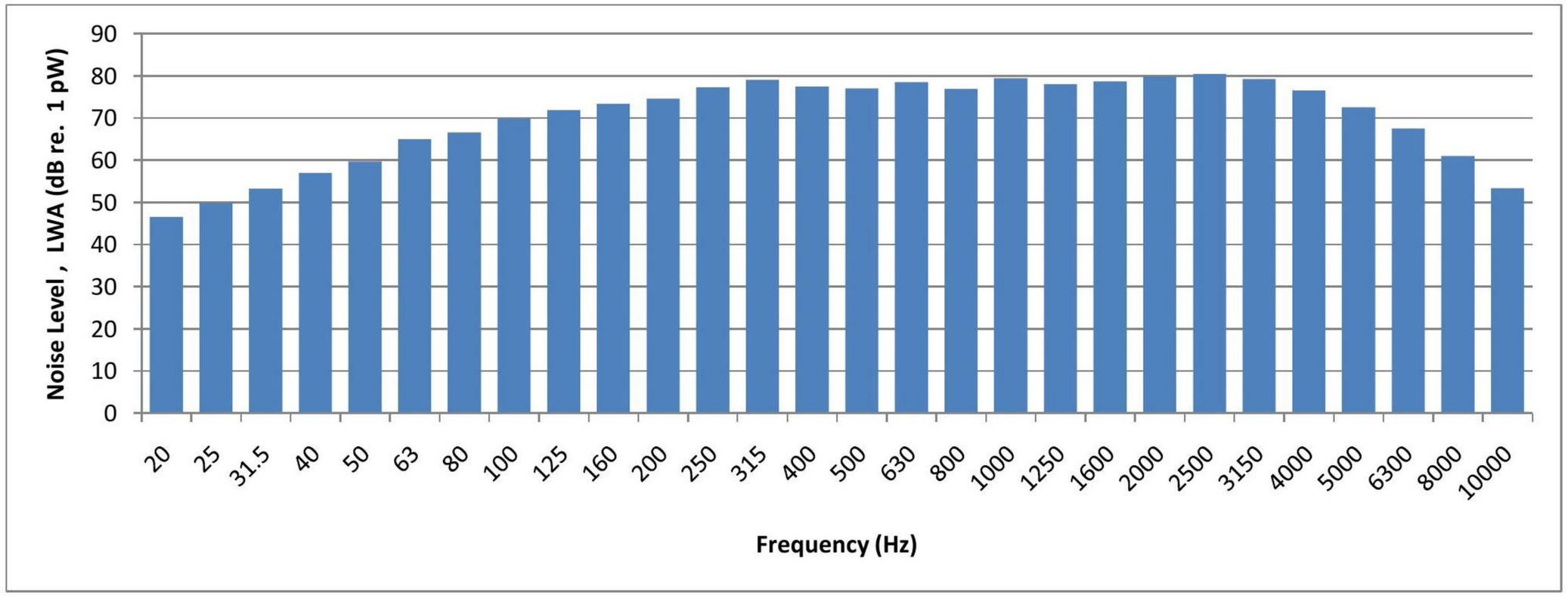
HM:2300/R1

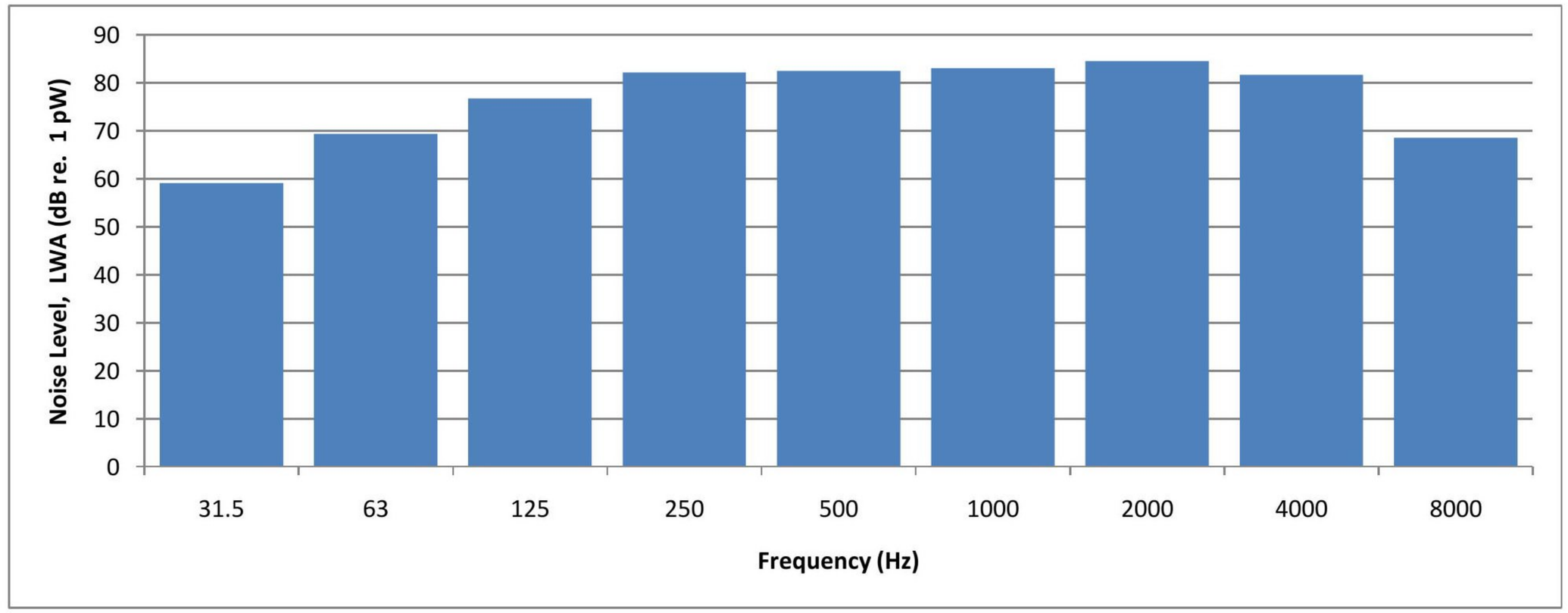
Endurance E-3120 Wind Turbine
Wind Speed - 7 m/s*

Frequency (Hz)	1/3 Octave Band (dB LWA)	Octave Band (dB LWA)
20	46.5	
25	49.9	59.1
31.5	53.2	
40	57.0	
50	59.7	69.4
63	65.0	
80	66.6	
100	69.9	76.7
125	71.9	
160	73.4	
200	74.6	82.1
250	77.3	
315	79.1	
400	77.5	82.5
500	77.0	
630	78.6	
800	76.9	83.0
1000	79.4	
1250	78.1	
1600	78.7	84.5
2000	80.0	
2500	80.5	
3150	79.3	81.7
4000	76.6	
5000	72.5	
6300	67.6	68.6
8000	61.0	
10000	53.4	

Overall	90.2

*Background taken from 6m/s



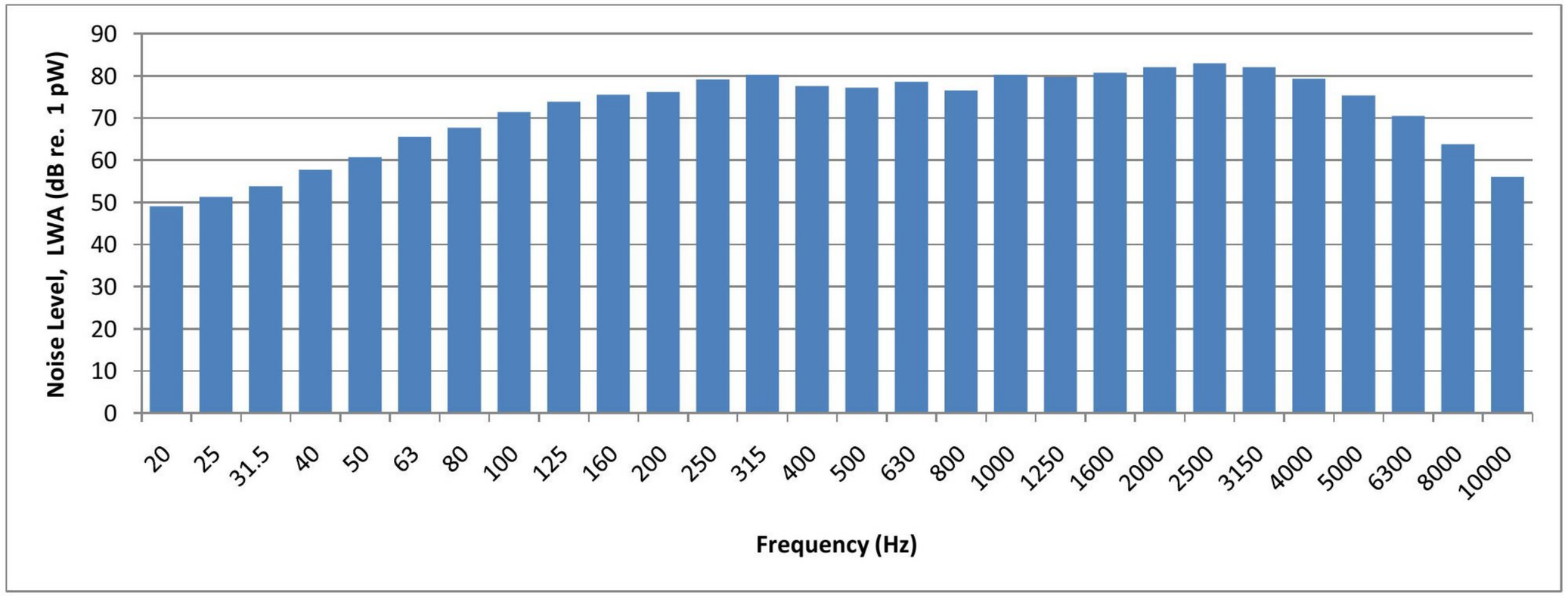


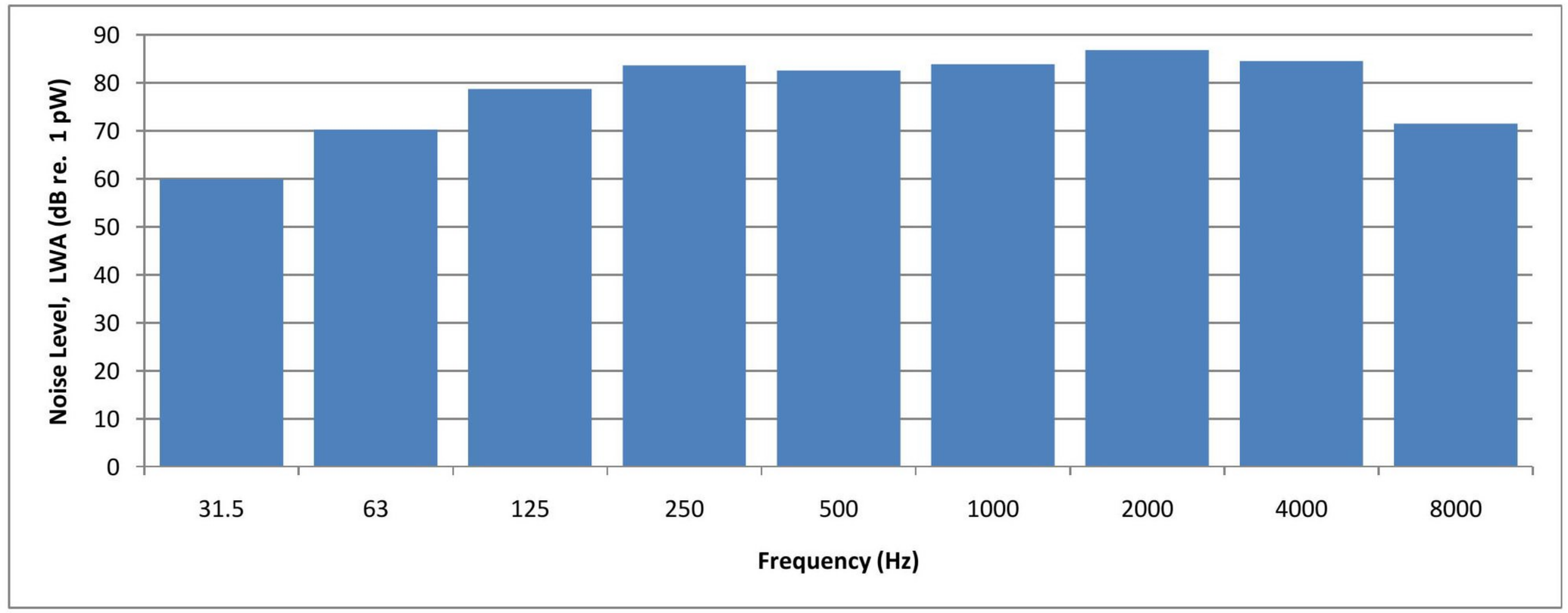
HM:2300/R1

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

Frequency (Hz)	1/3 Octave Band (dB LWA)	Octave Band (dB LWA)
20	49.1	
25	51.3	59.9
31.5	53.9	
40	57.8	
50	60.7	70.3
63	65.6	
80	67.7	
100	71.4	78.7
125	73.9	
160	75.6	
200	76.2	83.7
250	79.2	
315	80.3	
400	77.6	82.6
500	77.2	
630	78.6	
800	75.9*	83.9
1000	80.3	
1250	79.7	
1600	80.8	86.8
2000	82.1	
2500	83.0	
3150	82.1	84.5
4000	79.4	
5000	75.3	
6300	70.5	71.5
8000	63.9	
10000	56.1	

Overall	91.8

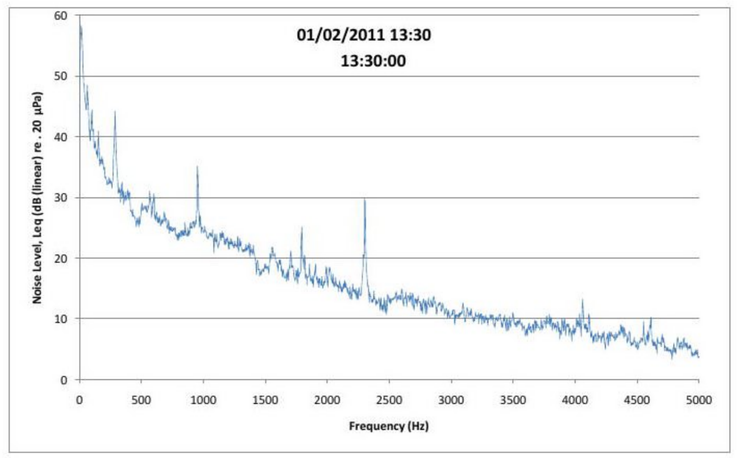


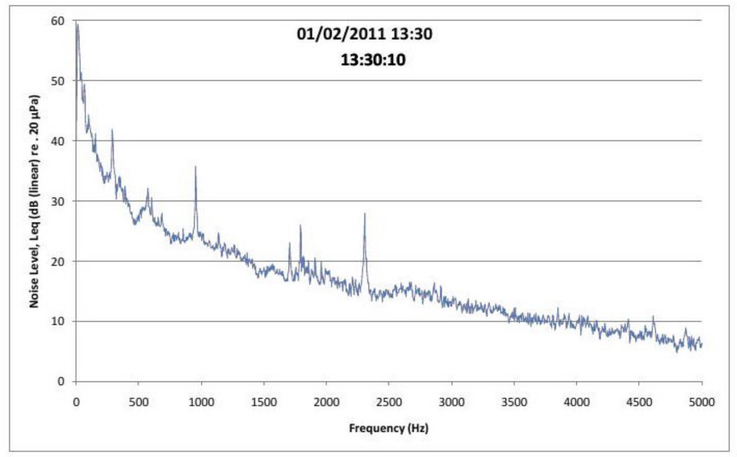


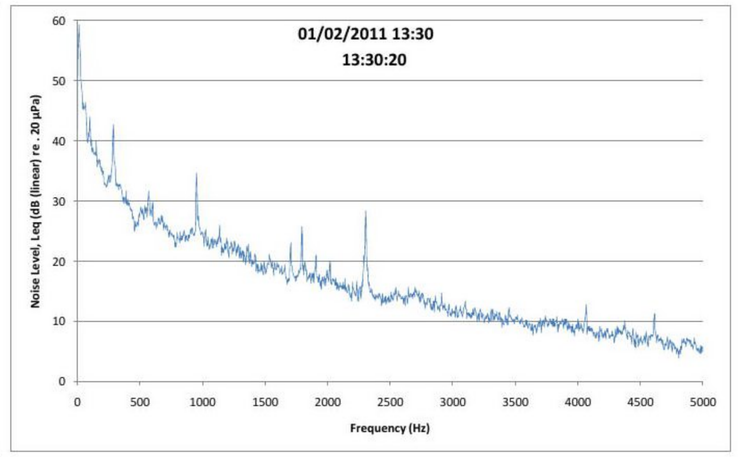
Appendix H
Narrowband Analysis

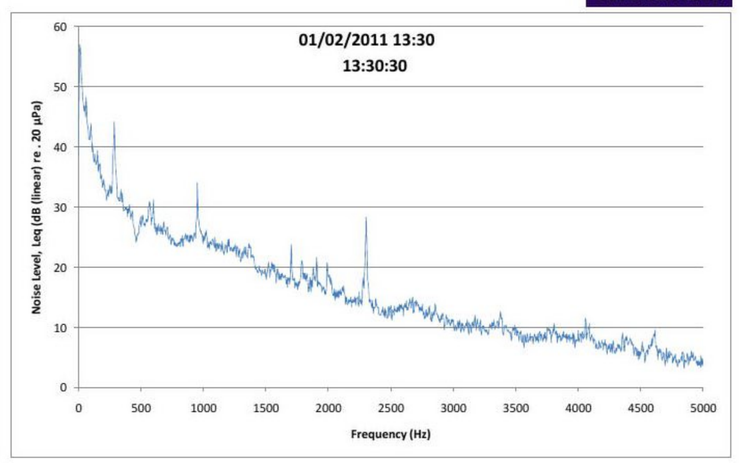
HM:2300/R1

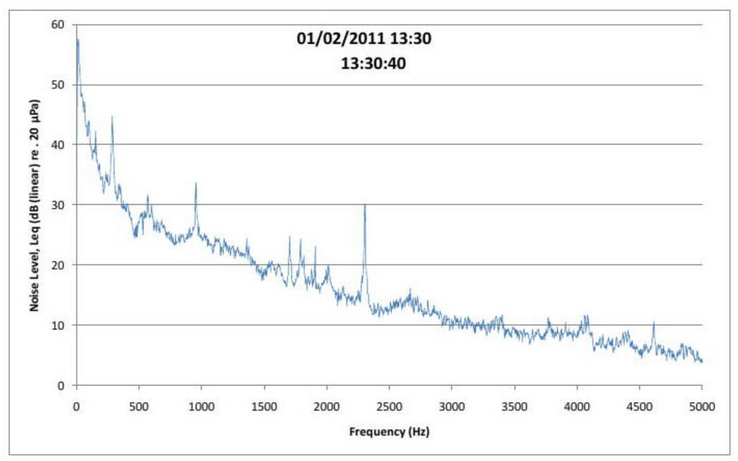
Endurance E-3120 - Narrowband Spectra
6m/s Wind Speed

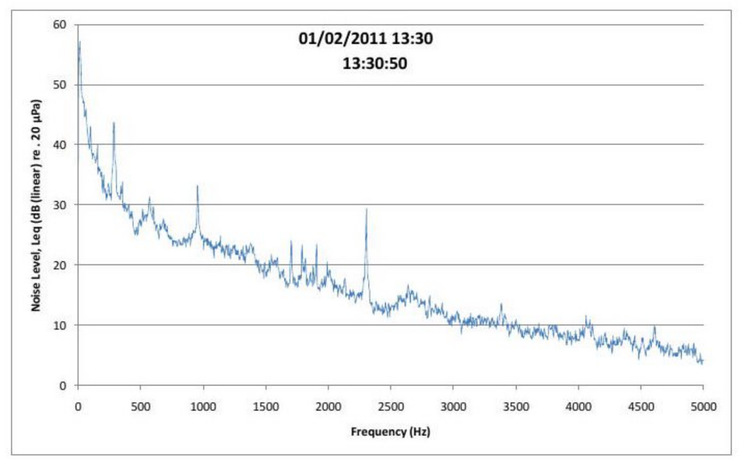


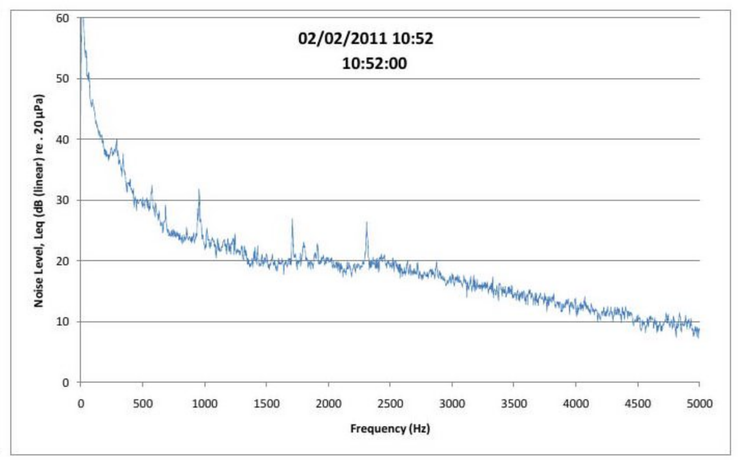


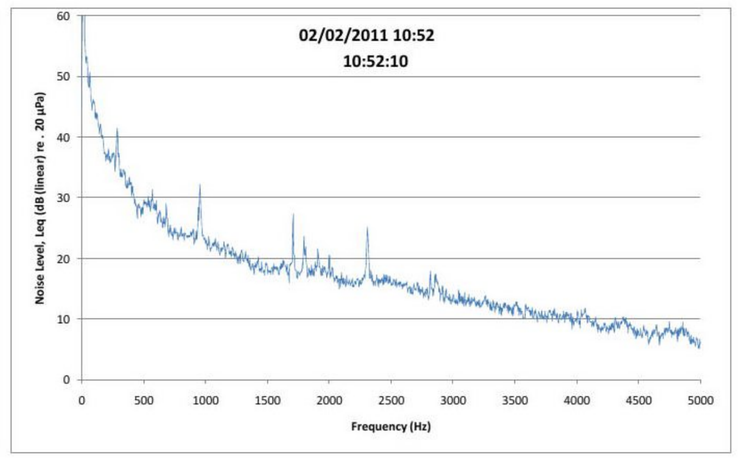


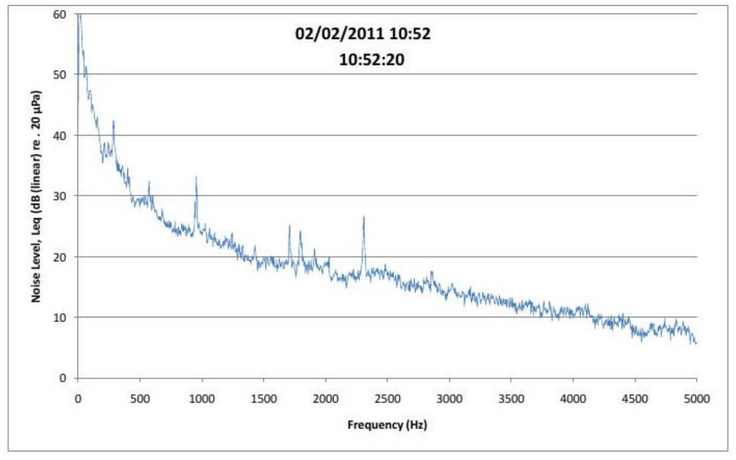


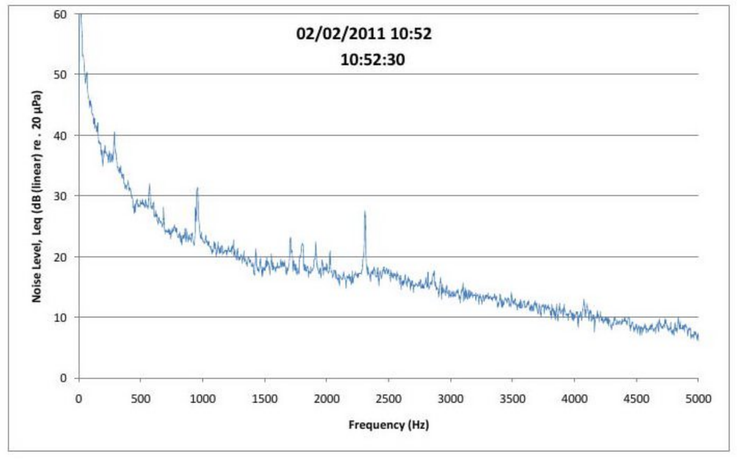


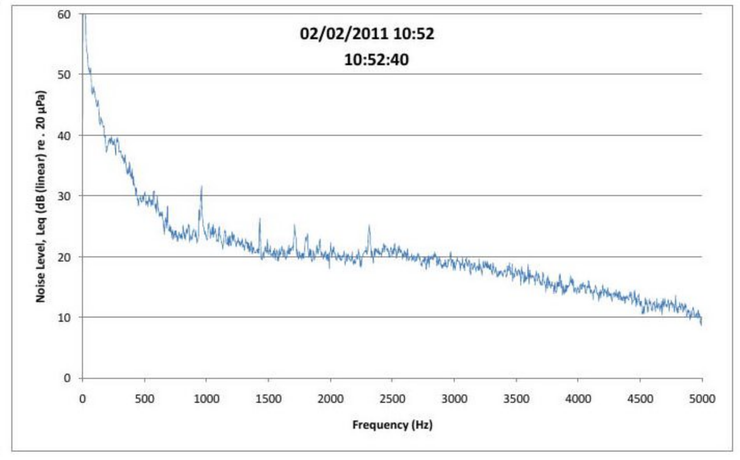


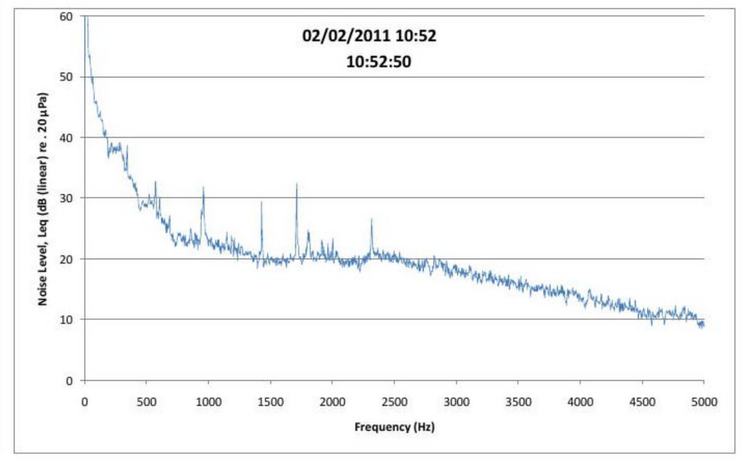


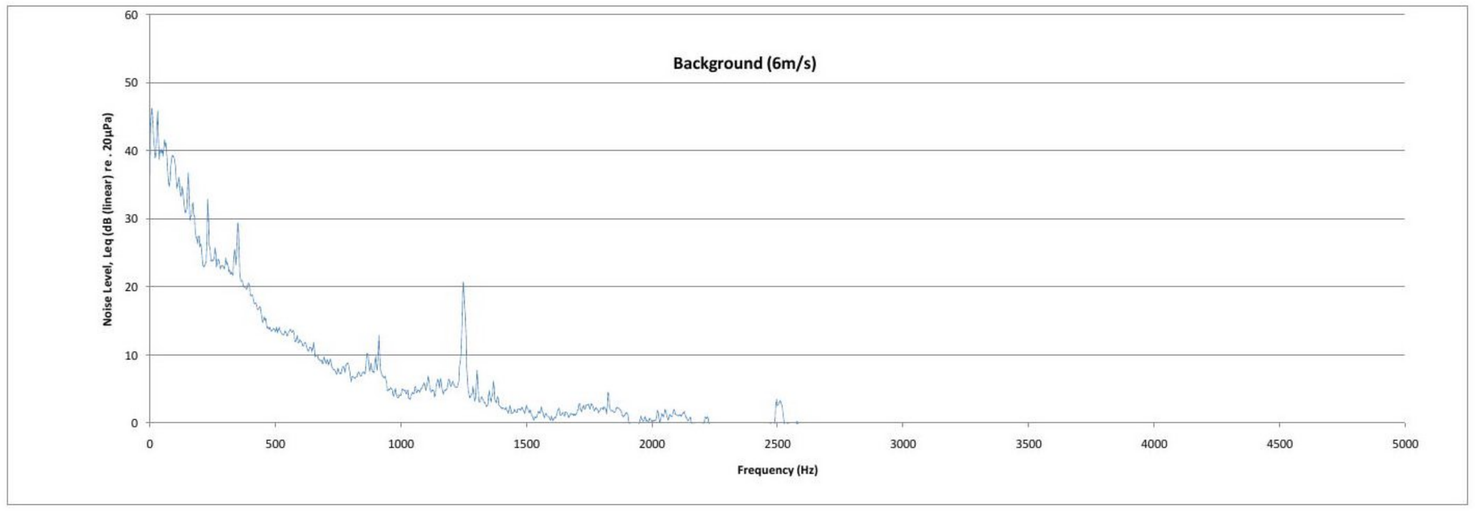










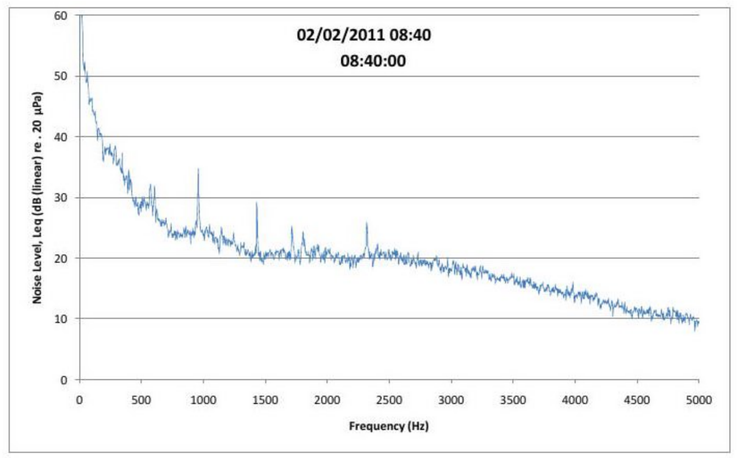


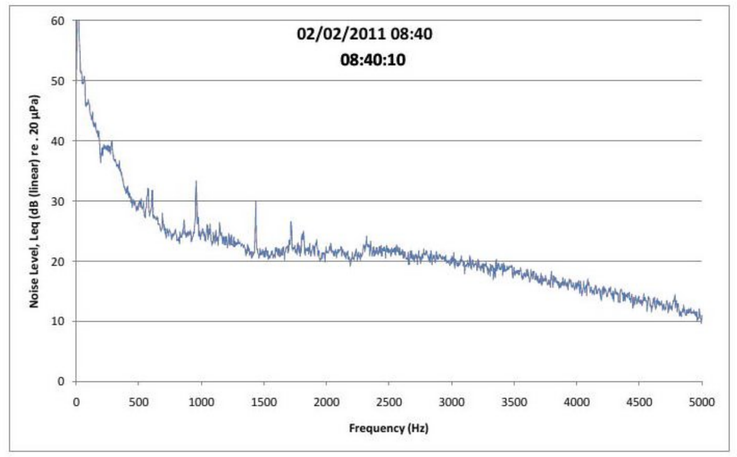
Results of tonal assessment

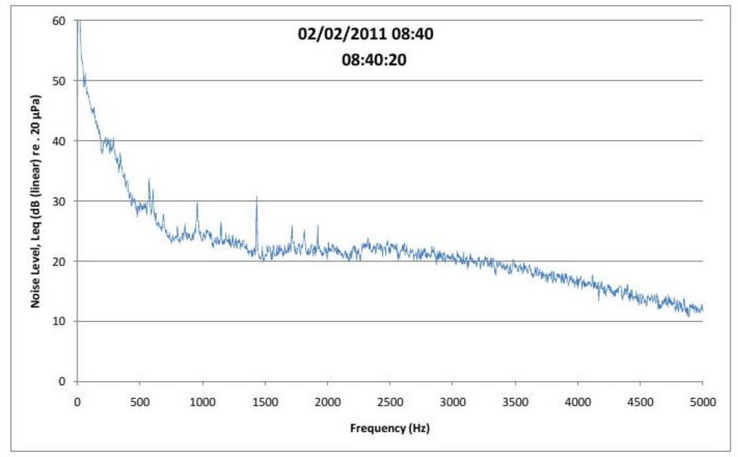
Frequency (Hz)	Tonal Audibility (dB)
287.2	-0.99
955.2	-2.08
2307.8	-0.01

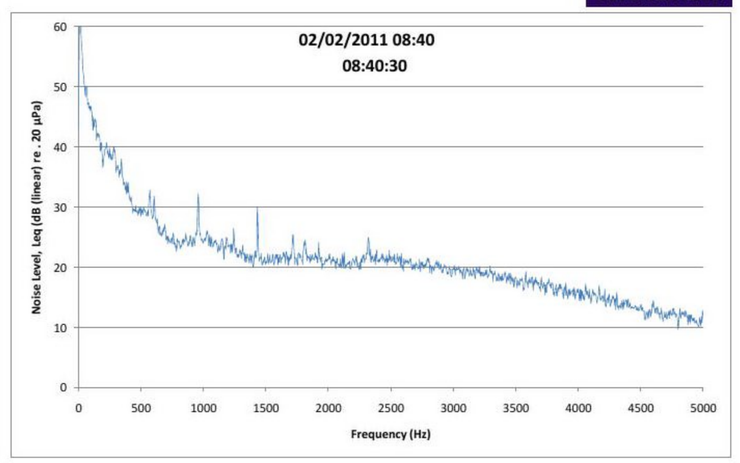
HM:2300/R1

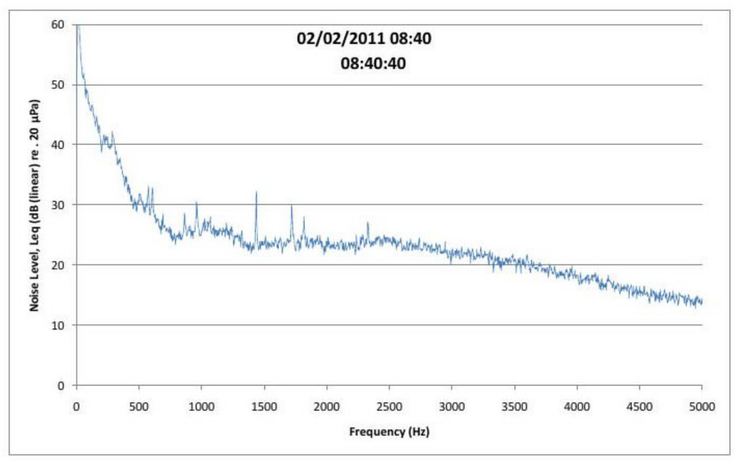
Endurance E-3120 - Narrowband Spectra
7m/s Wind Speed

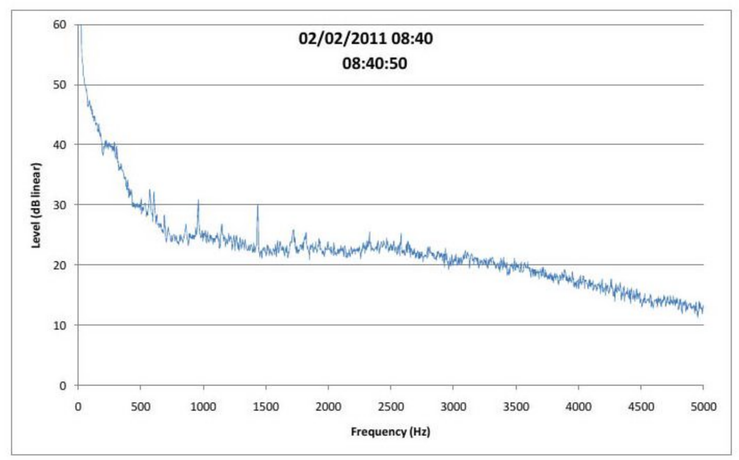


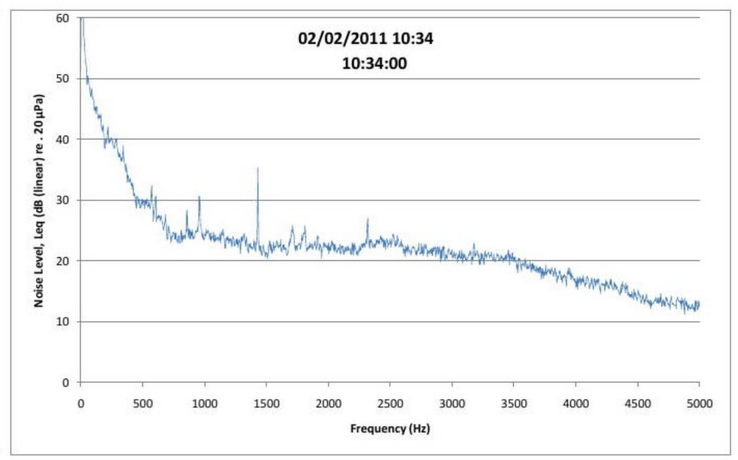


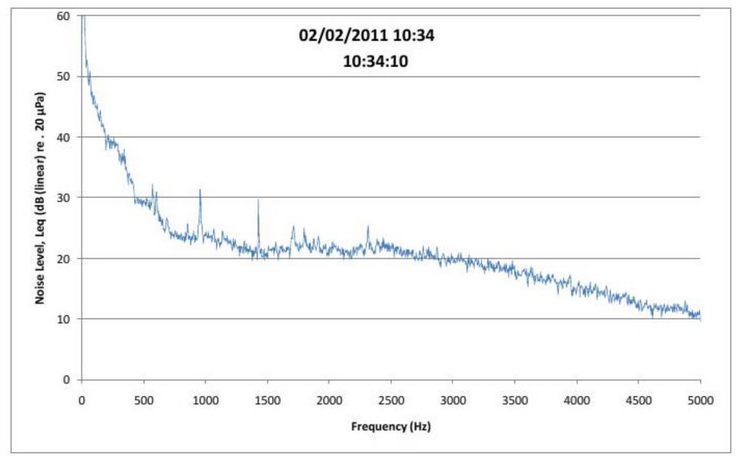


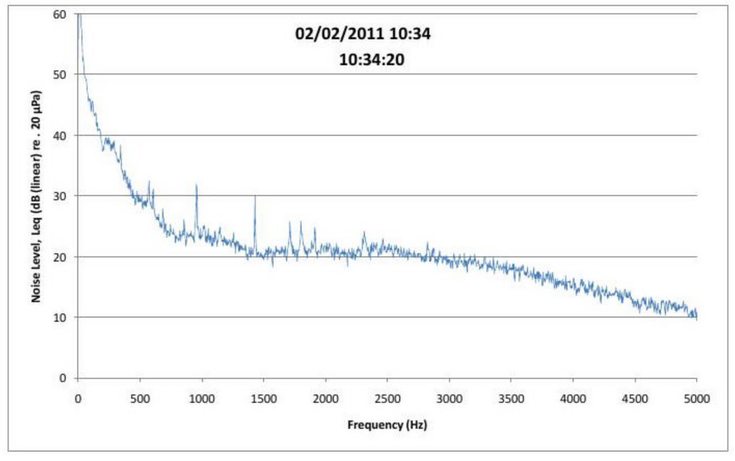


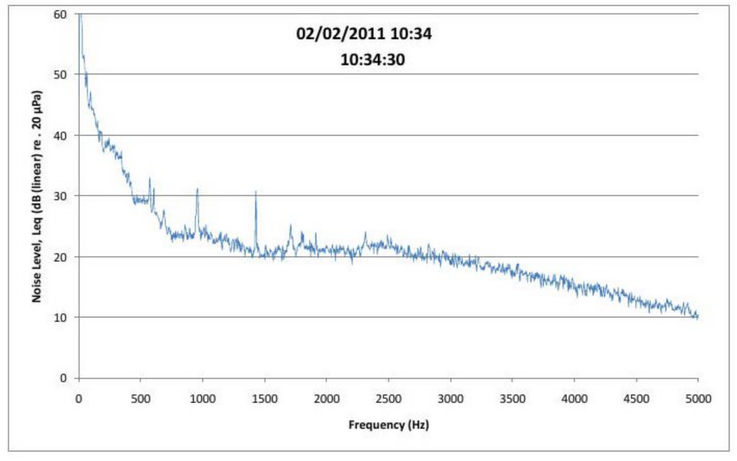


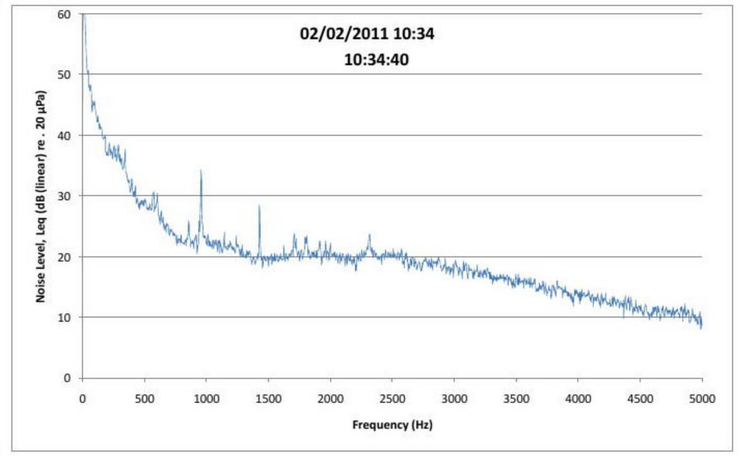


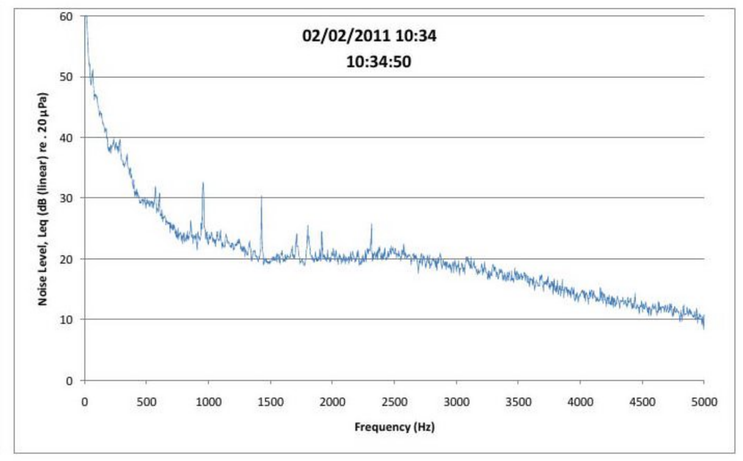


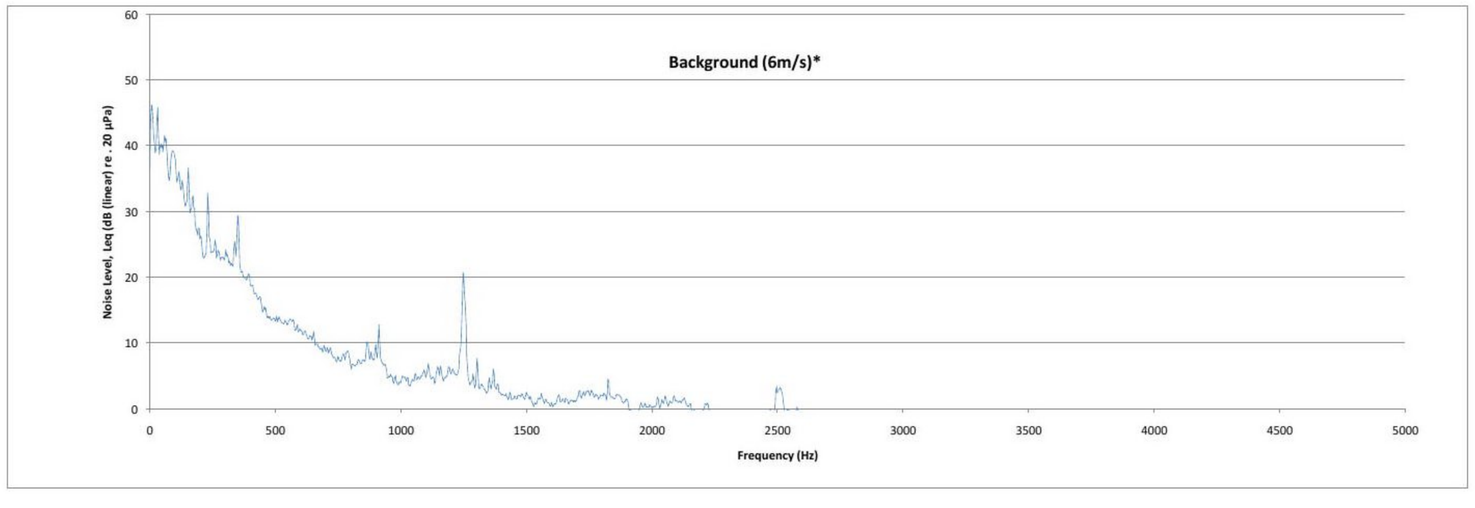












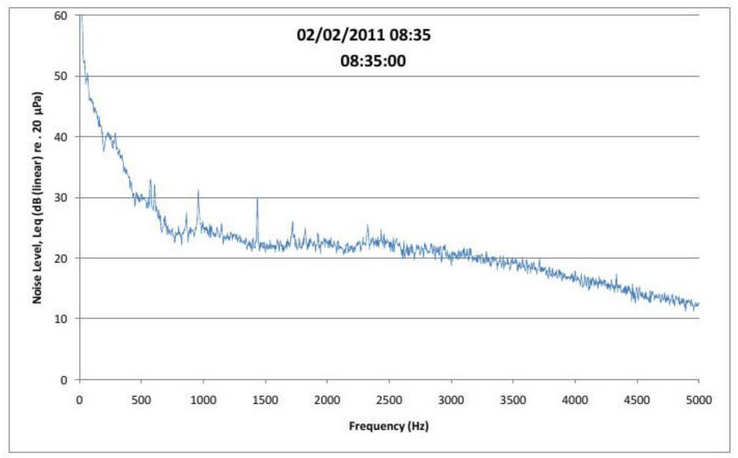
*No background noise data for 7m/s

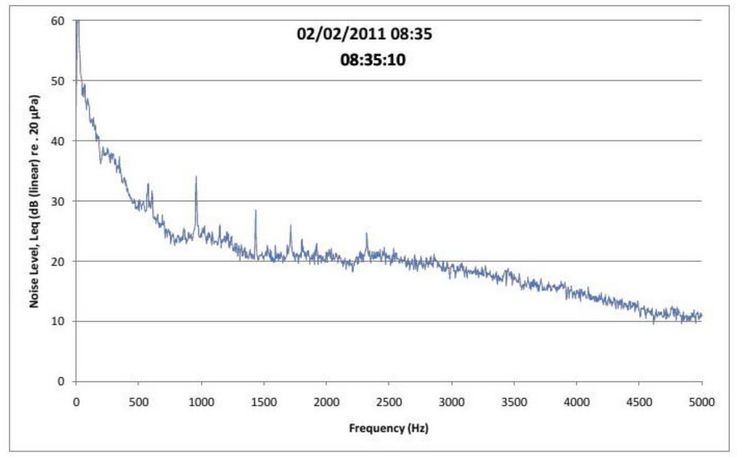
Results of tonal assessment

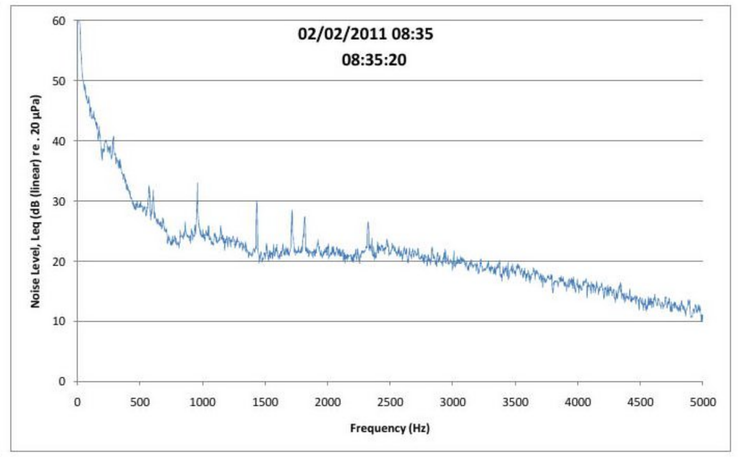
Frequency (Hz)	Tonal Audibility (dB)
No tones identified	

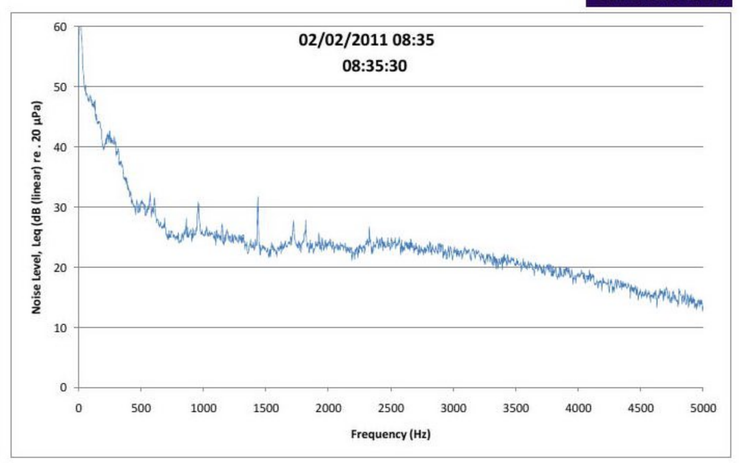
HM:2300/R1

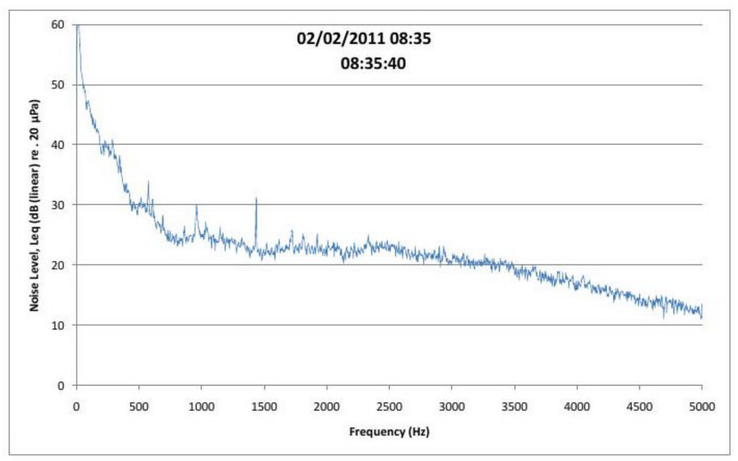
Endurance E-3120 - Narrowband Spectra
8m/s Wind Speed

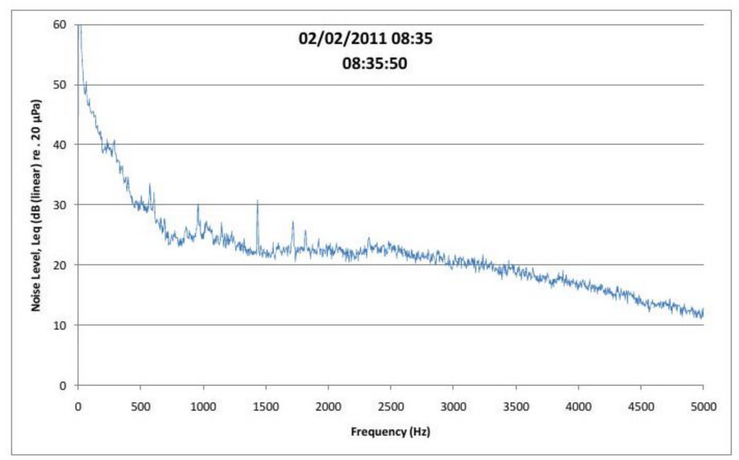


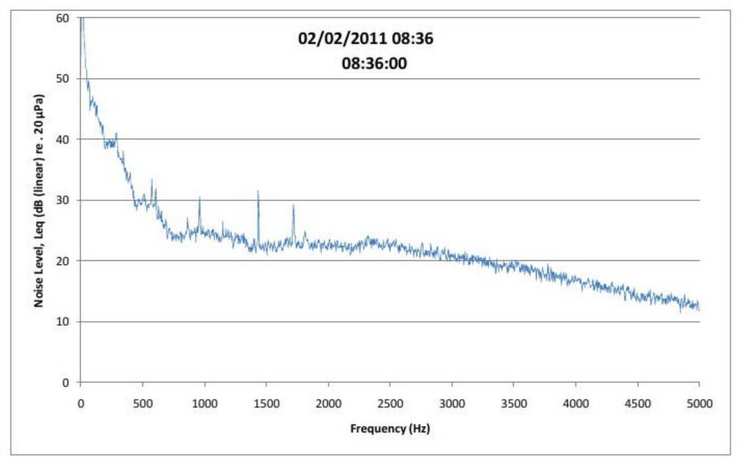


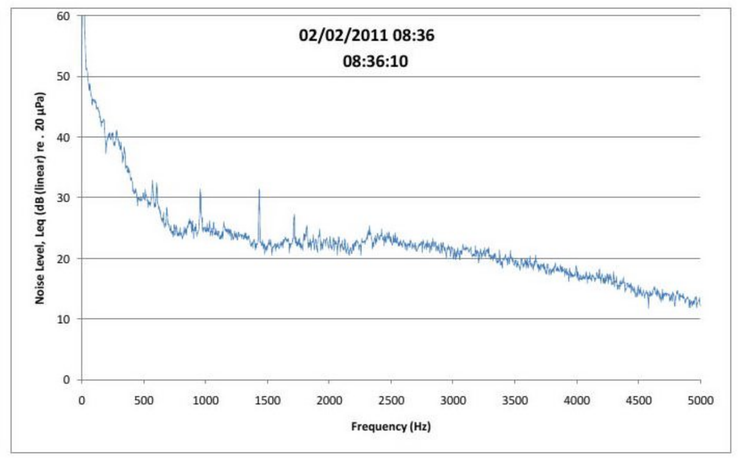


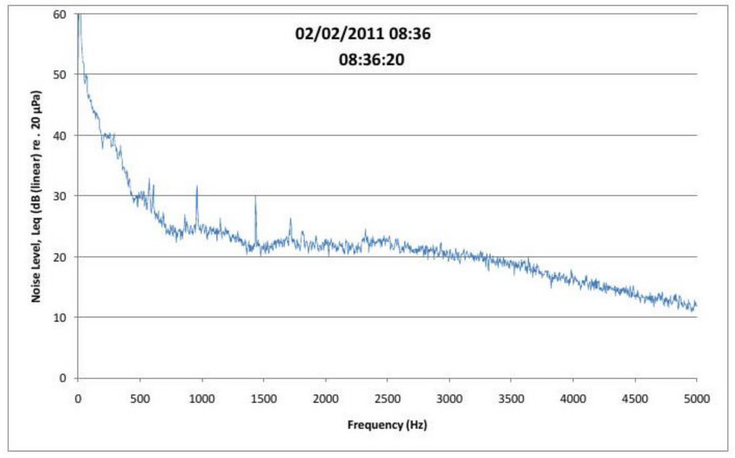


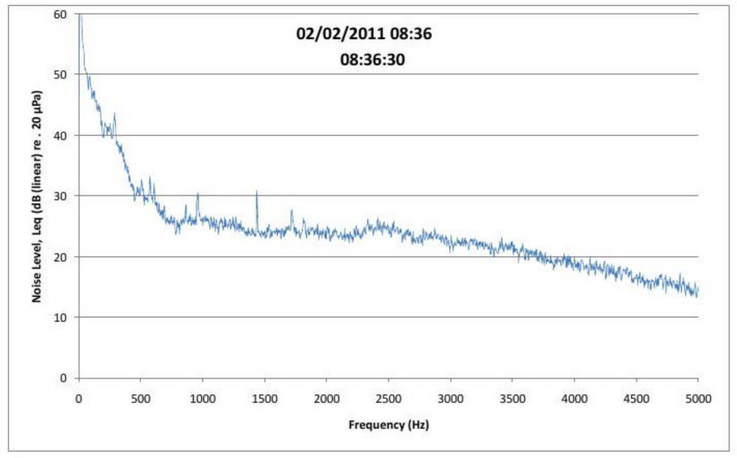


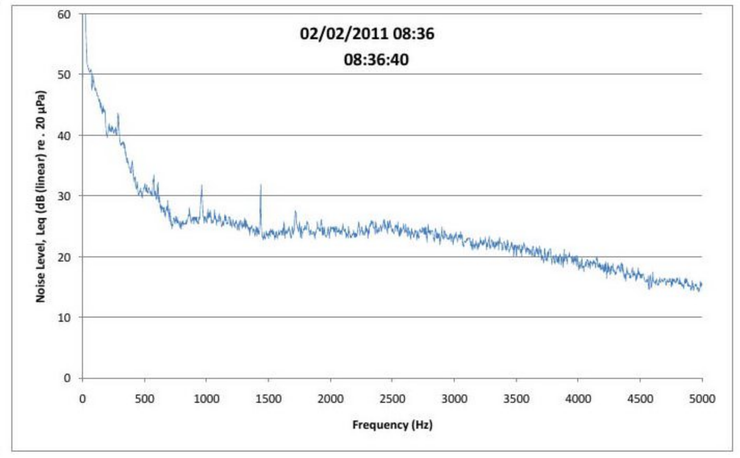


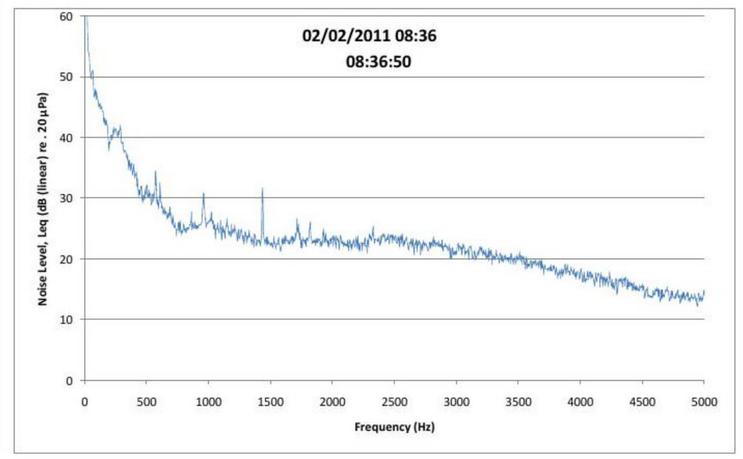


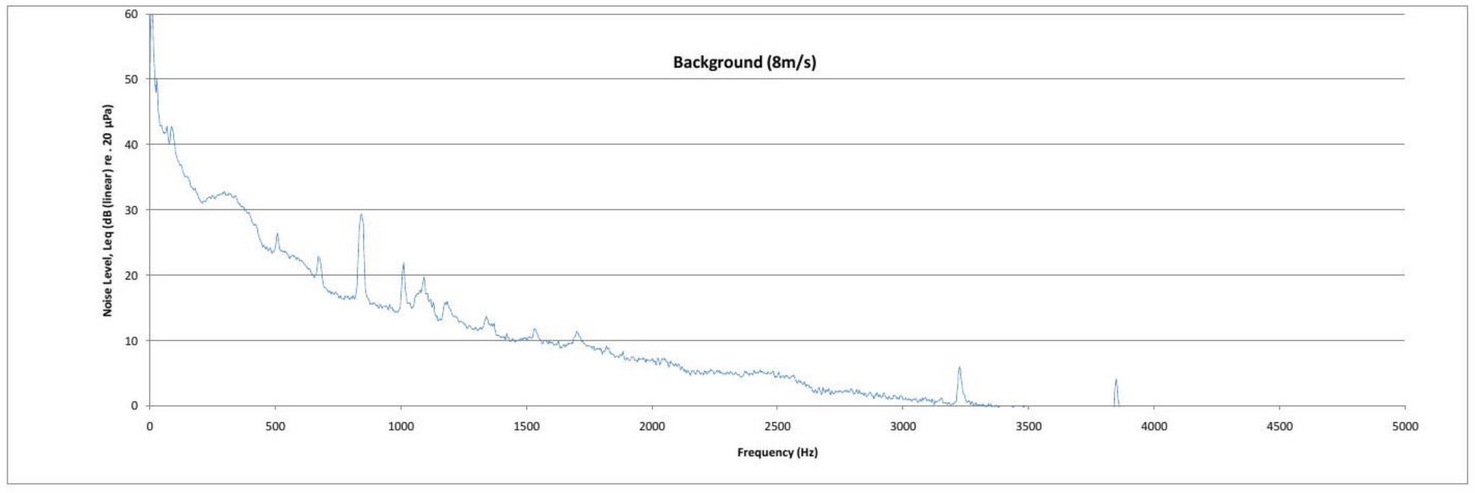










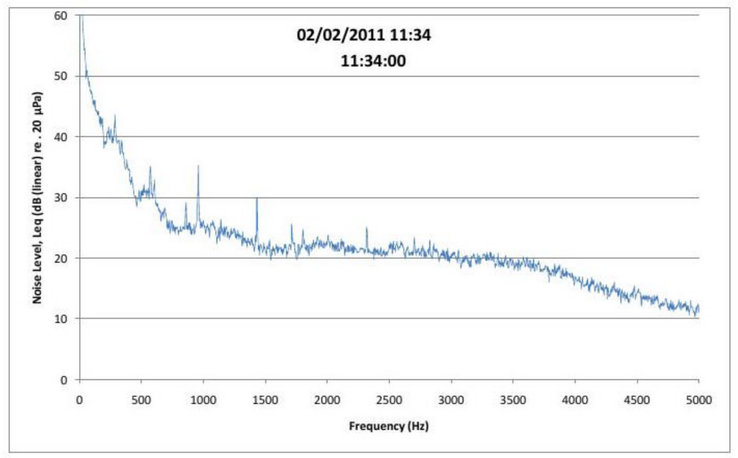


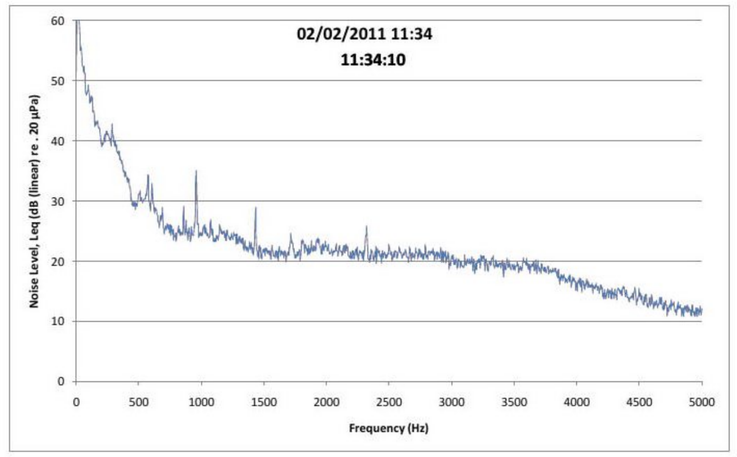
Results of tonal assessment

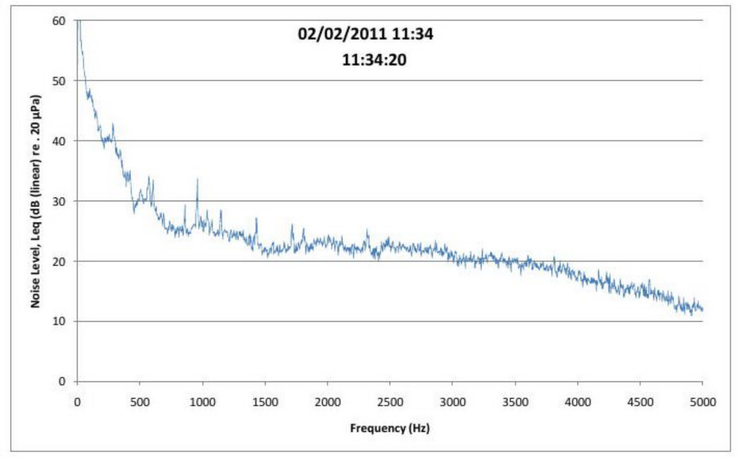
Frequency (Hz)	Tonal Audibility (dB)
No tones identified	

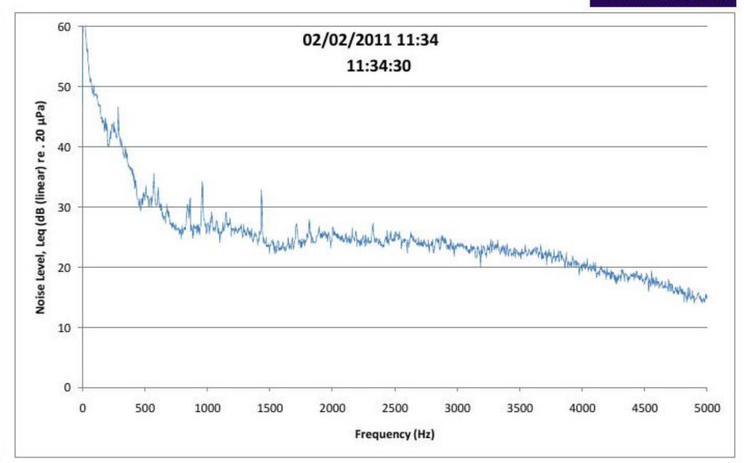
HM:2300/R1

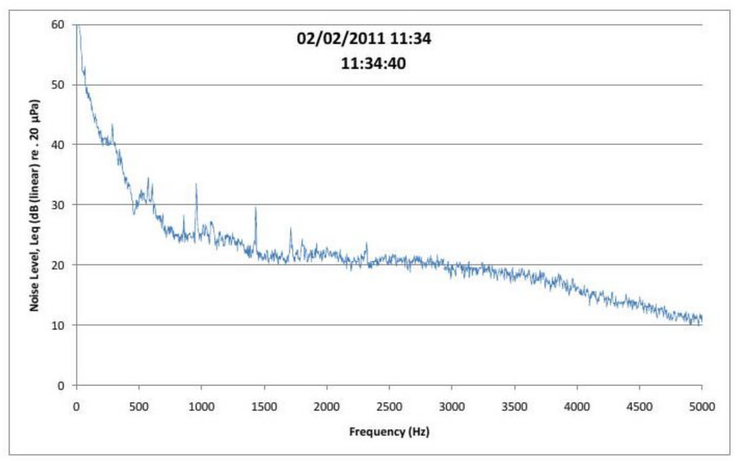
Endurance E-3120 - Narrowband Spectra
9m/s Wind Speed

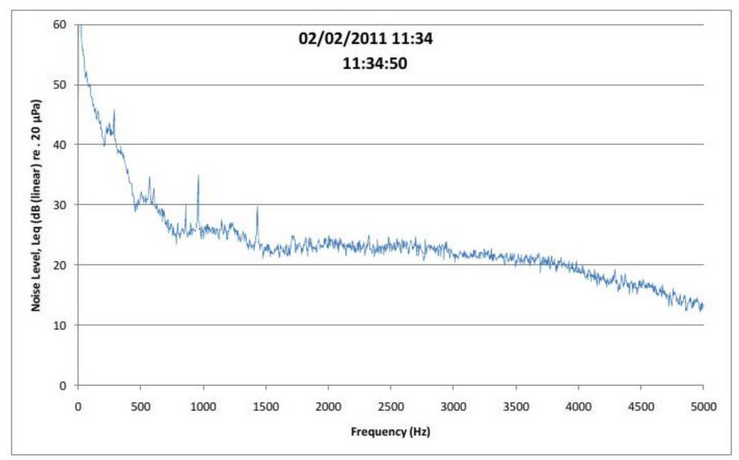


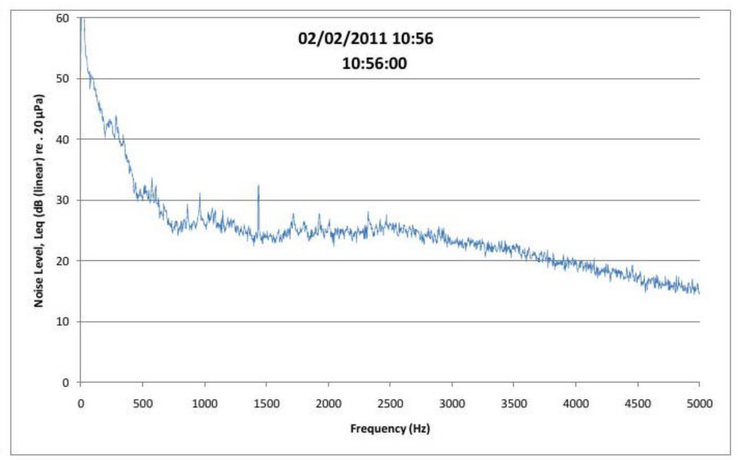


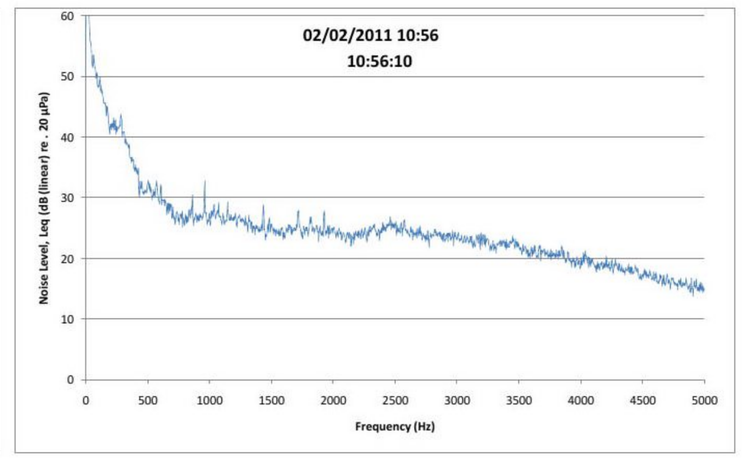


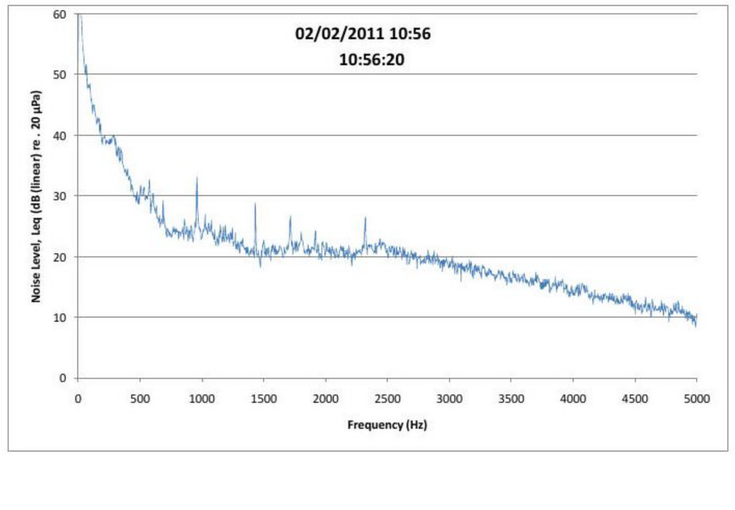


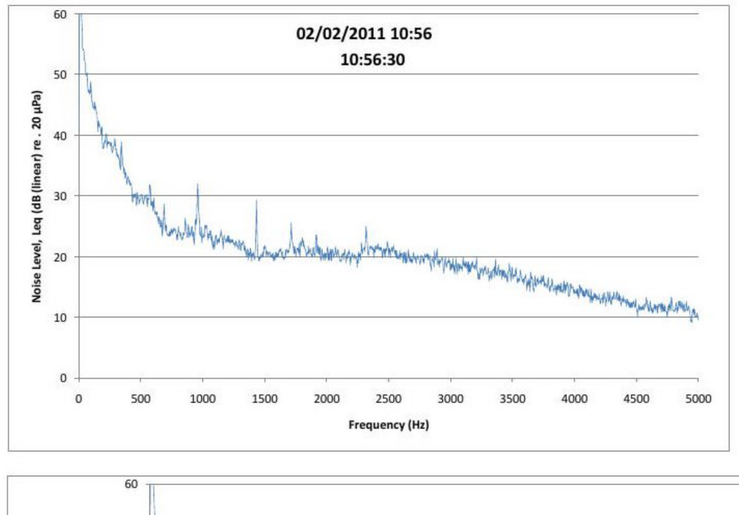


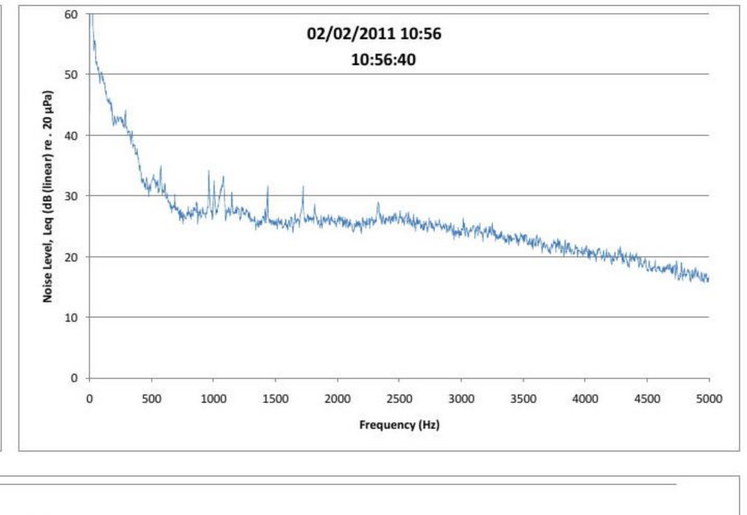


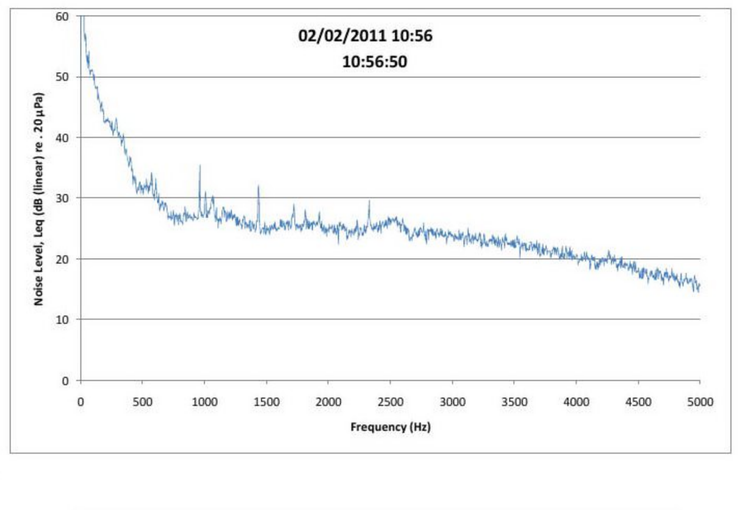


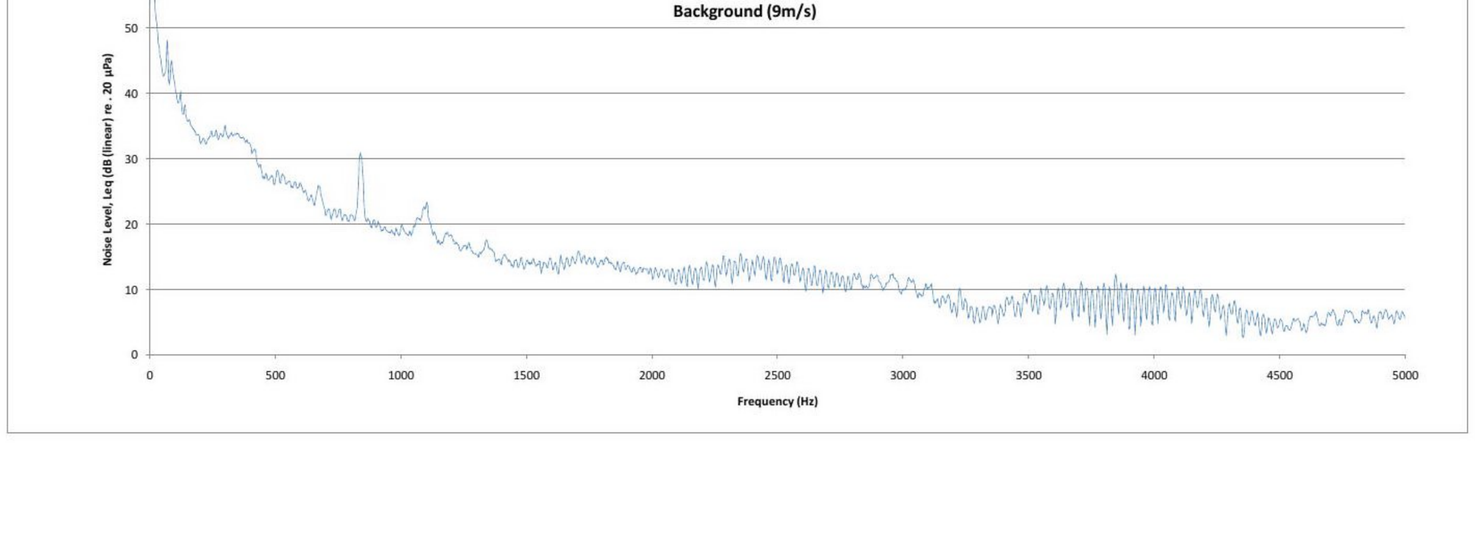










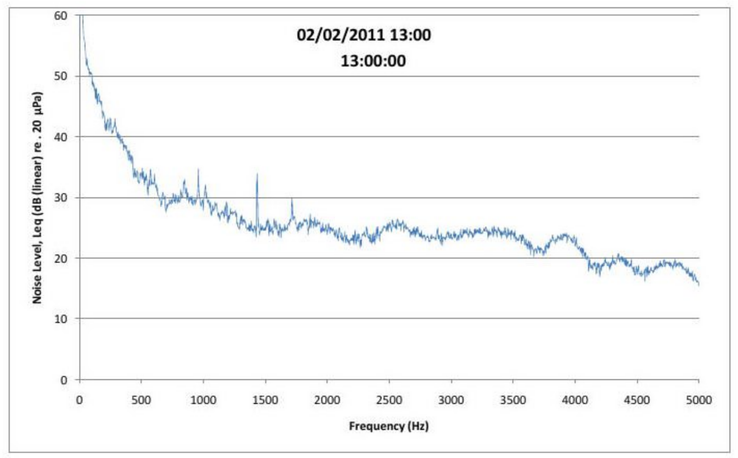


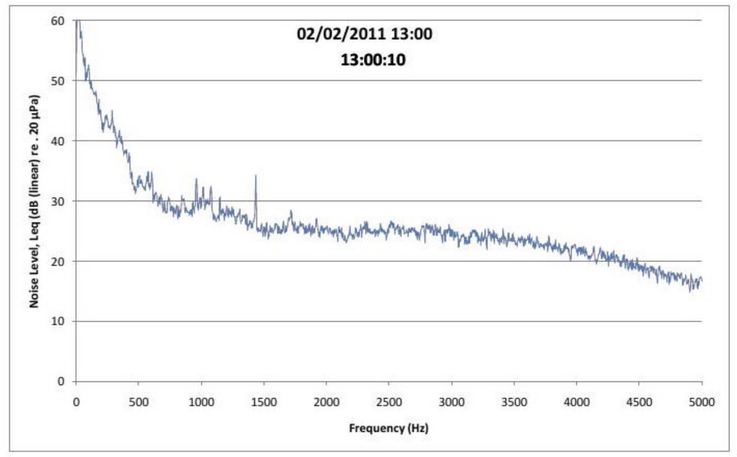
Results of tonal assessment

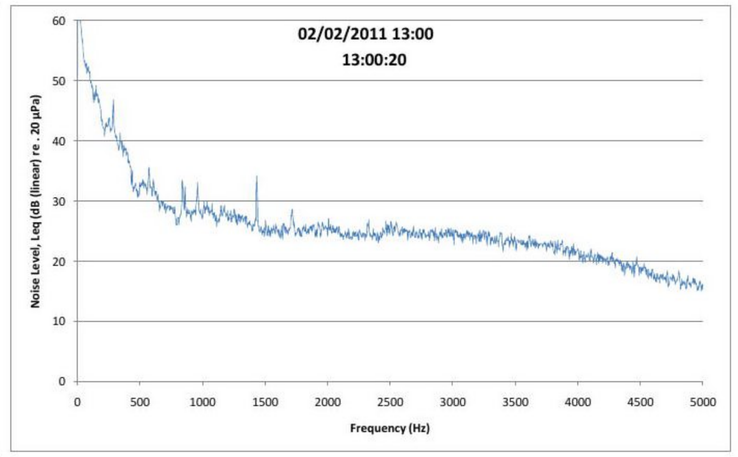
Frequency (Hz)	Tonal Audibility (dB)
No tones identified	

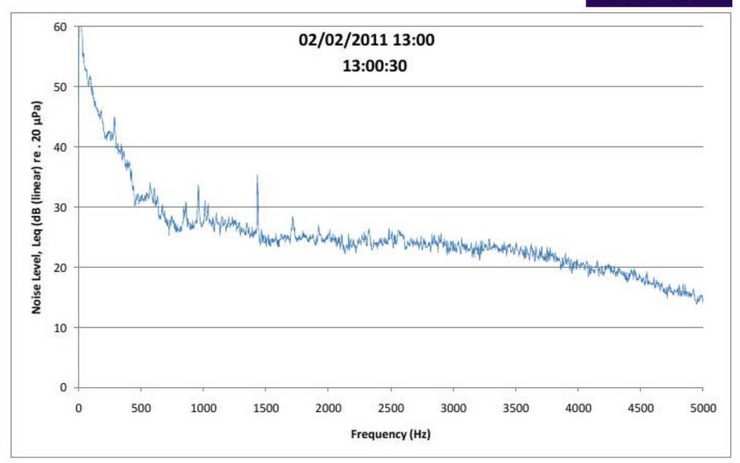
HM:2300/R1

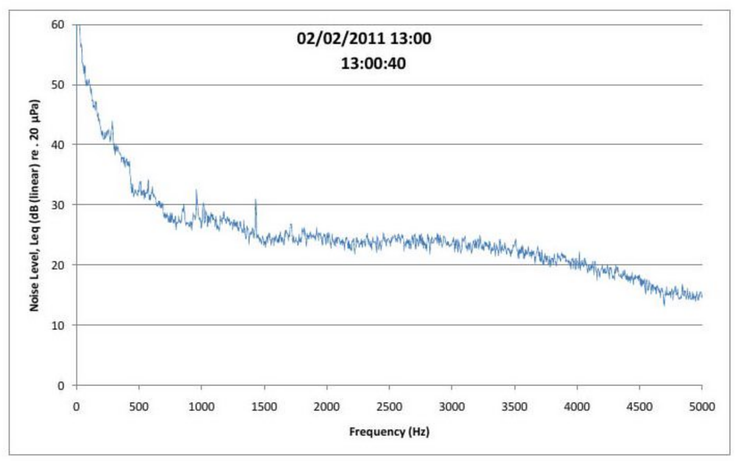
Endurance E-3120 - Narrowband Spectra
10m/s Wind Speed

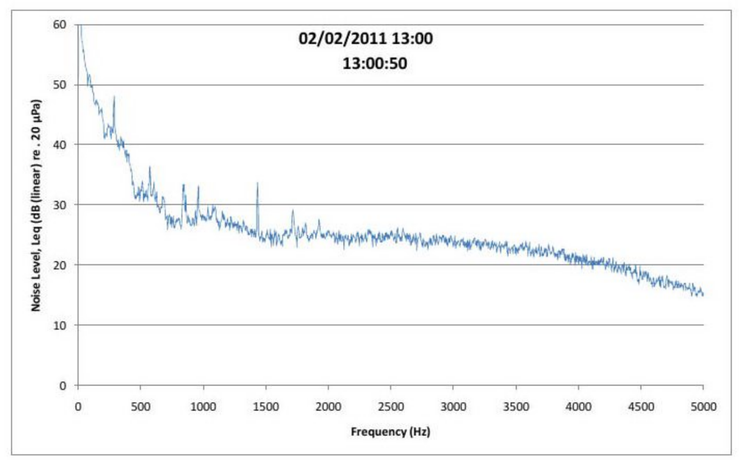


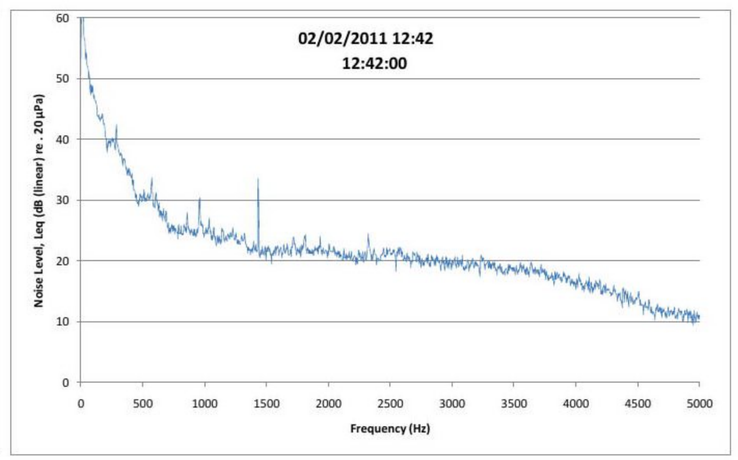


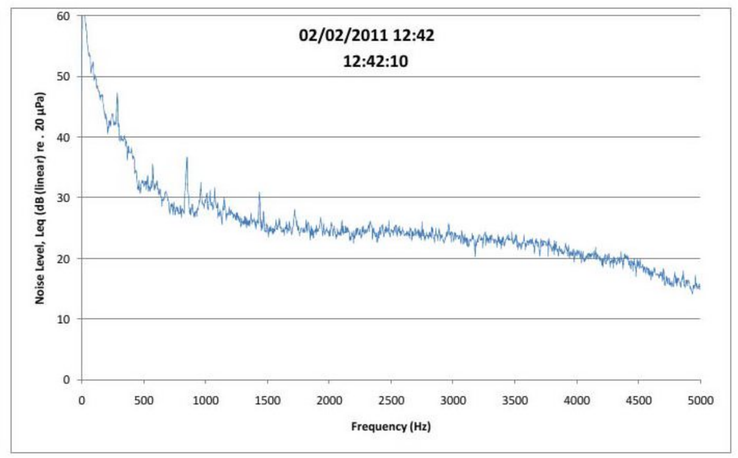


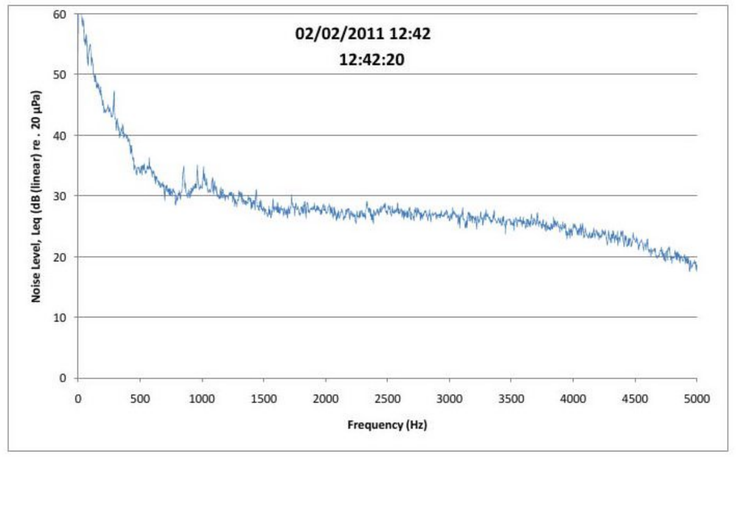


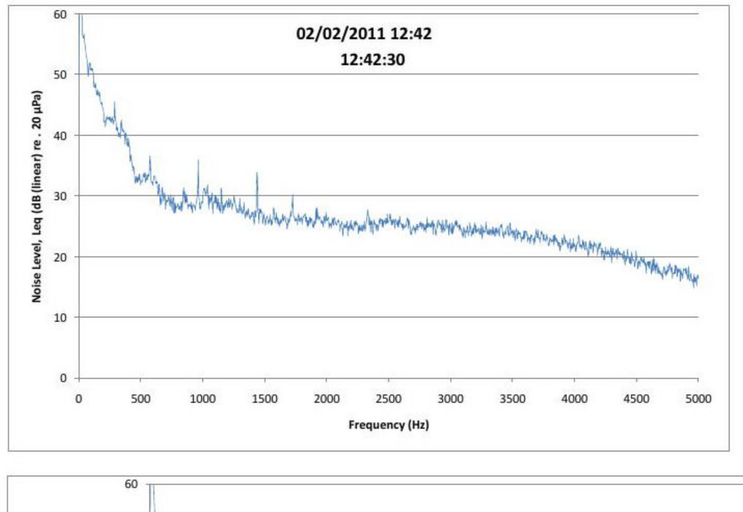


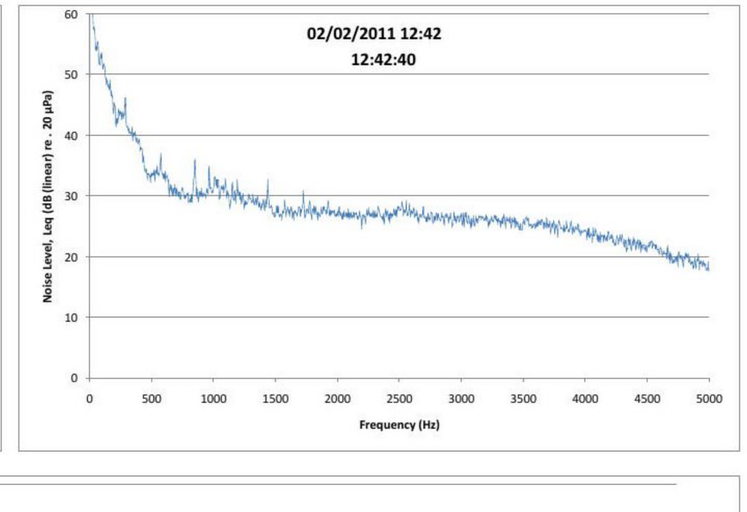


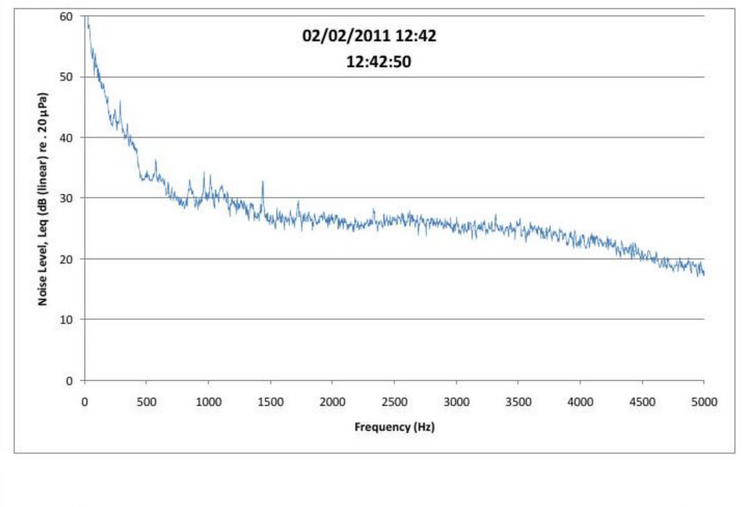


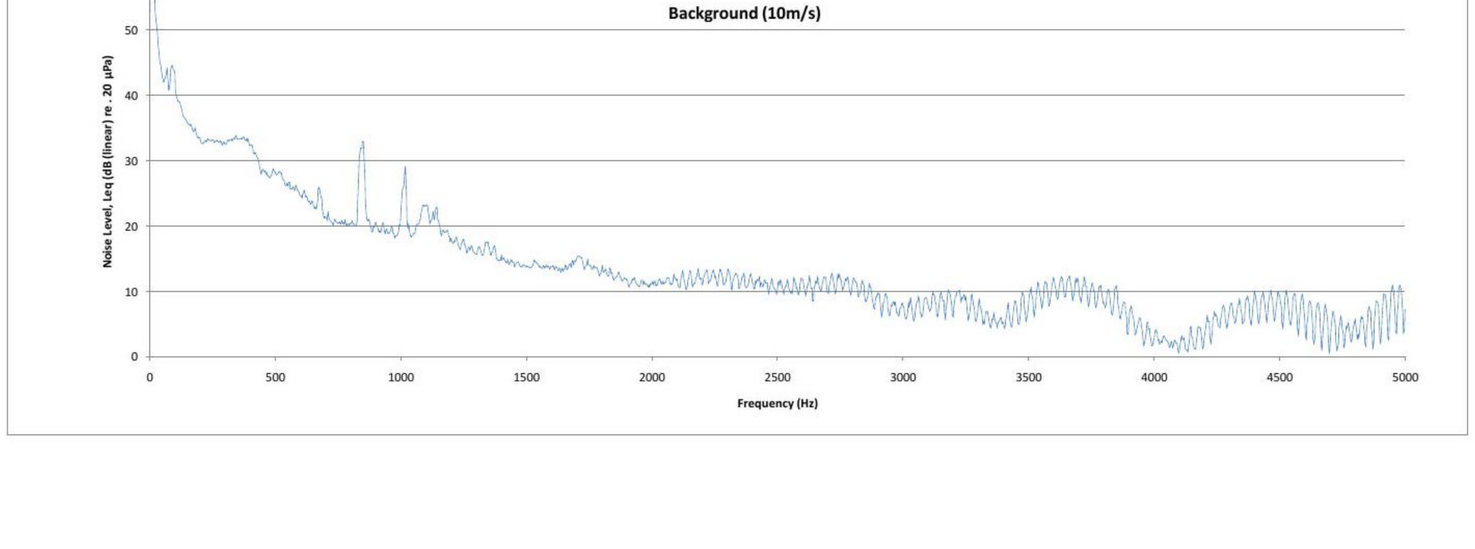












Results of tonal assessment

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

EWT	Emergya Wind Technologies BV
	DW54

Category:	Specification	Page 1 / 11
Doc code:	S-1005030	

Created by:	RH	Creation Date:	09-05-12
Checked by:	LE	Checked Date:	09-05-12
Approved by:	TY	Approved Date:	09-05-12

Title:

Specification

Sound power level DW54 - 500kW

Revision	Date	Author	Approved	Description of changes
01	17-08-12	RH	TY	corrected format
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-

Emergya Wind Technologies BV
Building 'Le Soleil' - Computerweg 1 - 3821 AA Amersfoort - The Netherlands
T +31 (0)33 454 0520 - F +31 (0)33 456 3092 - www.ewtinternational.com

EWT	Category:	Specification	Revision: 01
	Title:	Sound power level DW54 - 500kW	Page 2 / 11
	Doc code:	S-1005030	

Contents

EWT	Category:	Specification	Revision: 01
	Title:	Sound power level DW54 - 500kW	Page 3 / 11
	Doc code:	S-1005030	

1 Introduction

Following information with regard to the sound power level measurements, are distillated from measurement data of a *DIRECT**WIND*** 54 500kW turbine, located at the Elbaweg in Venhuizen, the Netherlands.

The measurements were performed by a third party according to the International Standard IEC 64100-11 December 2002: "Wind turbine generator systems – Part 11: Acoustic noise measurement techniques ".

2 Measurements

The measurements have been performed by measuring the sound pressure levels in the third octave bands of 25 Hz to 10,000 Hz at the reference point downwind of the operating turbine. The background noise level was measured during standstill of the turbine.

Measurements were carried out on the ground on a hard board according to the IEC standard. This method doubles the pressure on the microphone which raises the sound pressure level with +6 dB(A) compared to free field measurements.

The measured sound pressure levels can be found in Appendix 2 measured sound pressure levels.

3 Results

The sound power levels are calculated from the measured sound pressure levels according to IEC-61400-11. The wind velocities have been corrected for a reference roughness Z_0 of 0.05m by applying a factor of 1.1 on the measured wind velocity, and the sound power levels have been calculated for a reference height of 10m.

Sound power level Lwa in dB(A) **Wind speed at a height of 10m**		**middle frequency of the octave bands [hz]**								
		31.5	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
Wind 5 m/s	95.0 dB(A)	67.3	76.3	82.5	89.0	90.3	87.9	85.3	80.6	71.0
Wind 6 m/s	96.6 dB(A)	68.2	78.0	84.1	90.7	92.0	89.5	86.7	81.4	72.4
Wind 7 m/s	97.7 dB(A)	69.5	79.3	85.5	91.8	93.0	90.7	88.0	82.2	72.9
Wind 8 m/s	98.8 dB(A)	70.9	80.7	86.9	92.6	94.1	92.0	89.2	83.0	72.8
Wind 9 m/s	99.7 dB(A)	72.4	82.1	88.3	93.5	94.7	92.9	90.3	83.5	72.0
Wind 10 m/s	99.5 dB(A)	72.2	81.6	87.8	93.1	94.4	93.0	90.5	83.6	71.8

Table 3.1 gives the calculated sound power levels at the different wind speeds, and the calculated octave band power levels. Figure 3.1 gives the calculated 3rd octave band sound power levels, the values for these can be found in Appendix 1 Third octave band sound power levels.

Sound power level Lwa in dB(A) **Wind speed at a height of 10m**		**middle frequency of the octave bands [hz]**								
		31.5	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
Wind 5 m/s	95.0 dB(A)	67.3	76.3	82.5	89.0	90.3	87.9	85.3	80.6	71.0
Wind 6 m/s	96.6 dB(A)	68.2	78.0	84.1	90.7	92.0	89.5	86.7	81.4	72.4
Wind 7 m/s	97.7 dB(A)	69.5	79.3	85.5	91.8	93.0	90.7	88.0	82.2	72.9
Wind 8 m/s	98.8 dB(A)	70.9	80.7	86.9	92.6	94.1	92.0	89.2	83.0	72.8
Wind 9 m/s	99.7 dB(A)	72.4	82.1	88.3	93.5	94.7	92.9	90.3	83.5	72.0
Wind 10 m/s	99.5 dB(A)	72.2	81.6	87.8	93.1	94.4	93.0	90.5	83.6	71.8

Table 3.1 Sound power levels and the octave band data

EWT	Category:	Specification	Revision: 01
	Title:	Sound power level DW54 - 500kW	Page 6 / 11
	Doc code:	S-1005030	

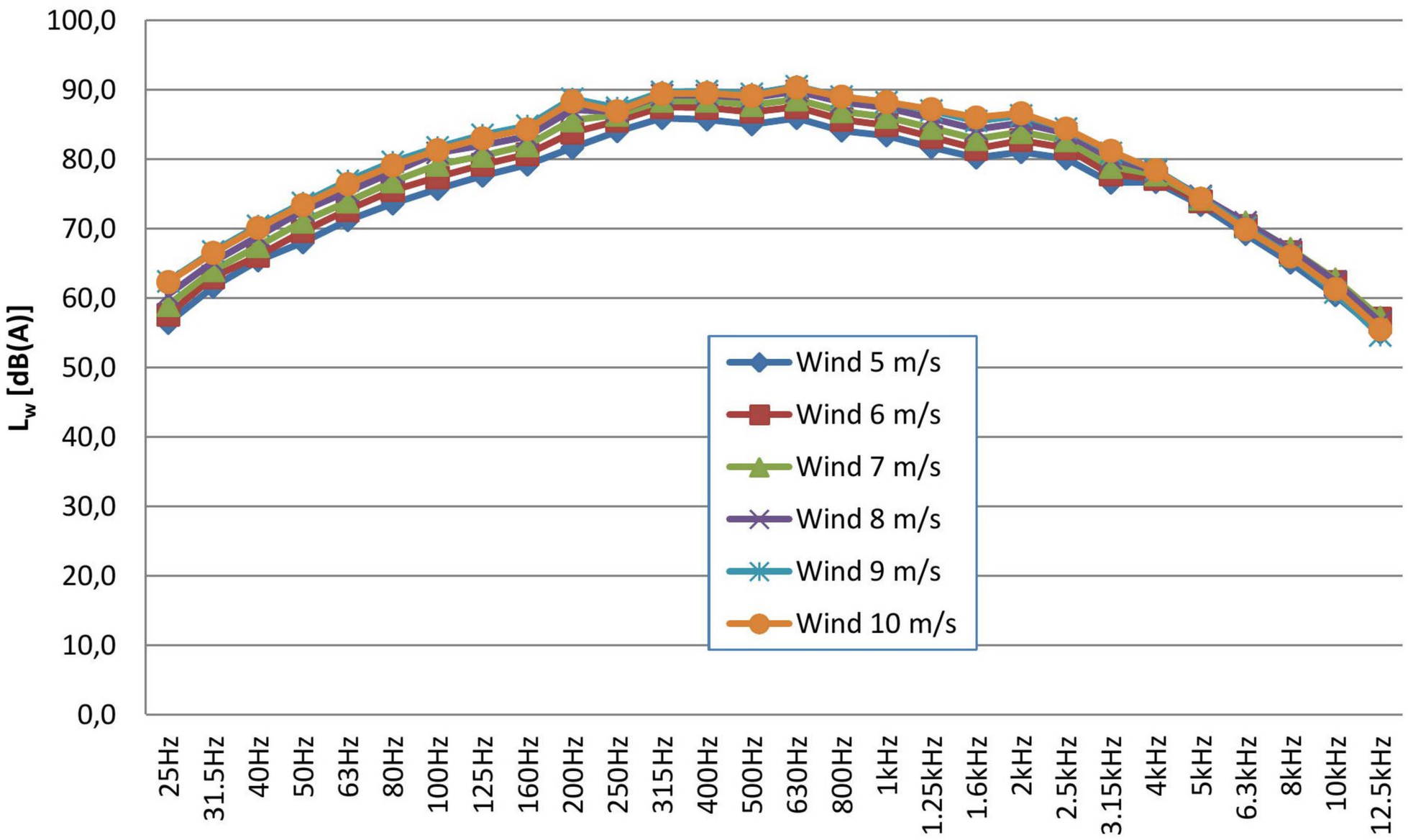


Figure 3.1 The 3rd octave band Sound Power Level spectra

EWT	Category:	Specification	Revision: 01
	Title:	Sound power level DW54 - 500kW	Page 7 / 11
	Doc code:	S-1005030	

3.1 Corrected sound power level graphical

Figure 3.2 and table 3.2 below provides all the calculated sound power levels at the different wind speeds at reference conditions (h = 10 m and z_0 = 0.05 m) and after correction for the background noise. The figure also gives the 4th order regression on this curve:

$$L_W = 0.0033V_{wind}^4 - 0.1327V_{wind}^3 + 1.7261V_{wind}^2 - 7.8733V_{wind} + 106.02\ dB(A)$$

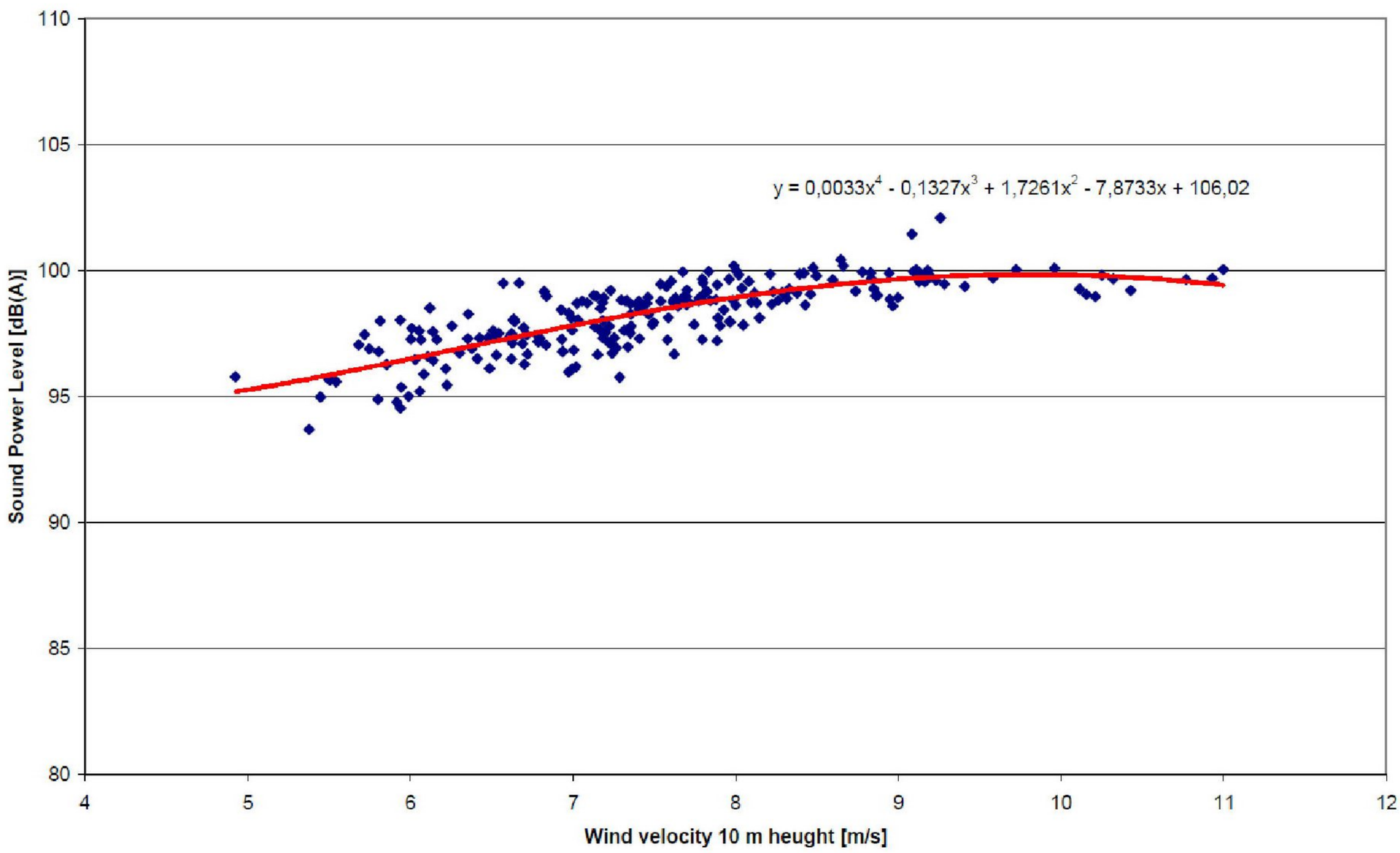


Figure 3.2 the calculated sound power level at different wind speeds

Sound power level with 4th Order regression in dB(A) **Wind speed at a height of 10m**	
Wind 5 m/s	95.3 dB(A)
Wind 6 m/s	96.5 dB(A)
Wind 7 m/s	97.8 dB(A)
Wind 8 m/s	98.9 dB(A)
Wind 9 m/s	99.6 dB(A)
Wind 10 m/s	99.8 dB(A)

Table 3.2 Sound Power Levels with 4th Order regression

3.2 Tonal Audibility

The audibility of the tones in the sound was analysed at the reference position and is given in Table 3.3 Tonal Audibility. The most important frequencies are 2.2 and 4.4 kHz. In Table 3.3 also the tonal penalty according to ETSU-R-97 (The assessment and rating of noise from wind farms – September 2006) is given. For the tone level of 3.3, the ETSU penalty of 2.5 dB can be found in Figure 3.3. No penalties are incurred for audibility levels below 2.0 dB.

According to ETSU-R-97, the tonal penalty should be added at the receiver for the specific wind speed at which the tonal audibility is present.

Wind @ 10 m ([m/s]	5	6	7	8	9
ΔL_A [dB(A)]	3.3	0.9	1.5	0.7	-0.7
ETSU Penalty [dB]	2.5	-	-	-	-

Table 3.3 Tonal Audibility

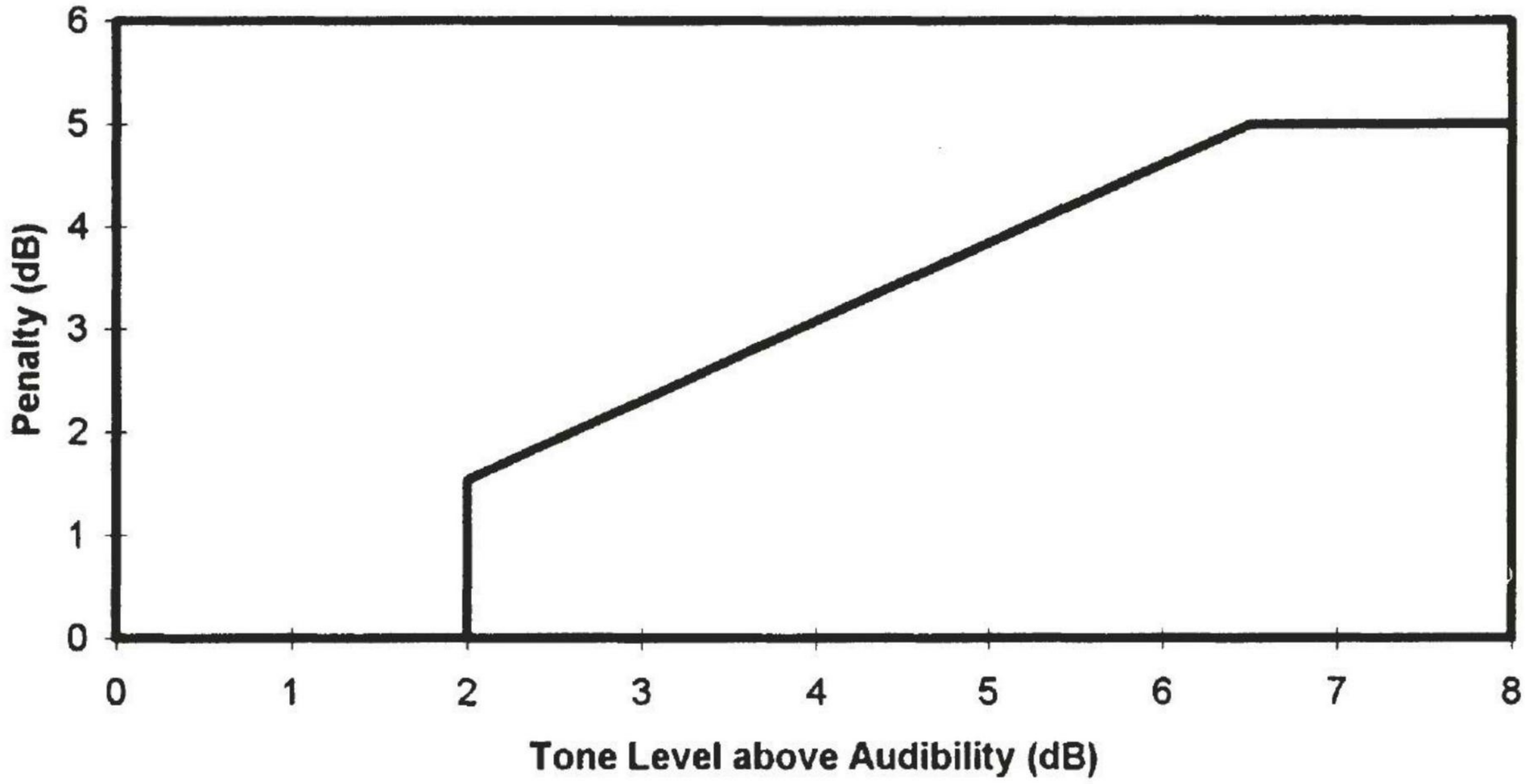


Figure 3.3 Tonal penalty according to ETSU-R-97

3.3 Uncertainty

The following Table 3.4 gives the number of measurements and the uncertainty in dB(A) for each different wind speed.

Wind Class	Number of measurements	Uncertainty [dB(A)]
Wind 5 m/s	4	1.7
Wind 6 m/s	37	1.4
Wind 7 m/s	77	1.2
Wind 8 m/s	68	0.9
Wind 9 m/s	26	0.9
Wind 10 m/s	9	0.7

Table 3.4 Number of measurements and uncertainty

Appendix 1 Third octave band sound power levels

V10[m/s]	25Hz	31.5Hz	40Hz	50Hz	63Hz	80Hz	100Hz	125Hz	160Hz
Wind 5 m/s	56,4	61,6	65,4	68,0	71,2	73,6	75,7	77,6	79,2
Wind 6 m/s	57,6	63,0	66,1	69,6	72,7	75,5	77,4	79,2	80,7
Wind 7 m/s	59,0	64,0	67,5	71,0	73,9	76,8	79,2	80,5	82,0
Wind 8 m/s	60,5	65,2	68,9	72,6	75,3	78,1	80,9	82,0	83,3
Wind 9 m/s	62,4	66,7	70,4	73,7	76,9	79,6	81,7	83,5	84,8
Wind 10 m/s	62,3	66,5	70,1	73,4	76,4	79,1	81,3	83,0	84,3

V10[m/s]	200Hz	250Hz	315Hz	400Hz	500Hz	630Hz	800Hz	1kHz	1.25kHz
Wind 5 m/s	81,6	84,0	85,9	85,7	85,0	85,9	84,1	83,4	81,7
Wind 6 m/s	83,8	85,5	87,5	87,4	86,8	87,5	85,7	84,9	83,2
Wind 7 m/s	85,6	86,4	88,4	88,4	87,8	88,6	86,9	86,1	84,5
Wind 8 m/s	87,1	86,9	89,2	89,2	88,8	89,8	88,2	87,4	85,9
Wind 9 m/s	88,7	87,4	89,7	89,8	89,4	90,5	89,0	88,2	87,0
Wind 10 m/s	88,3	86,9	89,4	89,5	89,1	90,3	89,0	88,2	87,2

V10[m/s]	1.6kHz	2kHz	2.5kHz	3.15kHz	4kHz	5kHz	6.3kHz	8kHz	10kHz	12.5kHz
Wind 5 m/s	80,2	81,0	80,1	76,6	76,7	73,4	69,2	65,1	60,4	55,0
Wind 6 m/s	81,5	82,7	81,6	77,8	77,2	73,9	70,4	66,6	62,3	57,0
Wind 7 m/s	82,9	83,9	82,7	78,9	77,8	74,3	70,9	67,1	62,7	57,2
Wind 8 m/s	84,3	85,2	83,7	80,1	78,3	74,7	70,9	67,0	62,4	56,5
Wind 9 m/s	85,5	86,3	84,4	80,9	78,5	74,5	70,2	66,1	60,8	54,6
Wind 10 m/s	86,0	86,6	84,4	81,2	78,4	74,3	69,9	66,0	61,3	55,5

Appendix 2 measured sound pressure levels

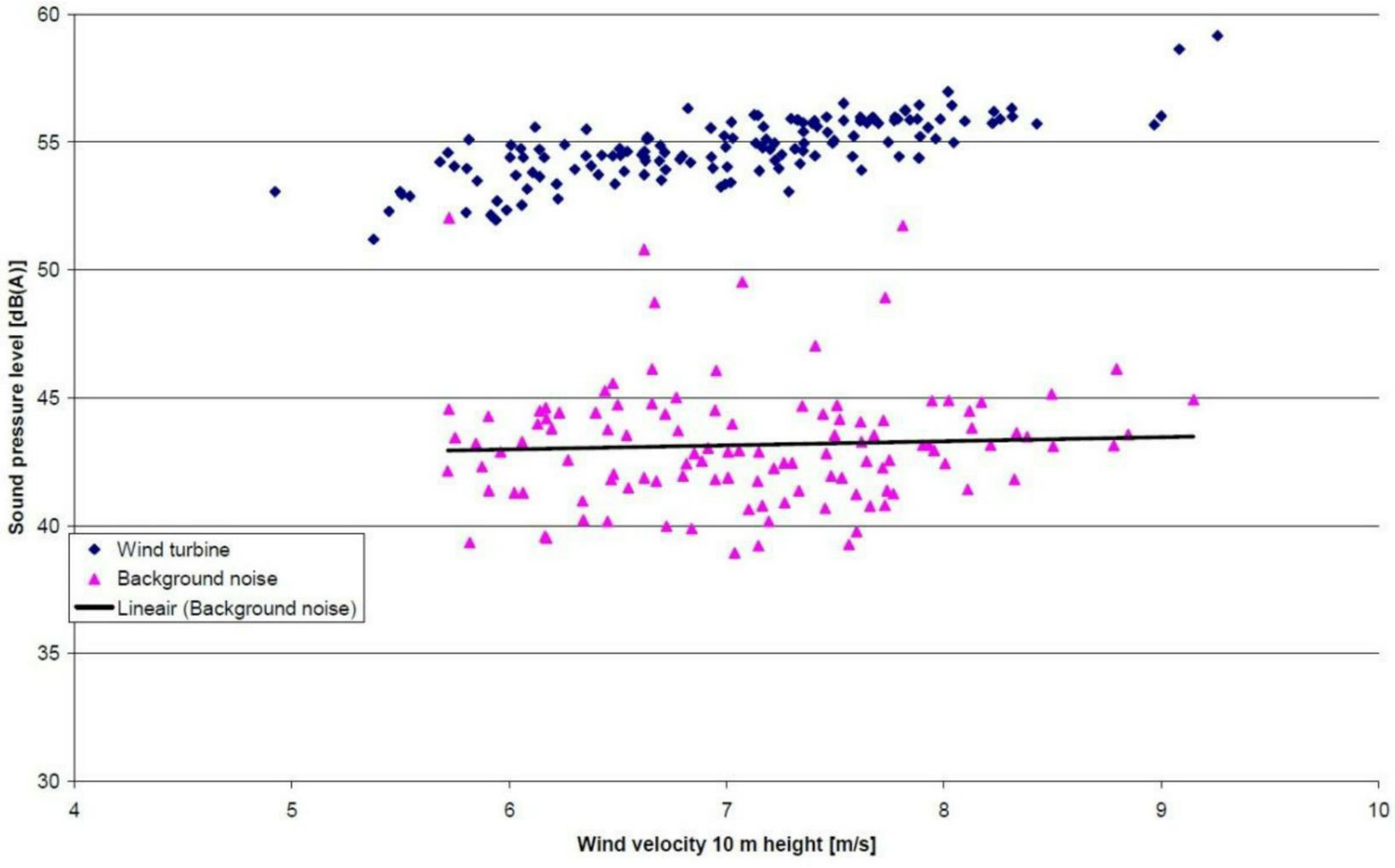


Figure 0.1 Measured sound pressure levels 11 November 2011

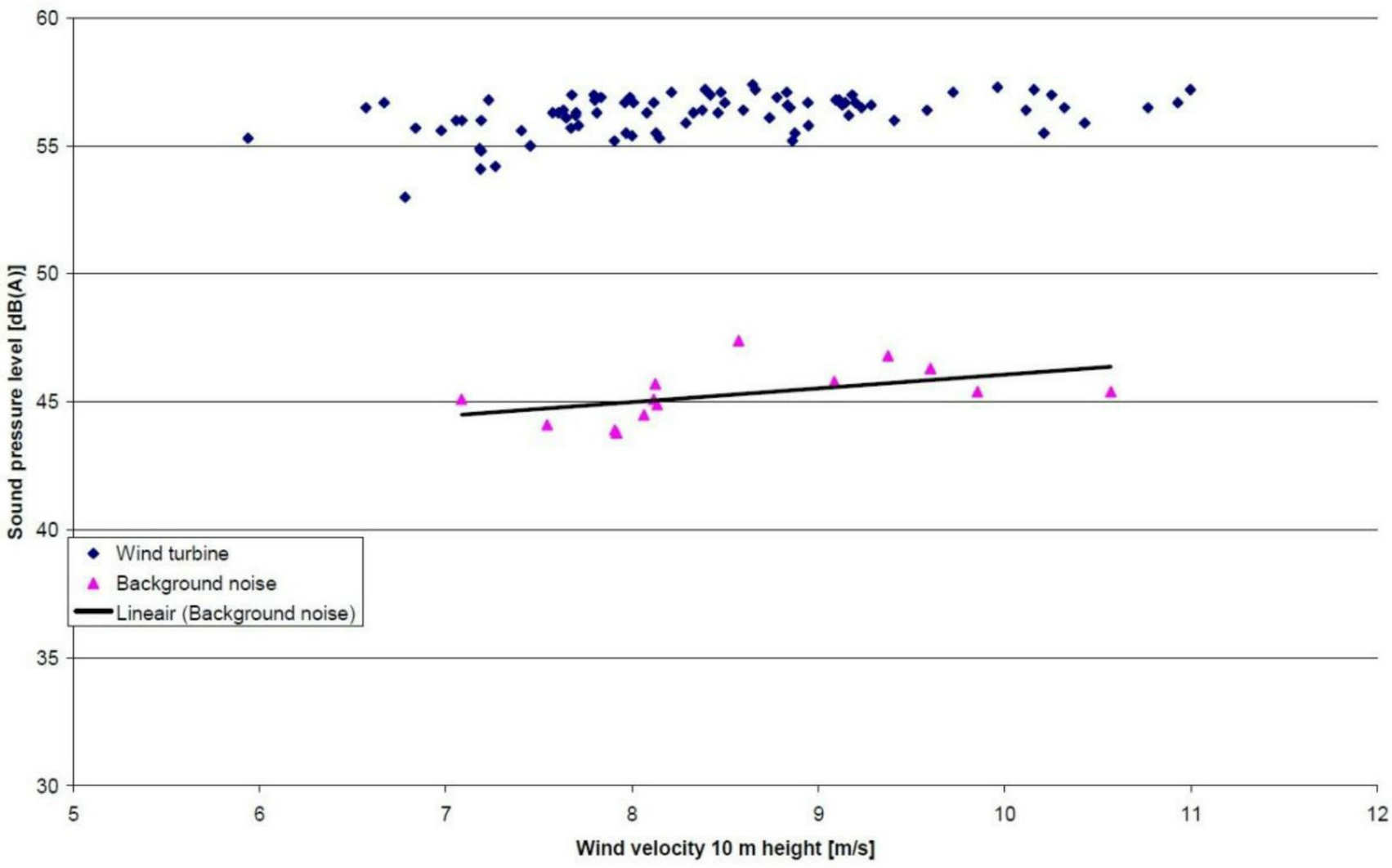


Figure 0.2 Measured sound pressure levels 15 February 2012

From: DuthieNG
Sent:22 Dec 2014 16:47:55 +0000
To: AkroydL
Subject:FW: EHO - Ownership confirmation - 14/00827/FULL - Finavon, Forfar

Louise

Please find attached confirmation of financial interest for your consideration. Please advise if now acceptable.

Regards

Neil Duthie

-----Original Message-----
From: Derek [mailto:derek@kilmac.co.uk]
Sent: 22 December 2014 11:49
To: DuthieNG; Graham Donnachie
Subject: FW: EHO - Ownership confirmation

Dear Neil,

I attach a scanned copy of the letter Jeff Sanderson sent to me on Thursday last week. I'm not in the office so have taken the chance to scan and send as confirmation on ownership.

The original will be posted out today.

Regards

Derek

Derek Ross
Director

Tel: 01738 620350
Fax: 01738 620267
Mobile: 07785550162
Email: derek@kilmac.co.uk
Website: www.kilmac.co.uk

Registered Address: Glendevon House, Old Gallows Road, Western Edge, Perth, PH1 1QE P Please consider the environment before printing this e-mail.

FAO Neil Duthie
Planning Officer (Development Standards)
Planning & Place
Angus Council
County Buildings
Market Street
Forfar
DD8 3LG

18th December 2014

Finavon Hill Estate Wind Turbine (14/00827/FLL):
Finavon House and Finavon Cottage Financial Interests

Dear Mr Duthie,

I am writing to confirm to the Angus Council Planning Service and the Environmental Health Department that as the co-applicant and occupier of Finavon House, I have a financial interest in the development.

Finavon Cottage, which is owned by my business partner, Mr. Brian Smith also has a financial interest in the development.

As business partners, we are in joint ownership of the Finavon Estate within which the proposed turbine will be situated.

I trust this clarifies which properties have a financial interest in the application, as requested by the Environmental Health Department.

Kind Regards,

Jeff Sanderson

Finavon House, Finavon Hill Estate, Forfar