Acoustic Noise Test Report for the Viryd CS8 Wind Turbine

J. Roadman and A. Huskey
National Renewable Energy Laboratory

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NREL/TP-5000-58565
July 2013

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Acoustic Noise Test Report

for the

Viryd CS8 Wind Turbine

at the

National Wind Technology Center

in Boulder, CO

Conducted for

National Renewable Energy Laboratory

15013 Denver West Parkway

Golden, Colorado 80401

Conducted by

National Wind Technology Center

National Renewable Energy Laboratory

15013 Denver West Parkway

Golden, Colorado 80401

Jason Roadman

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19 March 2013

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Approval By: [signature] 26 APR 2013
Jason Roadman, NREL Test Engineer — Date

Review By: Arlinda Huskey 26 Apr 2013
Arlinda Huskey, NREL Test Engineer — Date

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1 Background

This test was conducted as part of the U.S. Department of Energy's (DOE) Independent Testing project. This project was established to help reduce the barriers of wind energy expansion by providing independent testing results for small turbines. Several turbines were selected for testing at the National Renewable Energy Laboratory's (NREL) National Wind Technology Center (NWTC) as a part of the Small Wind Turbine Independent Testing project. Acoustic noise testing is one of up to five tests that may be performed on the turbines. Other tests include duration, safety and function, power performance, and power quality. Viryd Technologies, Inc. of Austin, Texas, was the recipient of the DOE grant and provided the turbine for testing.

The primary goal of this test was to characterize the acoustic emissions of the Viryd CS8 wind turbine in accordance with the International Electrotechnical Commission's (IEC) standard, *Wind Turbine Generator Systems - Part 11: Acoustic Noise Measurement Techniques*, IEC 61400-11, Edition 2.1, 2006-11; hereafter referred to as the "Standard." This test report documents the measurement techniques, turbine configuration, test site, test equipment, and results for the following quantities at integer wind speeds from 5 to 12 m/s:

- Apparent sound power level
- One-third octave band levels
- Tonality.

Engineers at the NWTC conducted this test in accordance with its quality system procedures to ensure that this final test report meets the full requirements accreditation by A2LA. NREL's quality system requires that the test meet all applicable requirements specified by A2LA and ISO/IEC 17025 (or to note any exceptions in the test report).

2 Test Summary

The turbine was tested in accordance with the Standard. Turbine acoustic emissions and meteorological data were collected on 05 December 2012. Standardized wind speed (at 10 meters) was derived from wind speed measured at hub height (24.9 m). Table 1 gives a summary of the test results.

Table 1. Test Results Summary

Standardized wind speed at 10 m height, Vs [m/s]	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Electrical power output calculated from power curve	0.0	0.4	1.8	3.3	4.8	5.8	6.5	6.3
Measured pitch angle [°]	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Apparent sound power level [dBA]	89.8	90.0	91.5	93.3	94.2	94.5	94.8	95.6
Combined uncertainty in the sound power level, U_C	1.0	1.2	1.5	1.2	1.1	1.0	0.9	1.0
Frequency of the most prevalent tone [Hz]	1,03	1,04	1,04	1,04	1,04	1,05	1,05	1,04
Tonality, ΔL_k [dBA]	0.62	3.41	5.86	7.00	6.78	6.69	5.80	5.63
Tonal audibility, $\Delta L_{a,k}$ [dBA]	3.46	6.26	8.72	9.87	9.64	9.55	8.67	8.49

3 Test Turbine Configuration

Table 2 lists the configuration of the Viryd turbine that was tested at the NWTC. During commissioning, small shims were inserted between the hub plate and the blade root, thereby pitching the leading edge of the blades into the wind. The pitch angle of each blade with respect to the hub plate is fixed. It was measured and is given in Table 3.

Table 2. Viryd Wind Turbine General Data

Turbine manufacturer and address	Viryd Technologies, Inc. 9701 Metric Blvd, Suite 200 Austin, TX 78758
Model	Viryd CS8
Rated power (kW)	8
Rated wind speed (m/s)	10
Serial number	CS008100X
Blade make, type, serial number	Viryd proprietary design, 011247-029, 011247-030, 011247-031
Generator make, type, serial number	Marathon, AC induction, I217, 215TBFW7027DD L
Gearbox make, type, serial number	Boston Gear, 662B-16L-VIR, Helical Gear, 594189
Control software	Proprietary – PCB
Wind turbine type	Horizontal axis, Upwind
Tower type	Guyed Lattice
Number of blades	3
Hub height (m)	25.0*
Rotor diameter (m)	8.5*
Horizontal distance from rotor center to tower axis (m)	0.66 m
Speed control	Passive stall
Constant or variable speed	Constant
Rotational speed at standardized integer wind speed from 6 to 10 m/s (rpm)	119-122
Pitch angle at standardized integer wind speeds from 6 to 10 m/s	Fixed, see Table 3
Rotor control devices	none

*Measurements verified the rotor diameter and hub height.

Table 3. Measured Blade Pitch Angle Relative to the Hub Plate

Blade	Pitch Angle
1	1.4°
2	1.1°
3	1.4°

Figure 1. Viryd CS8 test turbine at the NWTC
(*Photo by Mark Murphy, NREL 22258*)

4 Test Site Description

The Viryd CS8 wind turbine is located at test site 3.3 of the NWTC, approximately 8 km south of Boulder, Colorado. The site consists of mostly flat terrain with short vegetation (see Appendix A for photos) and has prevailing winds bearing 292° relative to true north. Figure 2 shows the turbine and meteorological tower locations, as well as nearby obstructions. NREL limited assessments of power and energy production to data obtained when winds were within the measurement sector of 211° to 38°. In this measurement sector, the influence of terrain and obstructions on the anemometer is small and meets the requirements in accordance with IEC 61400-12-1 without conducting a site calibration test.

Table 4 lists the nearby turbines and whether or not they were operating during data collection.

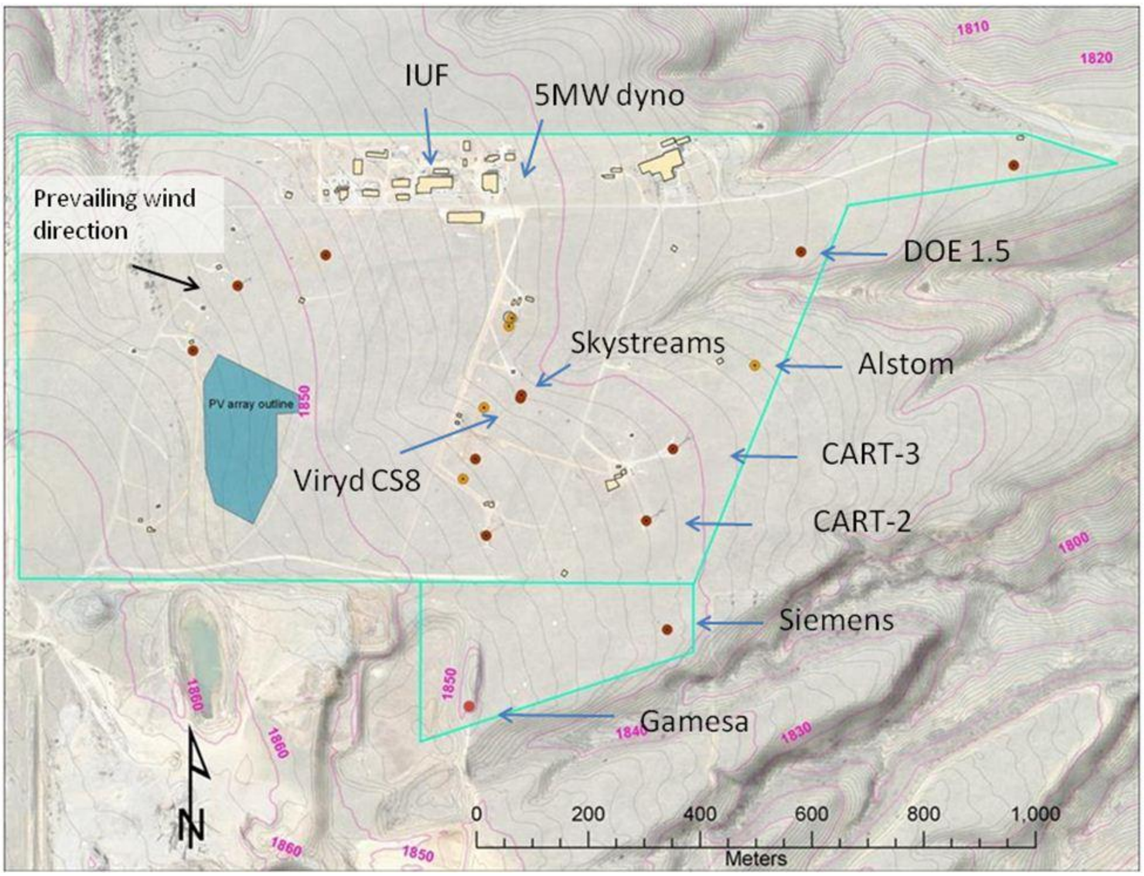

Figure 2. Map of the test site

Table 4. Sources of Noise Near the Turbine

Source	Location	Shutdown for Noise Test
DOE 1.5	4.0	Yes
Alstom ECO100 3.0 MW	4.1	Yes
CART-3	4.3	Yes
CART-2	4.3	Yes
Siemens 2.3MW	4.4	Yes
Southwest Windpower Skystream (two turbines)	3.2	Yes
NW100	1.2	No
Test shed heating, ventilating, and air conditioning (HVACs)	3.1, 3.2, 3.3	Yes
Building A60 Hydraulics	Industrial User Facility	Yes
Southwest Windpower Whisper (two turbines)	1E.2	No

5 Test Equipment

5.1 Equipment Descriptions

Table 5 shows the list of equipment used for the test. All instruments meet the requirements defined by the Standard.

Table 5. Equipment List for Acoustic Test

Instrument	Manufacturer	Model Number	Serial Number	Calibration Due Date
Digital recorder and signal analyzer	Delta Acoustics	NoiseLab	1283B54	19 Dec 2013
Microphone	Bruel & Kjaer	4189	2406812	18 Dec 2013
Preamplifier	Bruel & Kjaer	2671	2373722	18 Dec 2013
Calibrator	Bruel & Kjaer	4231	2388951	19 Dec 2012
Anemometer	Thies	First Class	0609006	17 Sep 2013
Wind vane	Met One	020C	W5515	17 Sep 2013
Pressure sensor	Vaisala	PTB101B	C10400014	13 Feb 2013
Temperature sensor	Met One	T200A	0603-1	17 Sep 2013
Power transducer	Secondwind	Phaser-5-485-4A20	01091	15 Sep 2013
Data acquisition	National Instruments	CompactDAQw/LabView		
		cDAQ-9172	0x1339A69	NA
		NI 9229	12A2037	27 Jun 2013
		NI 9217	12BFEE2	27 June 2013
		NI 9205	14DA726	27 June 2013

5.2 Instrument Locations

The primary anemometer on the meteorological tower was used to derive the standardized wind speed. This tower was located 22.9 meters (m) from the test turbine, at a bearing of 283^{o} true, with the top-mounted anemometer at a height of 24.9 m. The wind vane was mounted at a height of 23.0 m on the meteorological tower on a cross boom that was approximately perpendicular to the predominant wind direction. The turbine was 2.9 rotor diameters from the meteorological tower, within the range of 2 and 4 rotor diameters specified in the Standard.

Table 6 provides the location of the microphone for the measurement sessions.

Table 6. Reference Microphone Positions for the Turbine and Background Measurements Collected on 05 December 2012

Recording	Distance Turbine [m]	Slant Distance [m]	Position Relative to Turbine [deg true]
Recording 1–7	29.2	39.0	115
Recording 8	29.2	39.0	95

6 Results

6.1 Test Conditions

The analysis was done using the measured wind speed and 10-second averages of the data. NREL engineers have found that using 10-second averages instead of 1-minute averages better characterizes the dynamic nature of small turbines. The range of standardized wind speeds and wind directions used for the analysis were 3.3 to 15.1 m/s and 260 to 310 degrees, respectively. The range of temperature and pressure were 12.7°C to 18.8°C and 80.7 kPa to 80.9 kPa, respectively.

6.2 Standardized Wind Speed Calculation

Standardized wind speed, V_s, was calculated according to Equation 1 and the values in Table 7, where V_z is the measured wind speed.

$$V_s = V_z \left[\frac{\ln\left(\frac{z_{ref}}{z_{0ref}}\right)\ln\left(\frac{H}{z_0}\right)}{\ln\left(\frac{H}{z_{0ref}}\right)\ln\left(\frac{z}{z_0}\right)} \right] \quad (1)$$

Table 7. Test Parameters Used in Calculations

Parameter	Name	Value
Hub height, (m)	H	25.0
Roughness length, (m)	z_o	0.05
Anemometer height, (m)	z	24.9
Reference roughness length, (m)	z_{oref}	0.05
Reference height, (m)	z_{ref}	10.00

6.3 Apparent Sound Power Level

Sound pressure levels were binned by wind speed. Sound pressure levels at integer wind speed values were calculated using interpolation between bin averages and extrapolation at the ends. The sound pressure levels were then background corrected according to the Standard. Figure 3 shows the scatter plot of the sound pressure levels of the validated total (operating plus background) and background noise along with the binned sound pressure levels. The measured and background corrected apparent sound pressure level at standardized wind speeds of 5 through 12 m/s are shown in Table 8 along with the calculated sound power levels. Figure 4 shows sound power levels graphed against standardized wind speed.

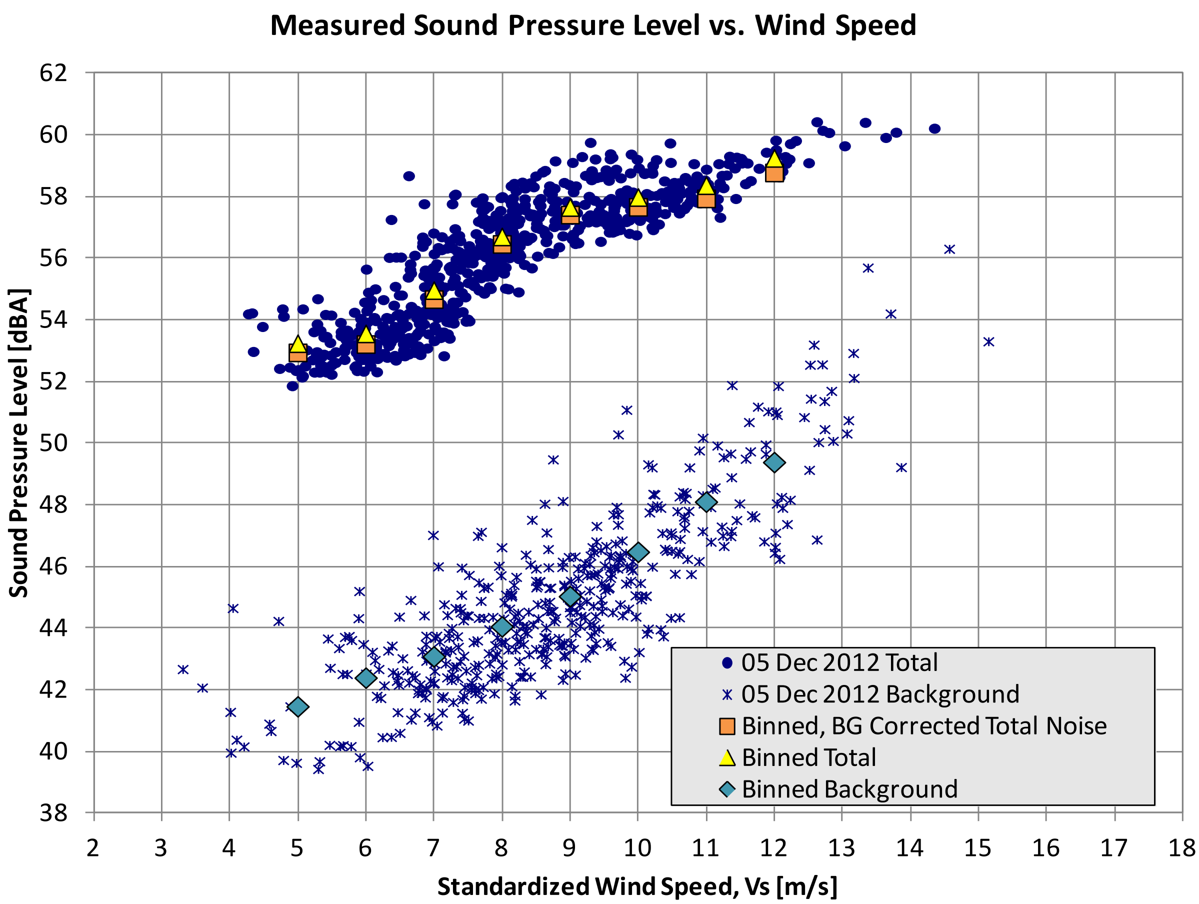

Figure 3. Measured and binned sound pressure levels as a function of the standardized wind speed

Table 8. Sound Pressure and Power Levels for Standardized Integer Wind Speeds (5 m/s Through 12 m/s)

Wind Speed Bin [m/s]	Total Sound Pressure Level [dBA)]	Background Sound Pressure Level [dBA]	Background Corrected Sound Pressure Level [dBA]	Sound Power Level [dBA]	Type A Uncert. [dBA]	Type B Uncert. [dBA]	Combined Uncert. [dBA]
5	53.3	41.5	53.0	89.8	0.7	0.7	1.0
6	53.6	42.4	53.2	90.0	0.9	0.7	1.2
7	55.0	43.1	54.7	91.5	1.3	0.7	1.5
8	56.7	44.1	56.5	93.3	0.9	0.7	1.2
9	57.7	45.1	57.4	94.2	0.8	0.7	1.1
10	58.0	46.5	57.7	94.5	0.8	0.7	1.0
11	58.4	48.1	58.0	94.8	0.6	0.7	0.9
12	59.3	49.4	58.8	95.6	0.6	0.8	1.0

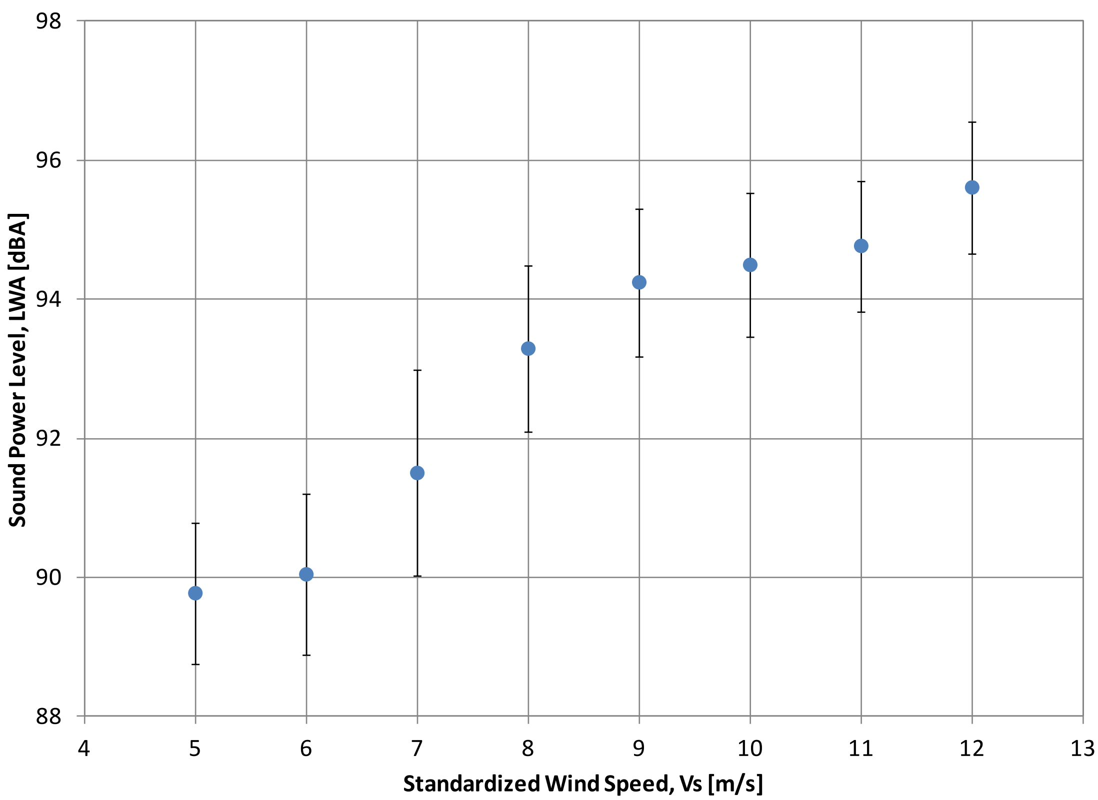

Figure 4. Sound power levels as a function of the standardized wind speed

6.4 One-Third Octave Analysis

One-third octave levels were analyzed at standardized wind speeds of 5 through 12 m/s. The results (with uncertainty) are provided in Table 9, Table 10, and Figure 5.

Table 9. One-Third Octave Analysis for Wind Speed Bins 5 Through 8 m/s

Center Frequency	5 m/s One-Third Octave Levels	6 m/s One-Third Octave Levels	7 m/s One-Third Octave Levels	8 m/s One-Third Octave Levels
[Hz]	[dBA]	[dBA]	[dBA]	
50	NR	NR	NR	NR
63	NR	NR	NR	NR
80	26.7* ± 2.0	26.4* ± 2.0	NR	26.6* ± 2.0
100	29.0* ± 2.0	30.4* ± 2.0	31.4* ± 2.0	32.6* ± 2.0
125	37.4 ± 1.9	39.8 ± 1.9	42.0 ± 1.8	43.4 ± 1.8
160	33.5* ± 2.0	33.3* ± 2.0	32.9* ± 2.0	34.4* ± 2.0
200	40.0 ± 1.9	39.7 ± 1.9	39.0* ± 2.0	38.9* ± 2.0
250	41.5 ± 1.8	41.6 ± 1.8	42.3 ± 1.8	43.9 ± 1.8
315	37.6 ± 1.9	36.6 ± 1.9	36.7* ± 2.0	39.0 ± 2.0
400	41.4 ± 1.9	39.4 ± 1.9	39.1 ± 1.9	40.8 ± 1.9
500	42.1 ± 2.0	39.1 ± 1.8	39.4 ± 1.8	41.6 ± 1.9
630	41.3 ± 1.8	40.4 ± 1.8	41.4 ± 1.8	43.2 ± 1.8
800	40.6 ± 1.8	40.5 ± 1.8	41.2 ± 1.8	42.3 ± 1.8
1,000	45.6 ± 1.8	48.3 ± 1.9	51.6 ± 1.9	53.9 ± 1.8
1,250	44.0 ± 1.8	44.6 ± 1.8	45.3 ± 1.8	46.9 ± 1.8
1,600	40.9 ± 1.8	40.1 ± 1.8	38.7 ± 1.8	38.8 ± 1.8
2,000	40.1 ± 1.8	39.0 ± 1.8	37.5 ± 1.8	37.5 ± 1.8
2,500	39.1 ± 1.8	38.5 ± 1.8	37.9 ± 1.8	37.8 ± 1.8
3,150	37.6 ± 1.8	37.5 ± 1.8	37.3 ± 1.8	37.4 ± 1.8
4,000	34.9 ± 1.8	34.4 ± 1.8	34.0 ± 1.8	33.6 ± 1.8
5,000	27.6* ± 2.0	27.1* ± 2.0	26.9* ± 2.0	27.0* ± 2.0
6,300	NR	NR	NR	NR
8,000	NR	NR	NR	NR
10,000	NR	NR	NR	NR

* The difference between total and background noise was less than 6 dB but greater than 3 dB. A standard background correction of 1.3 dB was applied per Section 8.2 of the Standard.

NR The difference between total and background noise was less than 3 dB. According to Section 8.2 of the Standard, the wind turbine noise was less than the background noise.

Table 10. One-Third Octave Analysis for Wind Speed Bins 9 Through 12 m/s

Center Frequency	9 m/s One-Third Octave Levels	10 m/s One-Third Octave Levels	11 m/s One-Third Octave Levels	12 m/s One-Third Octave Levels
[Hz]	[dBA]	[dBA]	[dBA]	[dBA]
50	NR	NR	22.4* ± 2.1	25.0* ± 2.1
63	NR	NR	NR	29.8* ± 2.0
80	NR	28.0* ± 2.0	29.6* ± 2.1	32.7* ± 2.1
100	33.5* ± 2.0	34.5 ± 1.9	34.6* ± 2.0	36.0* ± 2.0
125	44.4 ± 1.8	45.1 ± 1.8	44.5 ± 1.8	43.1 ± 1.9
160	35.6* ± 2.0	37.9* ± 2.0	39.4* ± 2.0	41.1* ± 2.1
200	40.0* ± 2.0	40.4* ± 2.0	41.8* ± 2.0	43.1* ± 2.0
250	45.3 ± 1.8	46.4 ± 1.8	46.0 ± 1.8	45.7 ± 1.9
315	41.3 ± 1.9	42.5 ± 1.9	43.1 ± 1.9	44.6 ± 1.9
400	42.4 ± 1.9	43.3 ± 1.9	43.7 ± 1.9	45.0 ± 1.9
500	43.1 ± 1.8	44.0 ± 1.8	44.3 ± 1.9	45.5 ± 1.9
630	44.4 ± 1.8	45.3 ± 1.8	46.1 ± 1.8	47.2 ± 1.8
800	43.4 ± 1.8	44.4 ± 1.8	45.6 ± 1.9	47.1 ± 1.9
1,000	54.7 ± 1.8	54.2 ± 1.8	54.3 ± 1.8	55.3 ± 1.8
1,250	48.0 ± 1.8	48.6 ± 1.8	48.9 ± 1.8	48.8 ± 1.8
1,600	39.9 ± 1.8	41.1 ± 1.8	42.3 ± 1.9	43.8 ± 1.9
2,000	38.3 ± 1.8	39.2 ± 1.8	40.2 ± 1.9	41.6 ± 1.9
2,500	38.0 ± 1.8	38.5 ± 1.8	39.0 ± 1.8	40.3 ± 1.9
3,150	37.7 ± 1.8	38.1 ± 1.8	38.6 ± 1.8	39.1 ± 1.9
4,000	33.5 ± 1.8	33.7 ± 1.9	34.2 ± 1.9	34.6 ± 2.0
5,000	27.3* ± 2.0	NR	NR	NR
6,300	NR	NR	NR	NR
8,000	NR	NR	NR	NR
10,000	NR	NR	NR	NR

* The difference between total and background noise was less than 6 dB but greater than 3 dB. A standard background correction of 1.3 dB was applied per Section 8.2 of the Standard.

NR The difference between total and background noise was less than 3 dB. According to Section 8.2 of the Standard, the wind turbine noise was less than the background noise.

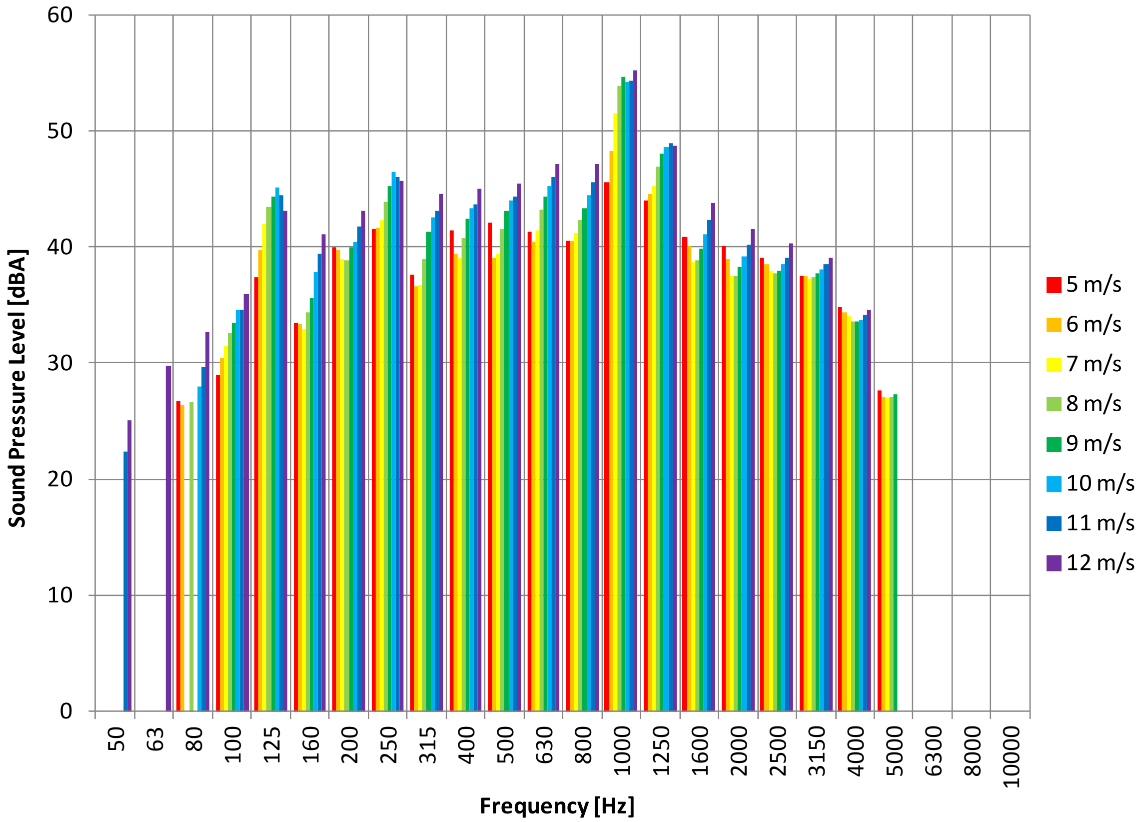

Figure 5. One-third octave levels

6.5 Tonality

The tonality analysis resulted in reportable tones for wind speed bins 5 through 12 m/s, detailed in Table 11 through Table 14. Figure 6 through Figure 30 show 10-second energy averaged spectra indicating the classification of spectral lines for each of the identified tones.

Table 11. Tonality Results (In dBA)

Wind speed:	5 m/s		6 m/s		7 m/s		
f [Hz]	1,032	1,293	1,041	1,311	1,047	1,173	1,311
ΔLtn,1	3.14	-0.89	9.07	-3.35	4.01	-1.72	-6.60
ΔLtn,2	-0.99	-2.93	-0.03	-0.62	7.40	3.61	-9.21
ΔLtn,3	3.83	0.55	1.95	3.75	8.23	2.91	-8.74
ΔLtn,4	-1.84	-0.34	2.96	3.43	1.32	1.81	-9.55
ΔLtn,5	2.67	-1.90	4.16	1.71	7.29	-1.25	-6.80
ΔLtn,6	-2.68	3.33	2.99	1.17	6.34	-16.02	-16.43
ΔLtn,7	-2.70	-8.65	3.19	-3.87	8.49	3.74	-12.74
ΔLtn,8	-0.34	-4.49	1.04	1.73	4.96	2.69	-16.43
ΔLtn,9	1.75	-3.98	4.18	2.80	2.44	2.41	-12.14
ΔLtn,10	0.78	-0.57	1.12	-1.94	4.73	3.97	-16.43
ΔLtn,11	-5.23	0.20	-0.02	-0.25	4.96	-0.20	-11.24
ΔLtn,12	0.24	-5.42	-0.67	0.72	4.06	1.43	-9.68
ΔLk	0.62	-1.11	3.41	1.04	5.86	-1.91	1.77
ΔLa,k	3.46	1.96	6.26	4.12	8.72	1.06	4.85
U_A	2.9	3.4	3.3	2.5	2.8	2.5	2.9
U_B	1.8	1.8	1.8	1.8	1.8	1.8	1.8
U_C	3.4	3.8	3.8	3.0	3.3	3.1	3.4

Table 12. Tonality Results (In dBA)

Wind speed:	8 m/s			9 m/s			
f [Hz]	1,047	1,170	1,326	246	1,047	1,173	1,338
ΔLtn,1	5.88	4.11	2.04	0.14	6.08	0.76	-4.39
ΔLtn,2	5.37	0.66	1.06	-0.03	4.30	-0.43	-3.91
ΔLtn,3	9.26	-16.02	-0.76	-13.55	8.09	-16.02	-0.09
ΔLtn,4	6.37	-1.63	-16.43	-1.58	7.11	3.25	1.43
ΔLtn,5	9.72	4.08	-0.01	-13.55	5.85	1.67	-0.47
ΔLtn,6	6.82	-2.27	2.37	-1.17	8.82	2.08	-0.53
ΔLtn,7	5.79	0.25	-0.14	-13.55	5.75	0.12	-3.62
ΔLtn,8	7.07	2.79	1.00	-13.55	5.77	1.31	1.05
ΔLtn,9	6.11	3.21	0.91	-13.55	6.64	-16.02	-0.20
ΔLtn,10	6.04	-3.43	-2.26	-13.55	7.63	1.61	2.36
ΔLtn,11	7.29	-0.05	3.95	-13.55	7.11	-16.02	0.02
ΔLtn,12	5.54	-0.86	1.39	-1.35	6.26	1.72	-1.83
ΔLk	7.00	0.95	0.78	-4.23	6.78	0.24	-0.39
ΔLa,k	9.87	3.92	3.87	-2.17	9.64	3.21	2.70
U_A	1.9	3.1	2.2	0.9	1.2	1.2	2.1
U_B	1.8	1.8	1.8	2.0	1.8	1.8	1.8
U_C	2.6	3.6	2.8	2.2	2.1	2.1	2.7

Table 13. Tonality Results (In dBA)

Wind speed:	10 m/s				11 m/s			
f [Hz]	246	1,050	1,170	1,329	1,053	1,173	1,341	3,174
ΔLtn,1	1.03	5.36	0.56	-4.13	4.13	1.99	-0.73	-4.86
ΔLtn,2	-0.43	7.67	2.15	-0.84	7.71	0.90	-7.89	-8.01
ΔLtn,3	-1.58	5.37	0.79	-0.97	6.30	0.13	-4.11	-7.06
ΔLtn,4	-2.65	8.37	2.73	-1.31	4.89	2.40	-1.52	-4.01
ΔLtn,5	-4.09	6.63	-0.62	-4.14	3.69	3.26	-0.15	-12.12
ΔLtn,6	-1.76	2.78	-2.01	-3.43	6.32	2.12	-0.88	-9.23
ΔLtn,7	-1.42	7.04	1.38	-2.60	4.53	-0.34	-2.93	-9.16
ΔLtn,8	-0.15	5.85	1.49	0.35	6.98	1.96	-5.87	-4.09
ΔLtn,9	-4.31	4.81	0.85	-1.67	5.07	-0.12	-2.97	-6.92
ΔLtn,10	-3.06	8.28	1.69	-6.24	6.22	1.21	-3.45	-20.54
ΔLtn,11	-0.32	7.61	1.54	-4.07	6.61	2.82	0.45	-5.33
ΔLtn,12	0.51	7.34	3.61	0.74	5.27	2.58	-0.14	-3.57
ΔLk	-1.21	6.69	1.39	-1.92	5.80	1.72	-1.93	-6.45
ΔLa,k	0.85	9.55	4.37	1.18	8.67	4.69	1.16	-2.45
U_A	1.8	1.9	1.6	2.3	1.1	1.2	2.6	2.9
U_B	1.9	1.8	1.8	1.8	1.8	1.8	1.8	1.9
U_C	2.6	2.6	2.4	2.9	2.1	2.1	3.2	3.5

Table 14. Tonality Results (In dBA)

Wind speed:	12 m/s		
f [Hz]	1,044	1,173	1,326
ΔLtn,1	4.70	-0.43	-0.48
ΔLtn,2	3.42	-15.23	-7.55
ΔLtn,3	4.70	-3.89	-16.02
ΔLtn,4	5.62	-1.58	-16.02
ΔLtn,5	6.54	-2.64	-2.07
ΔLtn,6	6.10	-1.06	-6.91
ΔLtn,7	7.08	-15.23	-16.02
ΔLtn,8	6.19	3.35	-16.02
ΔLtn,9	5.69	0.93	-4.50
ΔLtn,10	5.41	-1.00	-4.13
ΔLtn,11	5.09	-0.71	-5.95
ΔLtn,12	5.86	-1.04	-6.04
ΔLk	5.63	-1.14	-5.70
ΔLa,k	8.49	1.83	-2.61
U_A	1.1	1.4	2.5
U_B	1.8	1.8	1.8
U_C	2.1	2.3	3.1

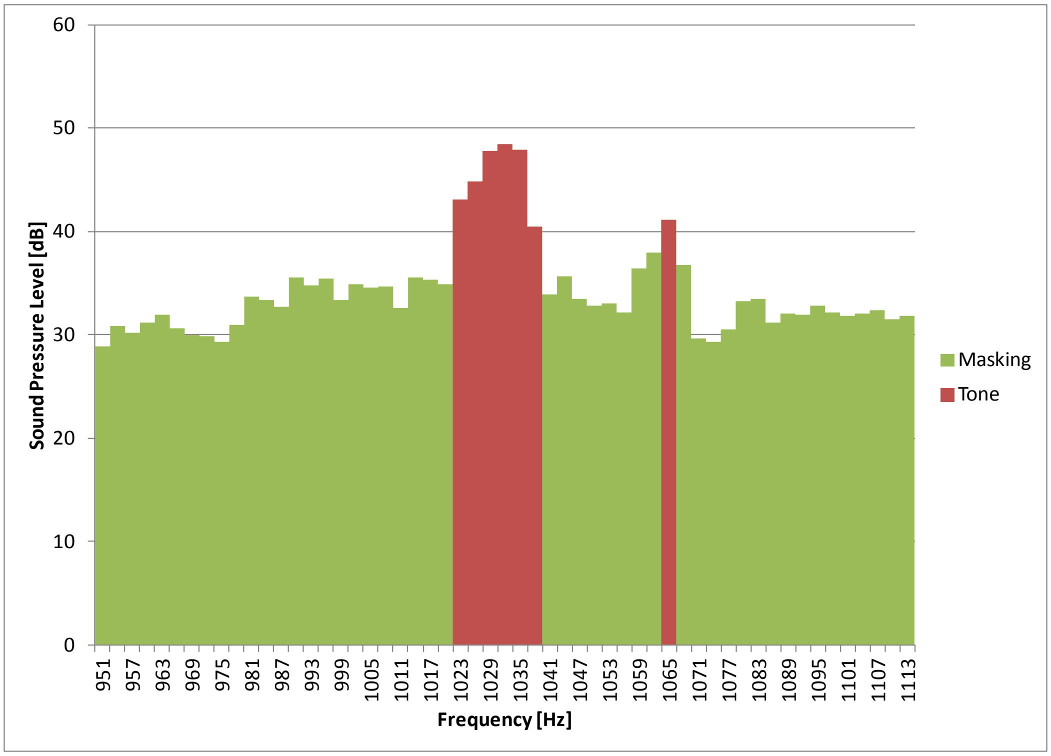

Figure 6. Classification of spectral lines for the 1,032 Hz tone (typical in the 5 m/s bin)

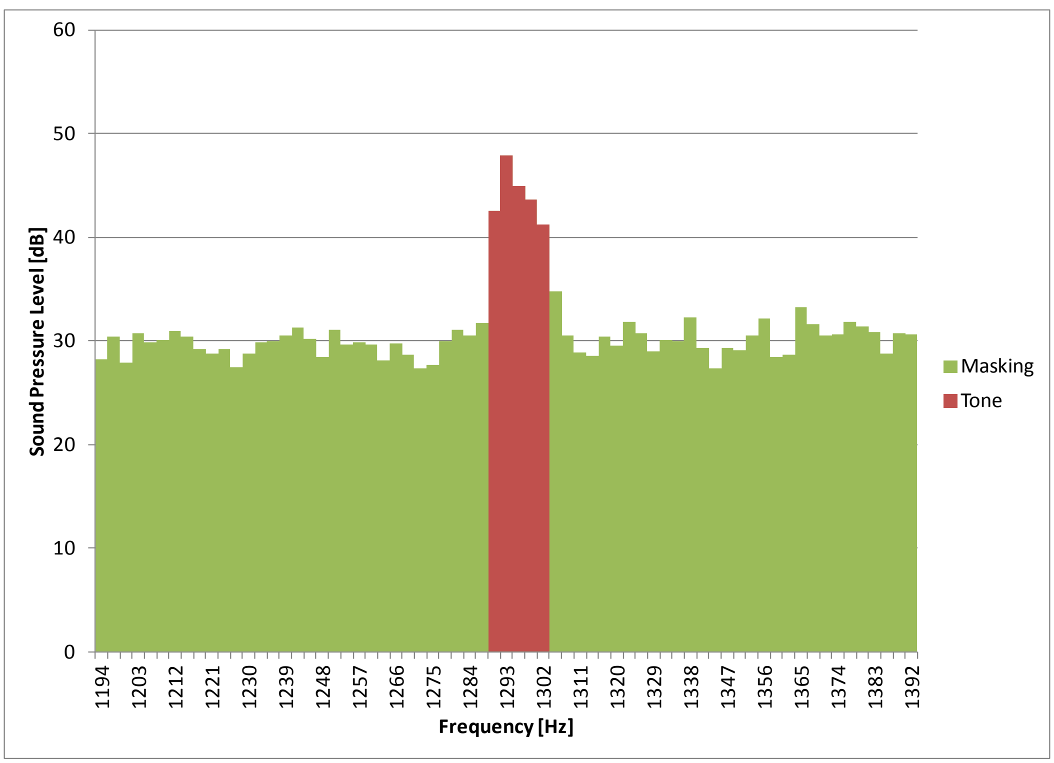

Figure 7. Classification of spectral lines for the 1,293 Hz tone (typical in the 5 m/s bin)

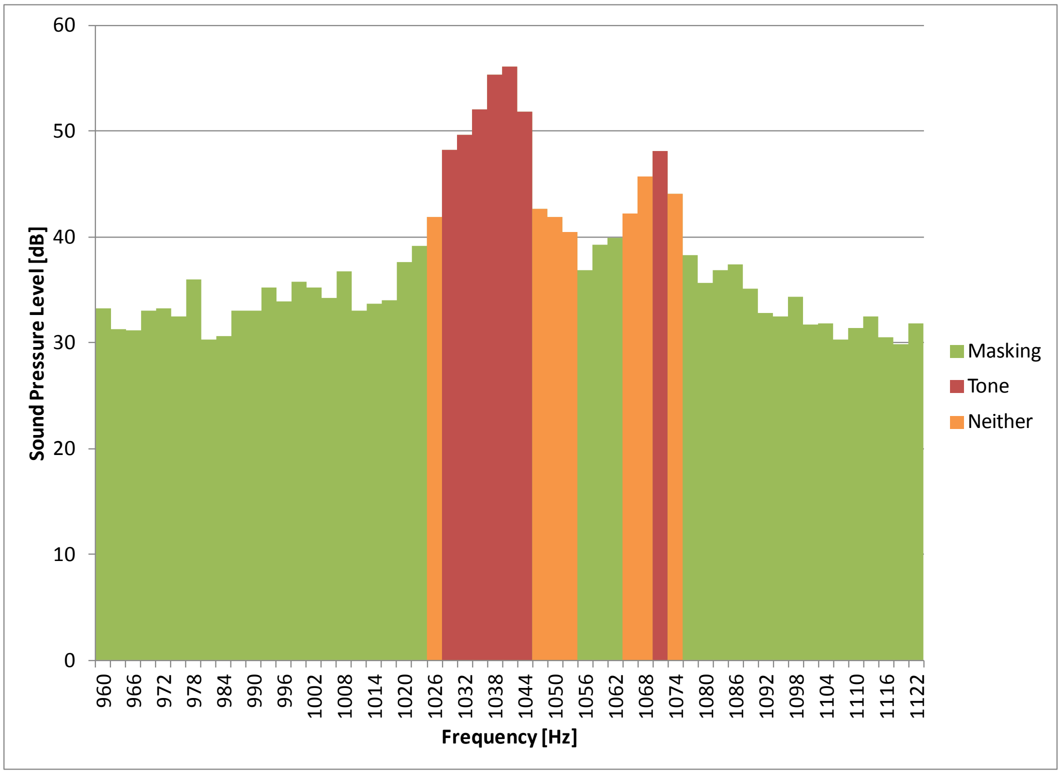

Figure 8. Classification of spectral lines for the 1,041 Hz tone (typical in the 6 m/s bin)

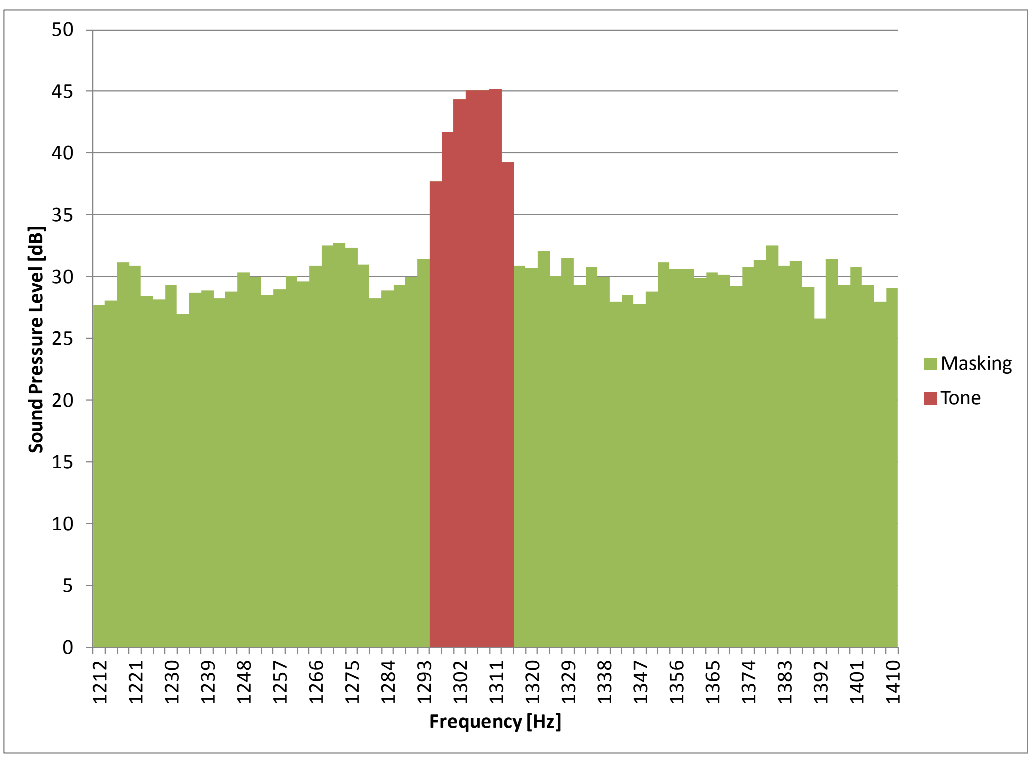

Figure 9. Classification of spectral lines for the 1,311 Hz tone (typical in the 6 m/s bin)

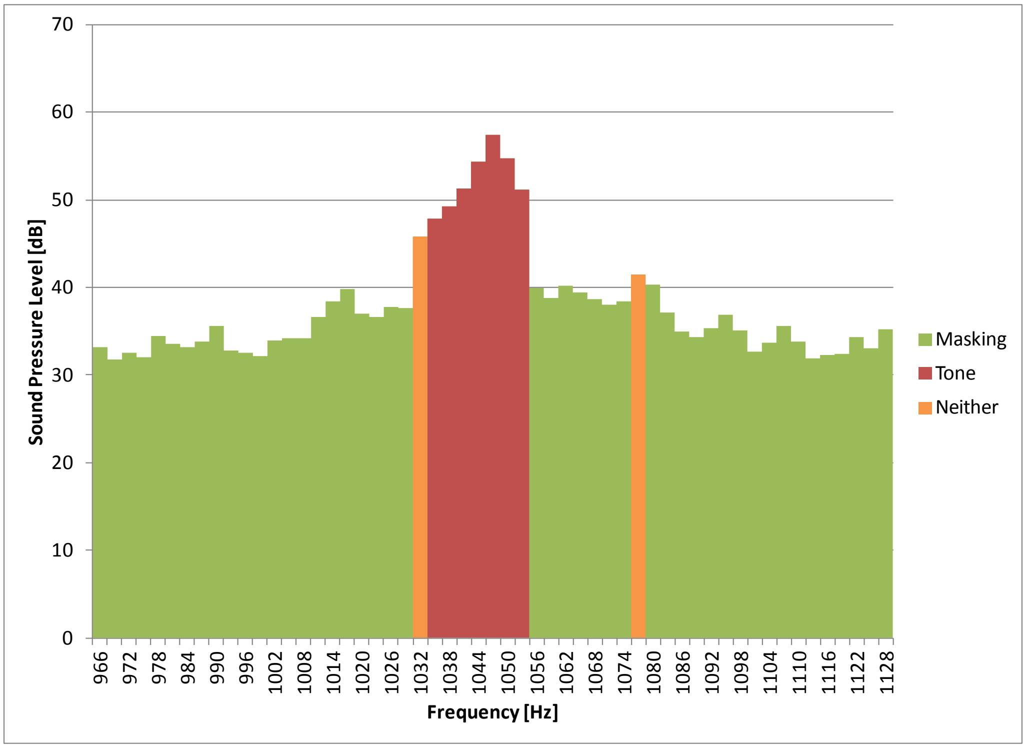

Figure 10. Classification of spectral lines for the 1,047 Hz tone (typical in the 7 m/s bin)

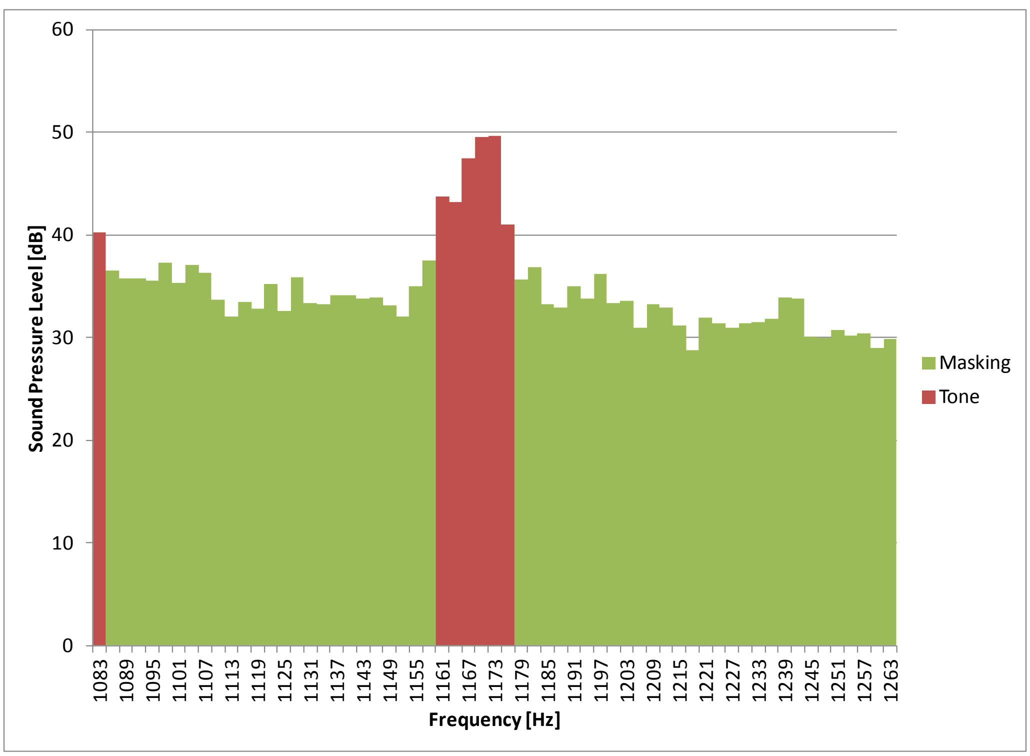

Figure 11. Classification of spectral lines for the 1,173 Hz tone (typical in the 7 m/s bin)

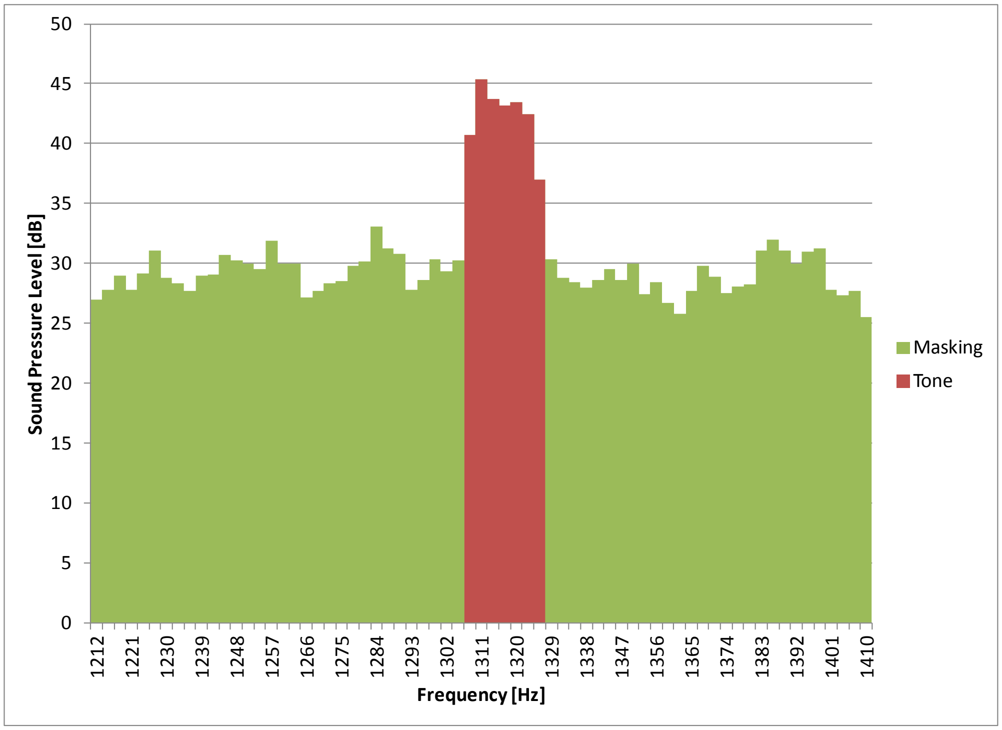

Figure 12. Classification of spectral lines for the 1,311 Hz tone (typical in the 7 m/s bin)

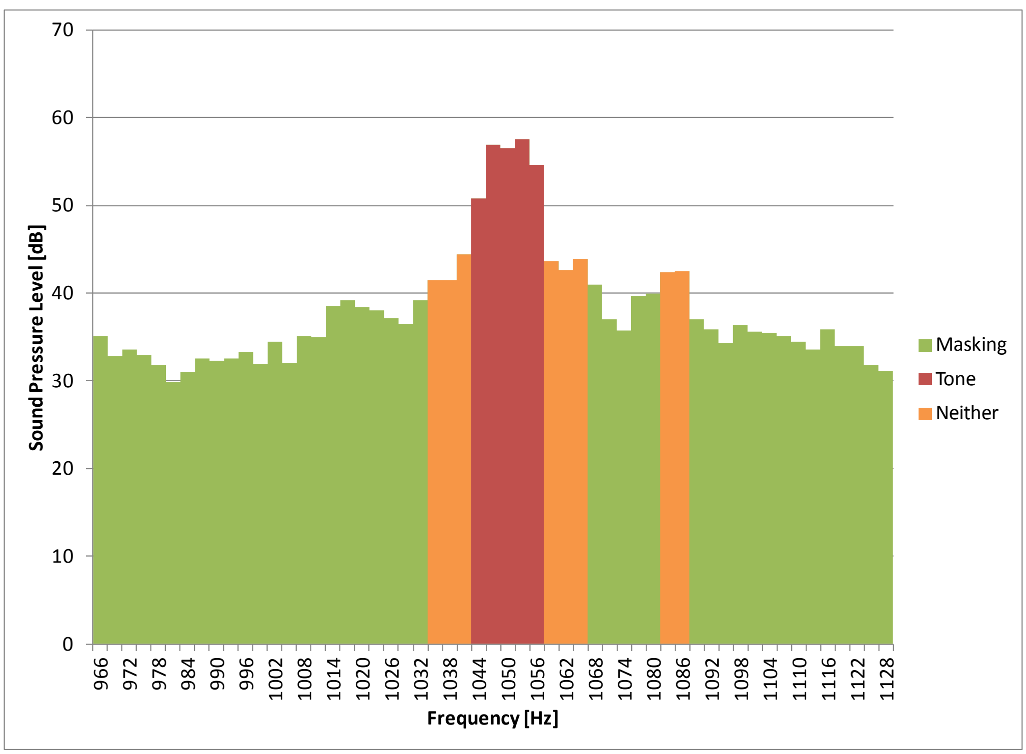

Figure 13. Classification of spectral lines for the 1,047 Hz tone (typical in the 8 m/s bin)

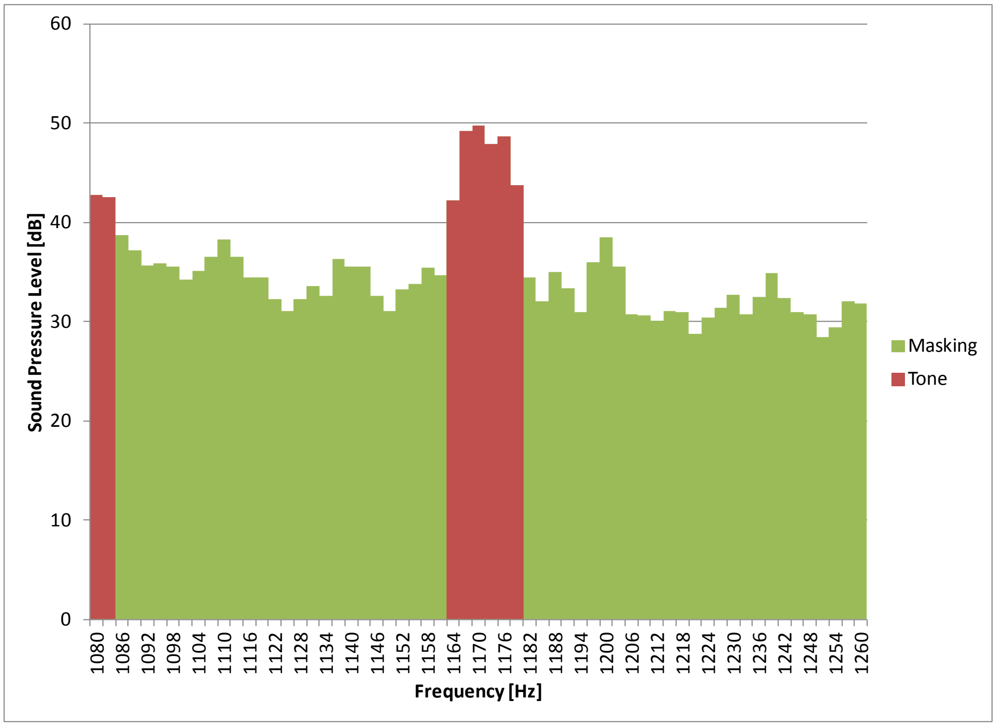

Figure 14. Classification of spectral lines for the 1,170 Hz tone (typical in the 8 m/s bin)

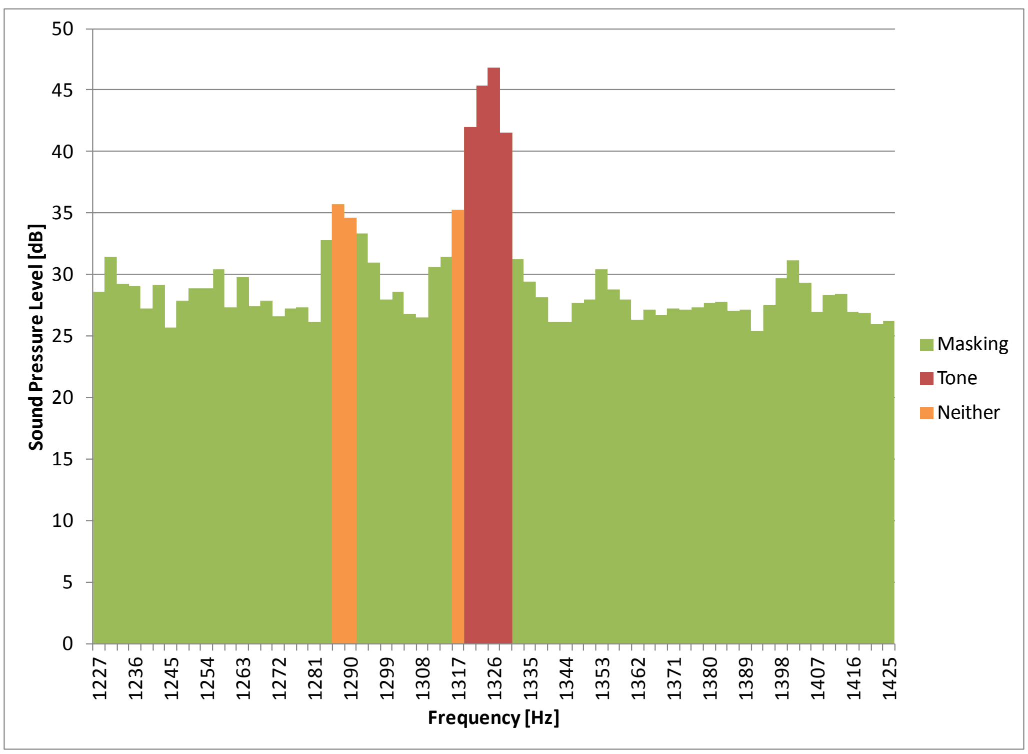

Figure 15. Classification of spectral lines for the 1,326 Hz tone (typical in the 8 m/s bin)

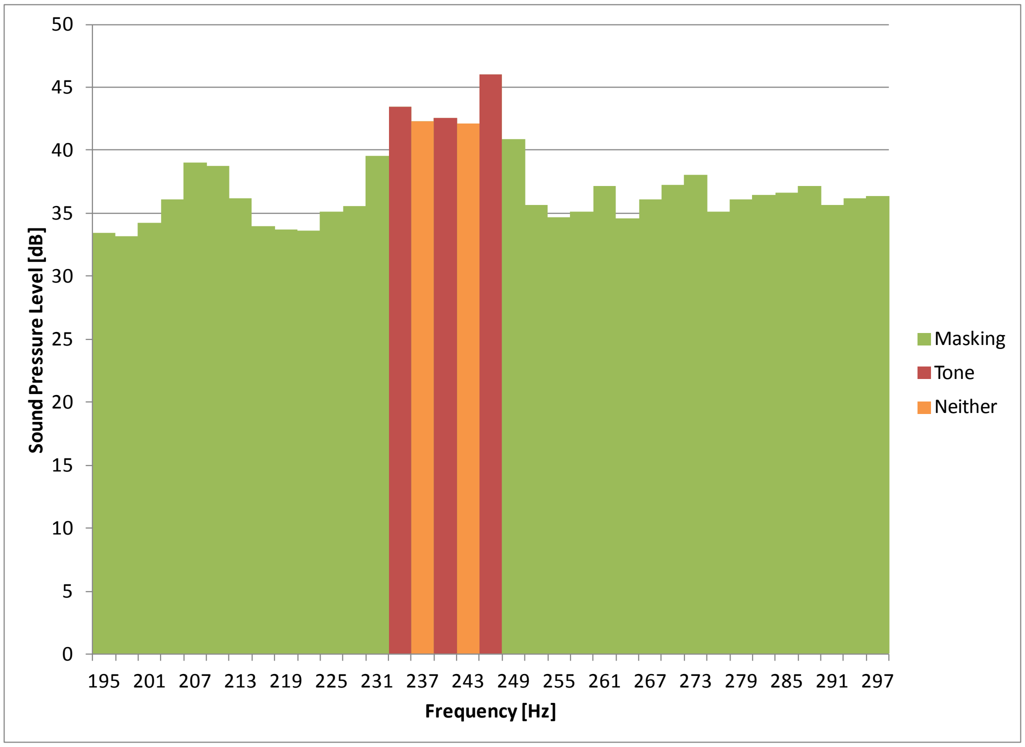

Figure 16. Classification of spectral lines for the 246 Hz tone (typical in the 9 m/s bin)

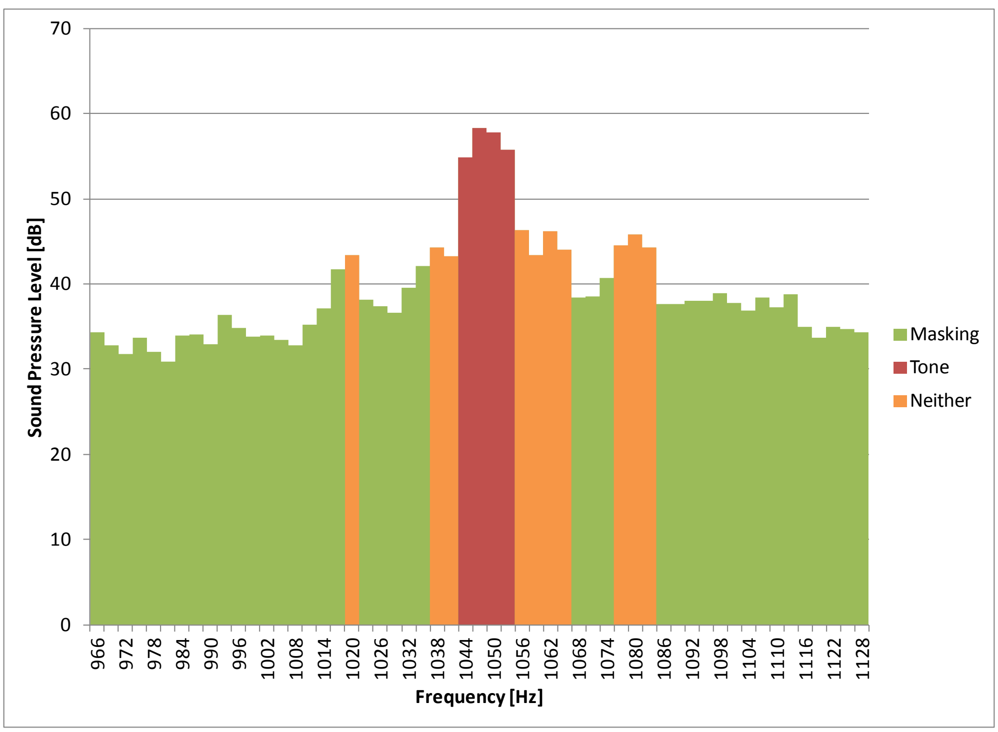

Figure 17. Classification of spectral lines for the 1,047 Hz tone (typical in the 9 m/s bin)

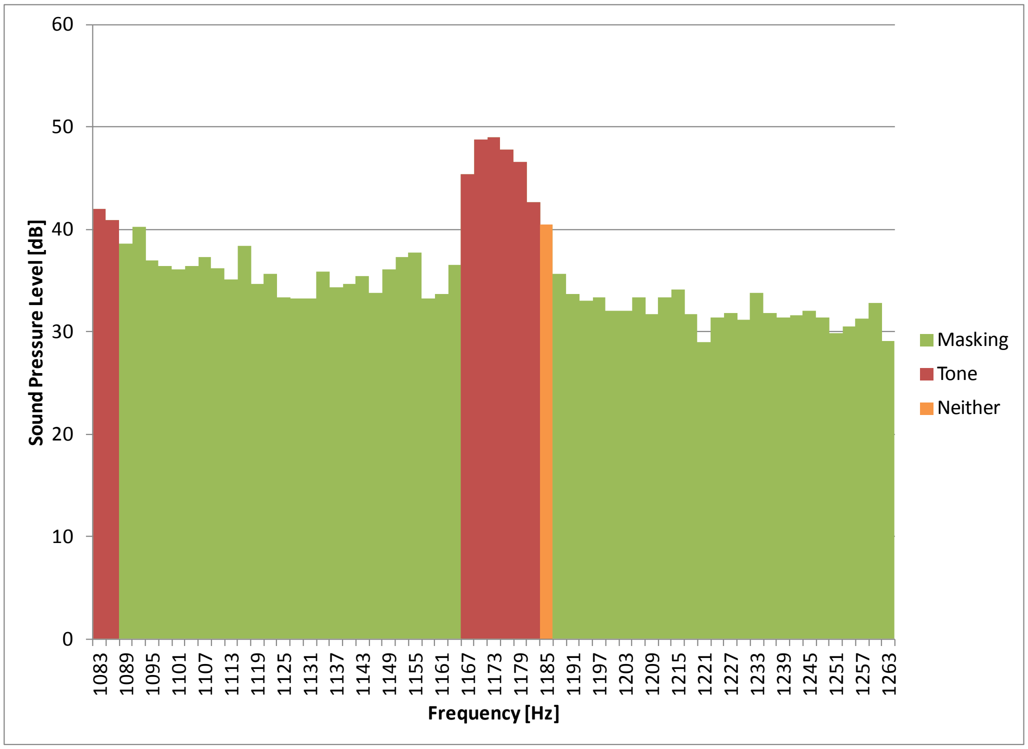

Figure 18. Classification of spectral lines for the 1,173 Hz tone (typical in the 9 m/s bin)

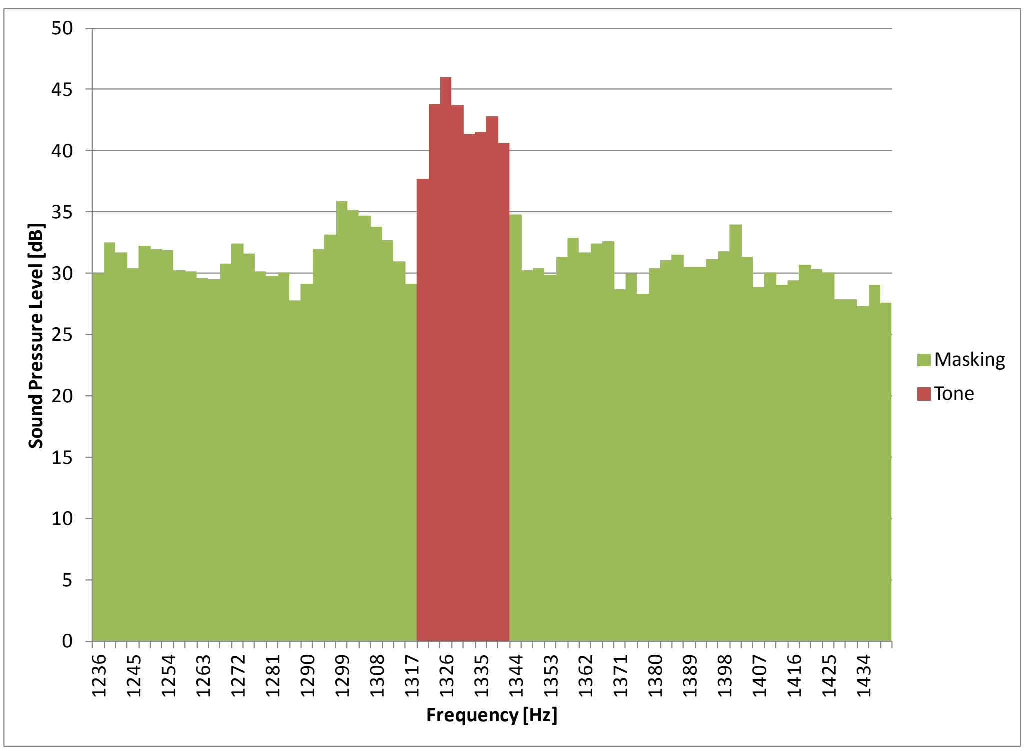

Figure 19. Classification of spectral lines for the 1,338 Hz tone (typical in the 9 m/s bin)

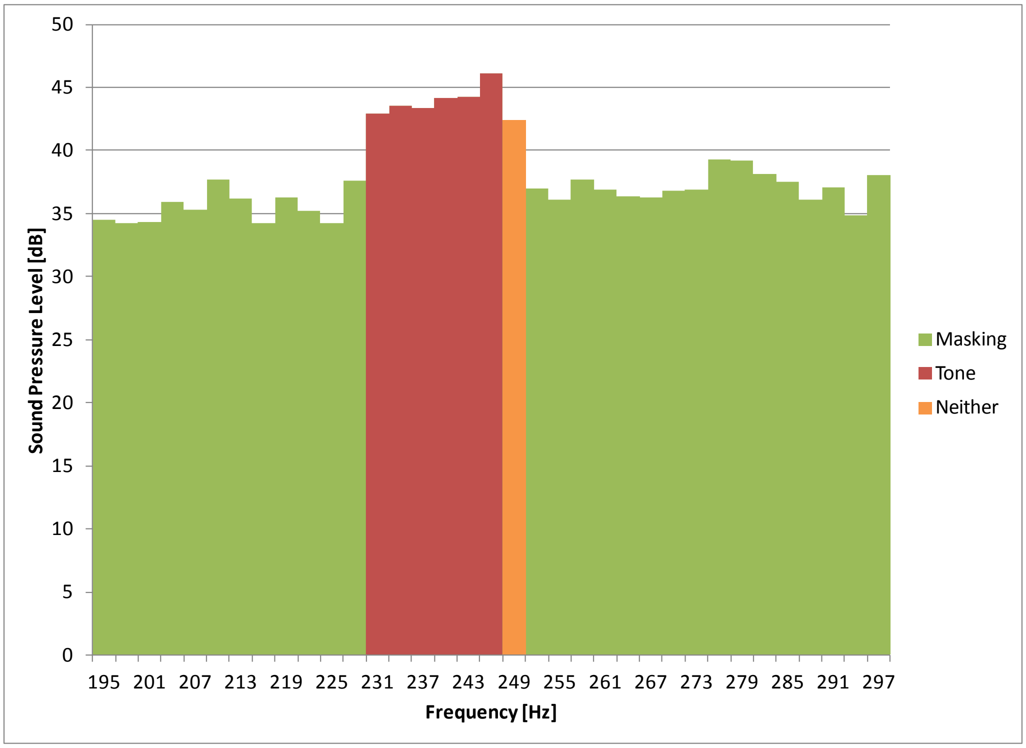

Figure 20. Classification of spectral lines for the 246 Hz tone (typical in the 10 m/s bin)

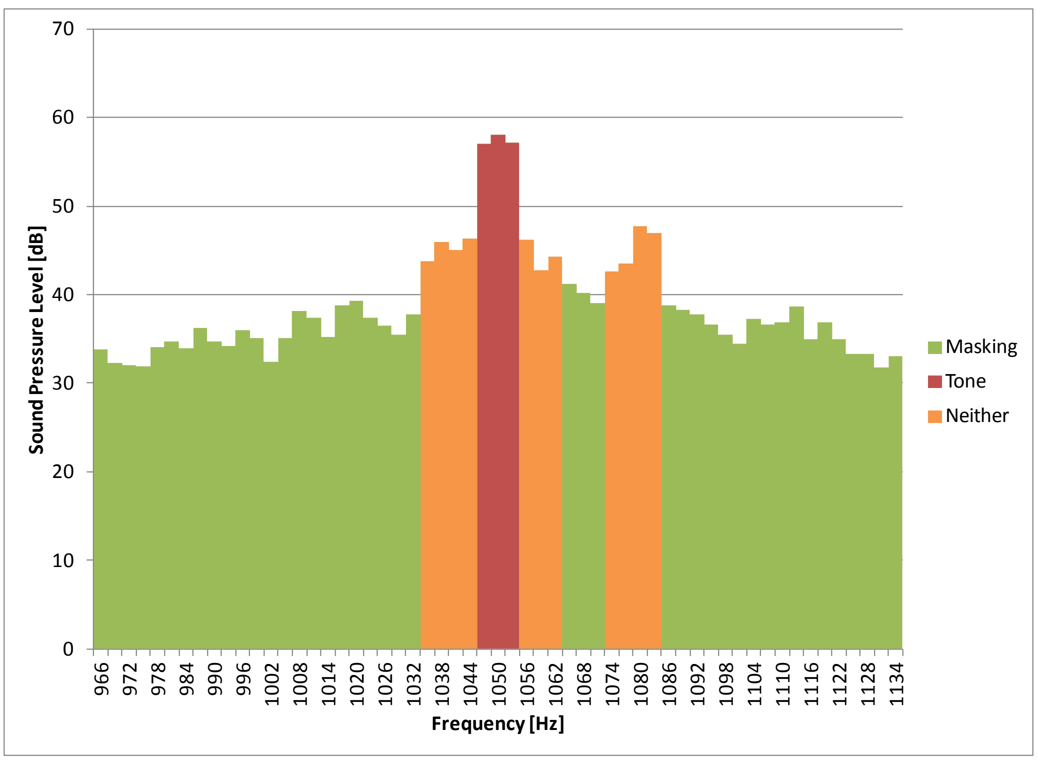

Figure 21. Classification of spectral lines for the 1,050 Hz tone (typical in the 10 m/s bin)

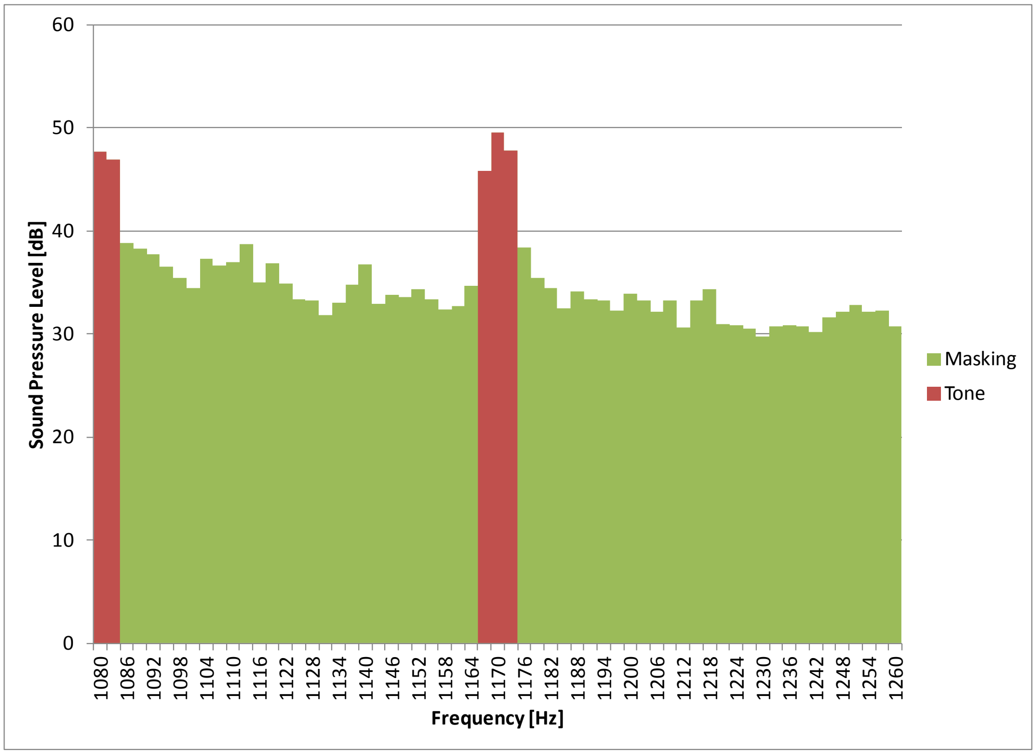

Figure 22. Classification of spectral lines for the 1,170 Hz tone (typical in the 10 m/s bin)

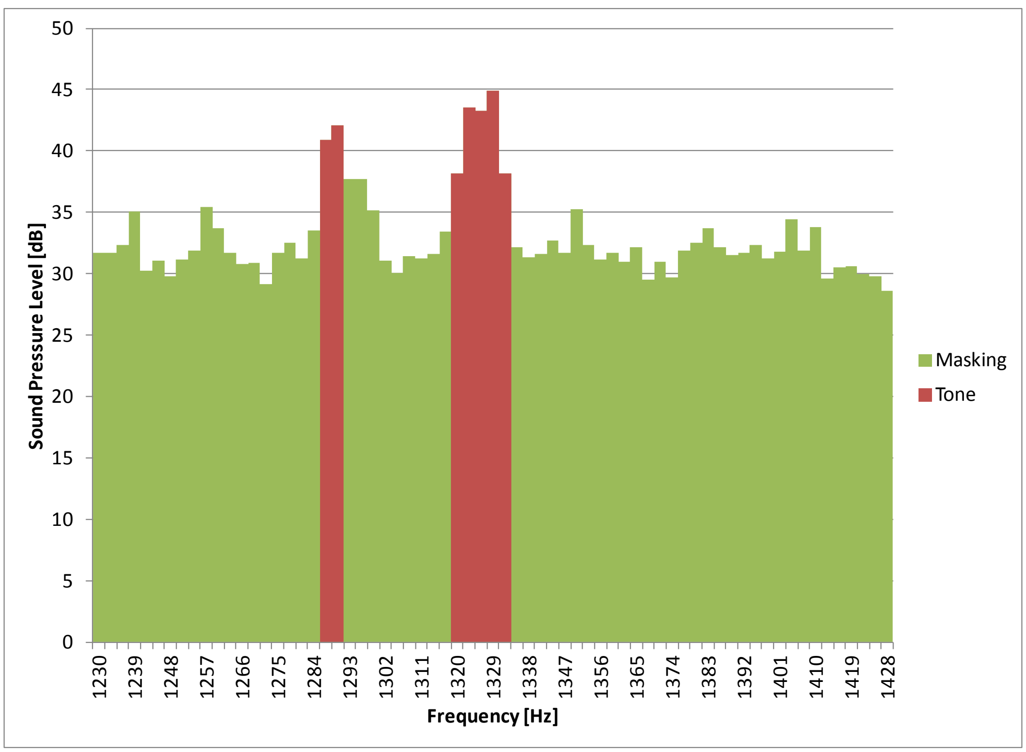

Figure 23. Classification of spectral lines for the 1,329 Hz tone (typical in the 10 m/s bin)

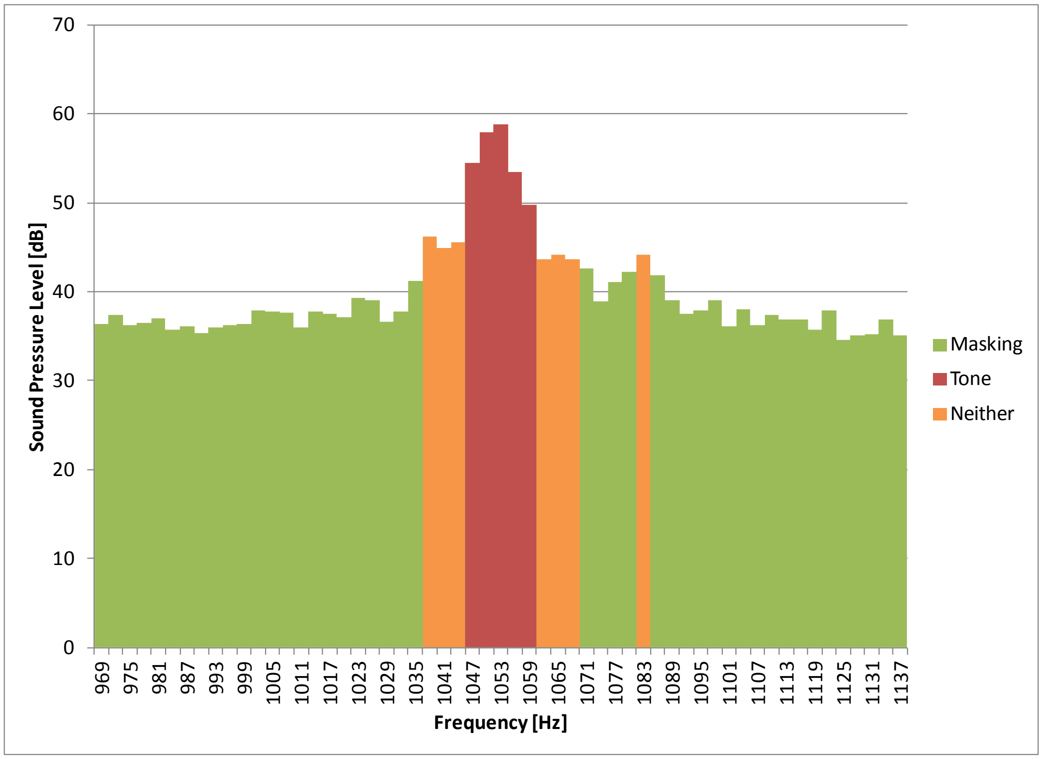

Figure 24. Classification of spectral lines for the 1,053 Hz tone (typical in the 11 m/s bin)

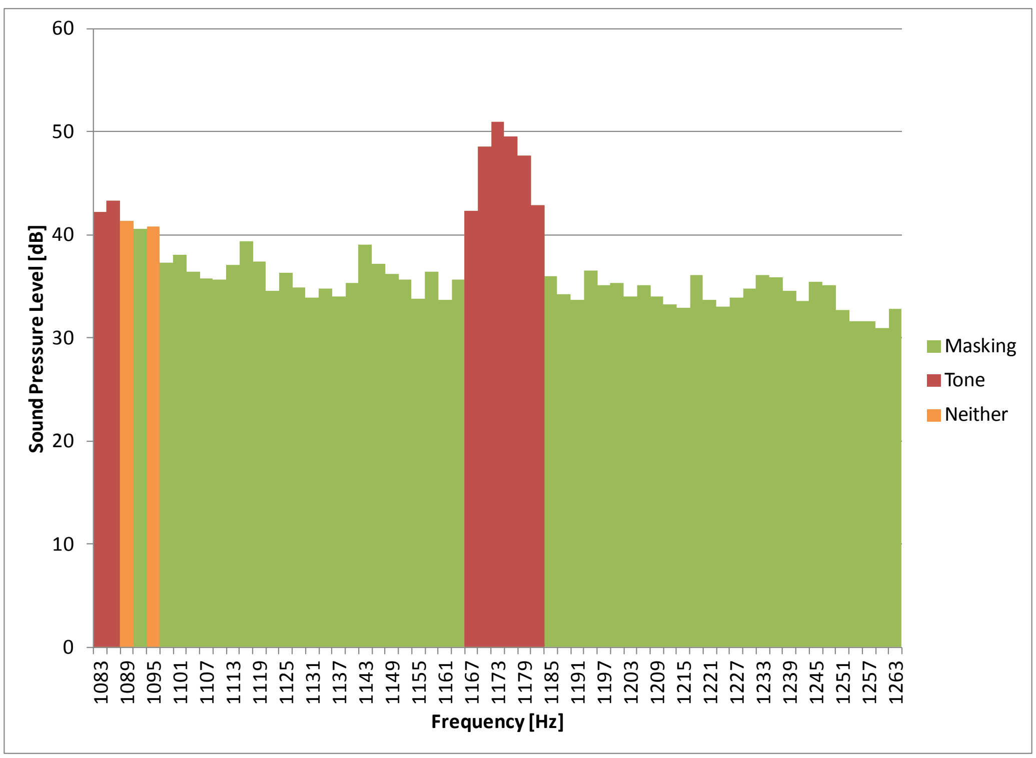

Figure 25. Classification of spectral lines for the 1,173 Hz tone (typical in the 11 m/s bin)

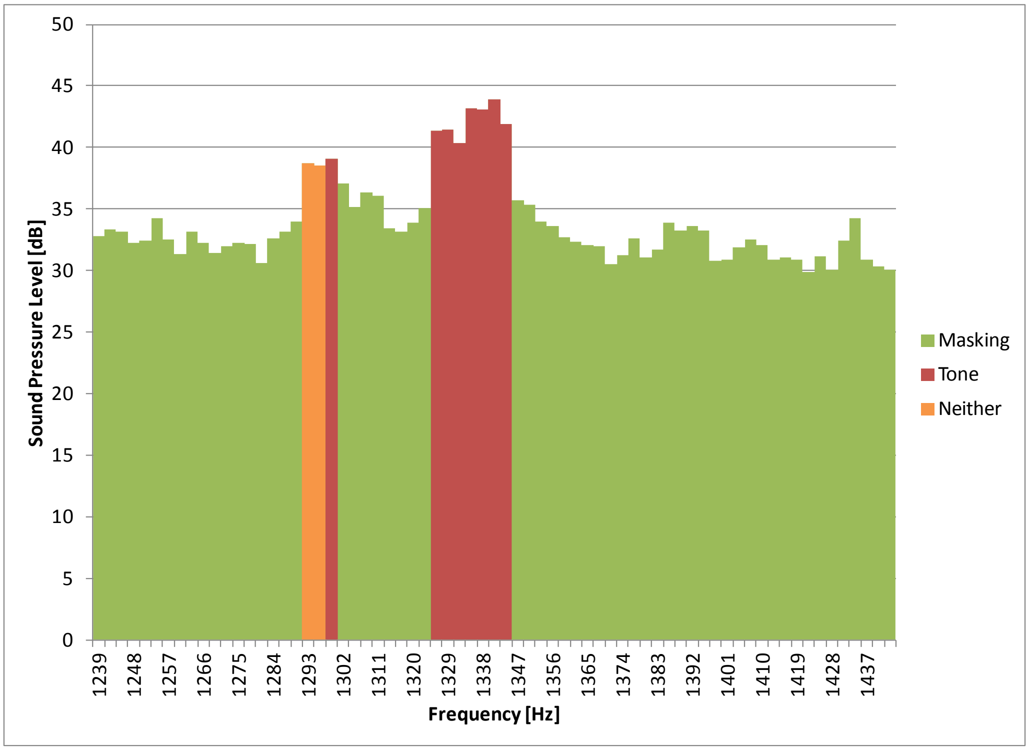

Figure 26. Classification of spectral lines for the 1,341 Hz tone (typical in the 11 m/s bin)

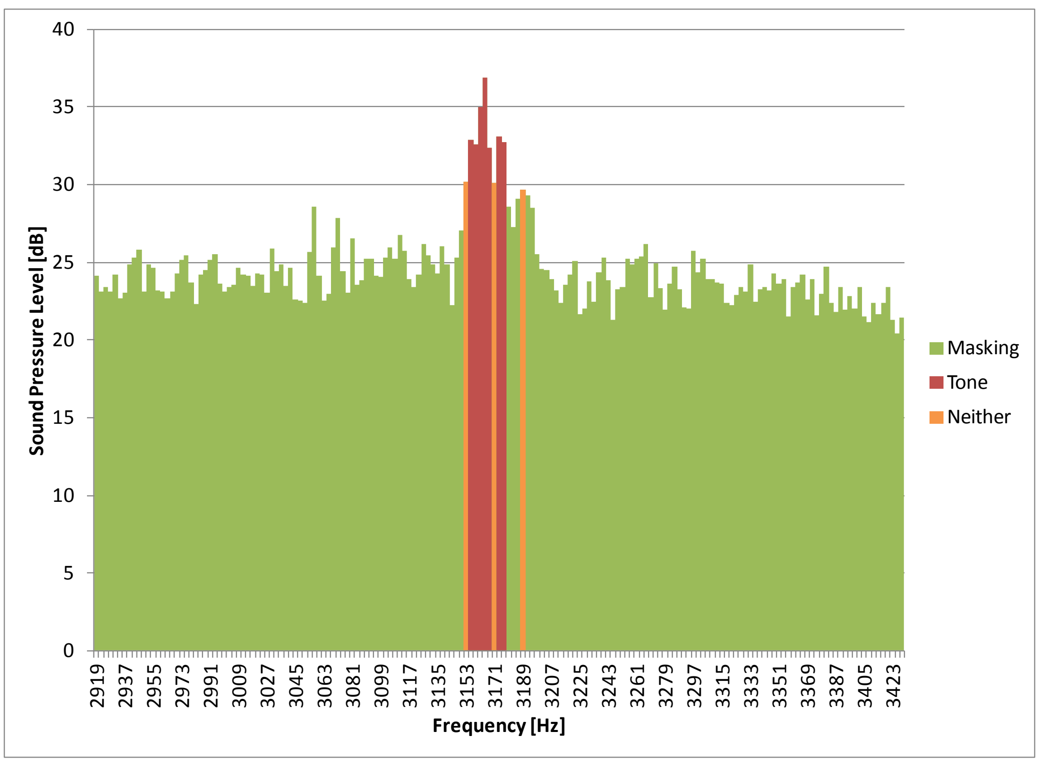

Figure 27. Classification of spectral lines for the 3,174 Hz tone (typical in the 11 m/s bin)

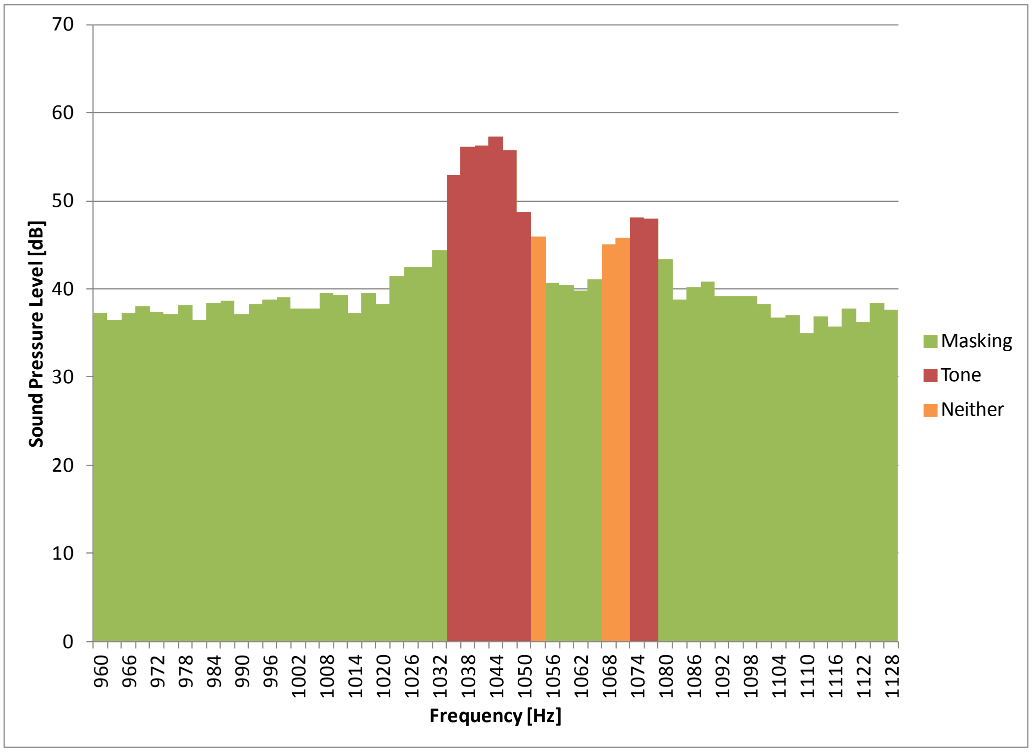

Figure 28. Classification of spectral lines for the 1,044 Hz tone (typical in the 12 m/s bin)

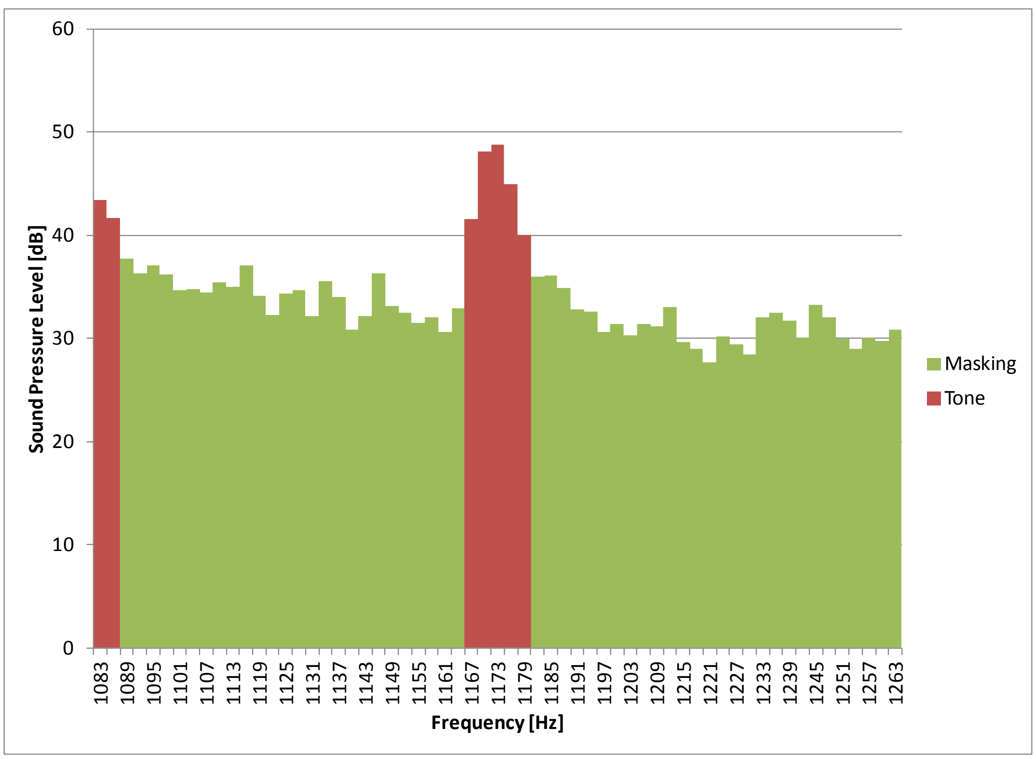

Figure 29. Classification of spectral lines for the 1,173 Hz tone (typical in the 12 m/s bin)

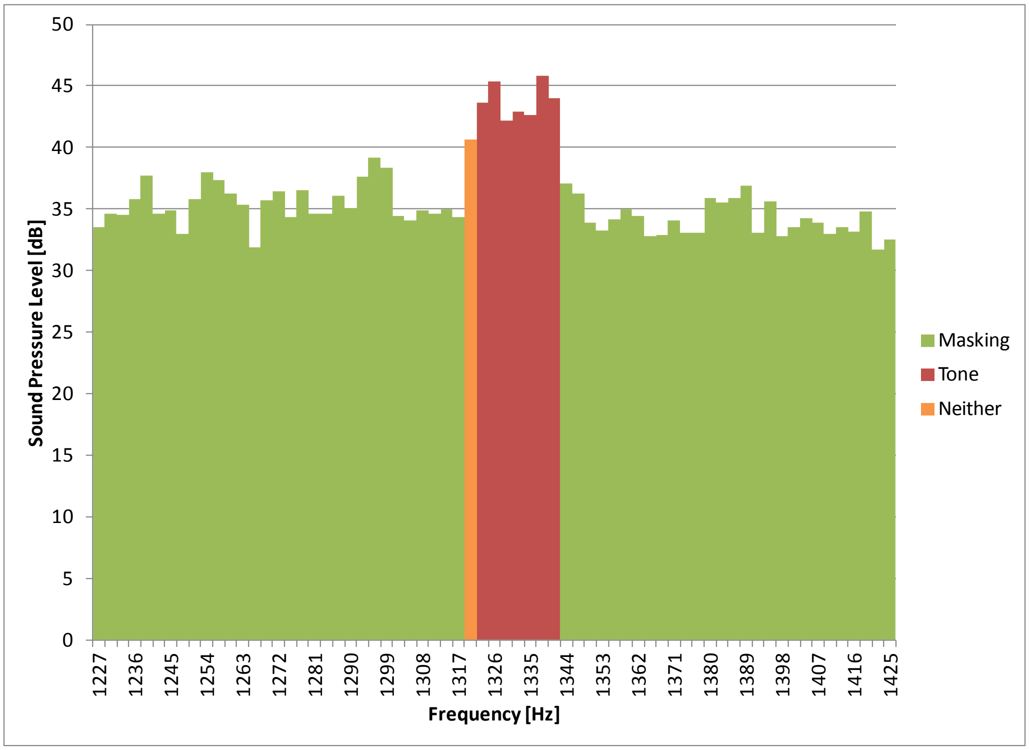

Figure 30. Classification of spectral lines for the 1,326 Hz tone (typical in the 12 m/s bin)

6.6 Uncertainty

The type A uncertainties for sound power levels, one-third octave levels, and tonality were calculated using the methods prescribed in the Standard. The type B uncertainty components are shown in Table 15.

Table 15. Type B Uncertainty Components for Sound Power Levels and Tonality

Var	Description	Type B Uncertainty for Sound Power Level	Type B Uncertainty for One-Third Octave Levels	Type B Uncertainty for Tonality	Comment
U_{B1}	Calibration	0.2	0.2	0.1	Assumption, used typical value
U_{B2}	Instrument	0.2	0.2	0.2	Assumption, used typical value
U_{B3}	Board	0.3	1.7	1.7	The board was placed well, used typical value
U_{B4}	Distance	0.1	0.1	0.05	Assumption, used typical value
U_{B5}	Impedance	0.1	0.1	0.1	Assumption, used typical value
U_{B6}	Turbulence	0.4	0.4	0.2	Assumption, used typical value
U_{B7}	Wind speed, measured	Varies with wind speed	Varies with wind speed and one-third octave center frequency bin	0.6	Calculated per IEC 61400-12-1 Ed. 1.0, 205-12 and converted to dBA for SPL and TOB. Typical value for tonality
U_{B8}	Direction	0.3	0.3	0.3	Assumption, used typical value
U_{B9}	Background	Varies with wind speed	Varies with wind speed and one-third octave center frequency bin	Varies by tone	Standard deviation of the applied correction

7 Exceptions

7.1 Exceptions to the Standard

NREL engineers altered the analysis for the small wind turbine. Ten-second averages were used in the analysis instead of 1-minute averages to better characterize the dynamic nature of this small wind turbine. In addition, binning by wind speed was used instead of regression analysis, and the integer values were calculated by interpolating between bins and extrapolating at the ends.

7.2 Exceptions to the Quality Assurance System

There were no exceptions to NREL's quality assurance system.

References

International Electrotechnical Commission (IEC). (2006). Wind Turbine Generator Systems – Part 11 Acoustic Noise Measurement Techniques, IEC 61400-11, Ed 2.1, 2006-11, Geneva, Switzerland.

Roadman, J., Murphy, M., Huskey, A., van Dam, J. (2011). Internal report. *Acoustic Noise Test Plan for the Viryd CS8 Wind Turbine*.

Appendix A. Pictures

Figure A1. The sound board during the test
(*Photo by Jason Roadman, NREL*)

Figure A2. Test turbine, as viewed from the reference microphone position
(*Photo by Jason Roadman, NREL*)

Figure A3. Test turbine, as viewed from the meteorological mast
(*Photo by Jason Roadman, NREL*)

Appendix B. Calibration Sheets

Scantek, Inc.
CALIBRATION LABORATORY

ISO 17025: 2005, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC and APLAC signatory)

NVLAP®

NVLAP Lab Code: 200625-0

Calibration Certificate No.25174

Instrument:	**Microphone Unit**	*Date Calibrated:*	**12/19/2011** *Cal Due:*	
Model:	**4189-A-021**	*Status:*	**Received**	**Sent**
Manufacturer:	**Brüel & Kjær**	*In tolerance:*	**X**	**X**
Serial number:	**2406812**	*Out of tolerance:*		
Composed of:	**Microphone 4189 s/n 2395210**	*See comments:*		
	Preamplifier 2671 s/n 2373722	*Contains non-accredited tests:* __Yes _X_ No		

Customer: **National Renewable Energy Laboratory**
Tel/Fax: **303-384-6385 / -6391**
Address: **1617 Cole Blvd. Golden, CO 80401-3305**

Tested in accordance with the following procedures and standards:
Calibration of Measurement Microphones, Scantek, Inc., Rev. 11/30/2010
Procedure for Microphone calibration using acoustical calibrator, Scantek, Inc., Rev. 10/7/2010

Instrumentation used for calibration: N-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
483B-Norsonic	SME Cal Unit	25747	Jul 1, 2011	Scantek, Inc./ NVLAP	Jul 1, 2012
DS-360-SRS	Function Generator	61646	Nov 16, 2011	ACR Env./ A2LA	Nov 16, 2013
34401A-Agilent Technologies	Digital Voltmeter	MY41022043	Dec 9, 2011	ACR Env. / A2LA	Dec 9, 2012
DPI 141-Druck	Pressure Indicator	790/00-04	Dec 13, 2010	ACR Env./ A2LA	Dec 13, 2012
HMP233-Vaisala Oyj	Humidity & Temp. Transmitter	V3820001	Jul 29, 2011	Vaisala / A2LA	Jul 29, 2012
PC Program 1017 Norsonic	Calibration software	v.5.2	Validated Mar 2011	Scantek, Inc.	-
1253-Norsonic	Calibrator	28326	Dec 13, 2011	Scantek, Inc./ NVLAP	Dec 13, 2012
1203-Norsonic	Preamplifier	14059	Jan 5, 2011	Scantek, Inc./ NVLAP	Jan 5, 2012
4180-Brüel&Kjær	Microphone	2246115	Nov 21, 2011	NPL-UK / UKAS	Nov 21, 2013

Instrumentation and test results are traceable to SI - BIPM through standards maintained by NPL (UK) and NIST (USA)

Calibrated by	Valentin Buzduga	Checked by	Mariana Buzduga
Signature		Signature	
Date	12/19/2011	Date	12/21/2011

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Figure B1. Calibration sheet for the microphone 2406812

Scantek, Inc.
CALIBRATION LABORATORY

ISO 17025: 2005, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC and APLAC signatory)

NVLAP®

NVLAP Lab Code: 200625-0

Calibration Certificate No.25173

Instrument: **Sound Level Meter**
Model: **noiseLab3-NI-9233**
Manufacturer: **Delta**
Serial number: **1283B54**
Tested with: **Microphone 4189-A-021 s/n 2406812**
Preamplifier 2671 s/n 2373722
Type (class): **1**

Date Calibrated: **12/20/2011** *Cal Due:*

Status:	Received	Sent
In tolerance:	X	X
Out of tolerance:		
See comments:		

Contains non-accredited tests: __Yes _X_ No
Calibration service: __ Basic _X_ Standard

Customer: **National Renewable Energy Laboratory**
Tel/Fax: **303-384-6385 / -6391**
Address: **1617 Cole Blvd.**
Golden, CO 80401-3305

Tested in accordance with the following procedures and standards:
Calibration of Sound Level Meters, Scantek Inc., Rev. 6/7/2005
SLM & Dosimeters – Acoustical Tests, Scantek Inc., Rev. 7/6/2011

Instrumentation used for calibration: Nor-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
483B-Norsonic	SME Cal Unit	25747	Jul 1, 2011	Scantek, Inc./ NVLAP	Jul 1, 2012
DS-360-SRS	Function Generator	61646	Nov 16, 2011	ACR Env./ A2LA	Nov 16, 2013
34401A-Agilent Technologies	Digital Voltmeter	MY41022043	Dec 9, 2011	ACR Env. / A2LA	Dec 9, 2012
DPI 141-Druck	Pressure Indicator	790/00-04	Dec 13, 2010	ACR Env./ A2LA	Dec 13, 2012
HMP233-Vaisala Oyj	Humidity & Temp. Transmitter	V3820001	Jul 29, 2011	Vaisala / A2LA	Jul 29, 2012
PC Program 1019 Norsonic	Calibration software	v.5.2	Validated Mar 2011	Scantek, Inc.	-
1251-Norsonic	Calibrator	30878	Dec 13, 2011	Scantek, Inc./ NVLAP	Dec 13, 2012

Instrumentation and test results are traceable to SI (International System of Units) through standards maintained by NIST (USA) and NPL (UK).

Environmental conditions:

Temperature (°C)	Barometric pressure (kPa)	Relative Humidity (%)
23 °C	100.621 kPa	44.1 %RH

Calibrated by	Valentin Buzduga	**Checked by**	Mariana Buzduga
Signature	[signature]	Signature	[signature]
Date	12/21/2011	Date	12/21/2011

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This Calibration Certificate or Test Reports shall not be used to claim product certification, approval or endorsement by NVLAP, NIST, or any agency of the federal government.
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Figure B2. Calibration sheet for the sound level meter

Scantek, Inc.
CALIBRATION LABORATORY

ISO 17025: 2005, ANSI/NCSL Z540:1994 Part 1 ACCREDITED
by NVLAP (an ILAC and APLAC signatory)

NVLAP®

NVLAP Lab Code: 200625-0

Calibration Certificate No.25175

Instrument: **Acoustical Calibrator**
Model: **4231**
Manufacturer: **Brüel and Kjær**
Serial number: **2388951**
Class (IEC 60942): **1**
Barometer type:
Barometer s/n:

Date Calibrated: **12/19/2011** *Cal Due:*

Status:	**Received**	**Sent**
In tolerance:	**X**	**X**
Out of tolerance:		
See comments:		

Contains non-accredited tests: __**Yes** _X_ **No**

Customer: **National Renewable Energy Laboratory**
Tel/Fax: **303-384-6385 / -6391**

Address: **1617 Cole Blvd.**
Golden, CO 80401-3305

Tested in accordance with the following procedures and standards:
Calibration of Acoustical Calibrators, Scantek Inc., Rev. 10/1/2010

Instrumentation used for calibration: Nor-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
483B-Norsonic	SME Cal Unit	25747	Jul 1, 2011	Scantek, Inc./ NVLAP	Jul 1, 2012
DS-360-SRS	Function Generator	61646	Nov 16, 2011	ACR Env./ A2LA	Nov 16, 2013
34401A-Agilent Technologies	Digital Voltmeter	MY41022043	Dec 9, 2011	ACR Env. / A2LA	Dec 9, 2012
DPI 141-Druck	Pressure Indicator	790/00-04	Dec 13, 2010	ACR Env./ A2LA	Dec 13, 2012
HMP233-Vaisala Oyj	Humidity & Temp. Transmitter	V3820001	Jul 29, 2011	Vaisala / A2LA	Jul 29, 2012
8903A-HP	Audio Analyzer	2514A05691	Dec 1, 2010	ACR Env./ A2LA	Dec 1, 2013
PC Program 1018 Norsonic	Calibration software	v.5.2	Validated March 2011	Scantek, Inc.	-
4134-Brüel&Kjær	Microphone	173368	Dec 13, 2011	Scantek, Inc. / NVLAP	Dec 13, 2012
1203-Norsonic	Preamplifier	14059	Jan 5, 2011	Scantek, Inc./ NVLAP	Jan 5, 2012

Instrumentation and test results are traceable to SI (International System of Units) through standards maintained by NIST (USA) and NPL (UK)

Calibrated by	Valentin Buzduga	Checked by	Mariana Buzduga
Signature		Signature	
Date	12/19/2011	Date	12/21/2011

Calibration Certificates or Test Reports shall not be reproduced, except in full, without written approval of the laboratory.
This Calibration Certificate or Test Reports shall not be used to claim product certification, approval or endorsement by NVLAP, NIST, or any agency of the federal government.
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Figure B3. Calibration sheet for the acoustic calibrator

Svend Ole Hansen ApS

SCT. JØRGENS ALLÉ 7 · DK-1615 KØBENHAVN V · DENMARK
TEL: (+45) 33 25 38 38 · FAX: (+45) 33 25 38 39 · WWW.SOHANSEN.DK

WIND ENGINEERING FLUID DYNAMICS

CERTIFICATE FOR CALIBRATION OF CUP ANEMOMETER

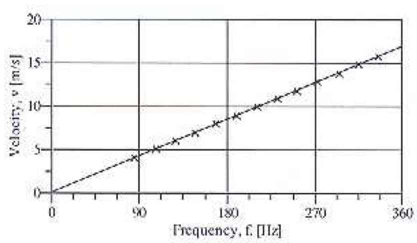
Certificate number: 12.02.6727
Date of issue: August 24, 2012
Type: Thies 4.3351.10.000
Serial number: 0609006
Manufacturer: ADOLF THIES GmbH & Co.KG, Hauptstrasse 76, 37083 Göttingen, Germany
Client: National Renewable Energy Lab, 1617 Cole Boulevard, Golden, Colorado 80401-3393, USA

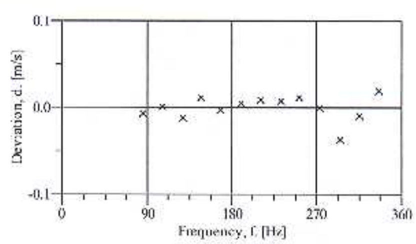
Anemometer received: August 13, 2012
Anemometer calibrated: August 23, 2012
Calibrated by: asj
Calibration procedure: IEC 61400-12-1, MEASNET
Certificate prepared by: ca
Approved by: Calibration engineer, ml

Calibration equation obtained: v [m/s] = 0.04654 · f [Hz] + 0.15404
Standard uncertainty, slope: 0.00114
Standard uncertainty, offset: 0.07713
Covariance: -0.0000006 (m/s)²/Hz
Coefficient of correlation: ρ = 0.999993
Absolute maximum deviation: -0.036 m/s at 13.844 m/s

Barometric pressure: 1009.3 hPa
Relative humidity: 27.6%

Succession	Velocity pressure, q. [Pa]	Temperature in wind tunnel [°C]	Temperature in control room [°C]	Wind velocity, v. [m/s]	Frequency, f. [Hz]	Deviation, d. [m/s]	Uncertainty u_c (k=2) [m/s]
2	9.65	33.4	25.5	4.112	85.1908	-0.007	0.021
4	14.95	33.3	25.5	5.119	106.6331	0.002	0.025
6	21.07	33.1	25.4	6.075	127.4800	-0.012	0.029
8	28.26	33.1	25.4	7.035	147.5747	0.012	0.033
10	36.34	33.0	25.4	7.977	168.1495	-0.003	0.037
12	45.88	33.0	25.4	8.962	189.1365	0.005	0.042
13-last	56.70	32.9	25.4	9.963	210.5526	0.009	0.046
11	68.46	33.0	25.4	10.948	231.7626	0.007	0.051
9	80.56	33.1	25.4	11.878	251.6408	0.012	0.055
7	94.56	33.1	25.4	12.870	273.2038	0.000	0.059
5	109.38	33.2	25.4	13.844	294.9135	-0.036	0.064
3	125.53	33.4	25.5	14.833	315.5930	-0.009	0.068
1-first	141.94	33.6	25.5	15.780	335.3141	0.020	0.073





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Accreditation to ISO 17025
measnet

Figure B4. Calibration sheet for the primary anemometer

NREL METROLOGY LABORATORY

TEST REPORT

Test Instrument: Phaser Power Transducer DOE #: 04195C

Model #: Phaser-5-485-4A20 S/N: 01091

Calibration Date: 9/13/2012 Date Due: 9/13/2014

Test No.	Function Tested	Nominal Input	Measured Output at 250 Ohm (DCV)		( ) Mfr Specs (X)Data Only
			As Found	As Left	
1.	Analog Output 1: Power in Watt applied to Phase A&B with 120V @ 60 Hz				
		-24000	1.008		
		-12000	2.004		
		0	2.999		
		12000	3.996		
		24000	4.993		
2.	Analog Output 2: Power Factor at 1200 W @ A&B with 120V @ 60 Hz				
		1	5.000		
		0.8	4.155		
		0.6	3.342		
		0.4	2.534		
		0.2	1.731		
		0	1.068		
3.	Analog Output 3: THD for current in % at 100A @ A&B with 120V @ 60 Hz				
		0	1.004		
		5	1.198		
		10	1.397		
		15	1.595		
		20	1.786		
		25	1.975		
		30	2.152		
4.	Analog Output 4: Voltage in volts between A&B @ 60 Hz				
		0	2.998		
		80	3.613		
		160	4.229		
		240	4.607		

Notes:

Figure B5. Page 1 of the power transducer calibration sheet

Branch #: 5000 Sheet: 1 of: 1

NREL METROLOGY LABORATORY

Test Report

Test Instrument: Pressure Transmitter DOE #: 03510C

Model # : PTB101B S/N : C1040014

Calibration Date: 02/13/2012 Due Date: 02/13/2013

No	Function Tested	Nominal Value (kPa)	Measured Output Voltage (VDC)		( )Mfr. Specs. OR (X)Data only (mb)
			As Found	As Left	
*	Absolute Pressure				
		65	0.2704	Same	
		70	0.5427	"	
		75	0.8146	"	
		80	1.0862	"	
		85	1.3577	"	
		90	1.6291	"	
		95	1.9005	"	
		100	2.1722	"	

Notes:
1. Expanded Uncertainty of the nominal value is ± 0.2 kPa, with k = 2.
2. Calibration was performed at 24°C and 43% RH.
3. Calibration was performed using standards that are traceable to NIST. DOE Numbers: 128120 and 02301C.

Calibrated By: P. Morse
Date: 02/13/2012

Approved By: Reda
Date: 02/13/2012

Figure B6. Calibration sheet for the pressure transducer

Branch #: 5000

Page 1 of 1

NREL METROLOGY LABORATORY

TEST REPORT

Test Instrument: RTD

DOE #: 03465C

Model #: T200A

S/N: 0603-1

Calibration Date: 7/20/2012

Date Due: 7/20/2013

Test No.	Function Tested	Applied Value (°C)	Measured Values (Ω)		( ) Mfr Specs (X)Data Only
			As Found	As Left	
1.					
	Temperature	-15	94.126		
		0	100.025		
		15	105.892		
		30	111.724		

Notes:

- Calibration was performed using instruments that are traceable to NIST. DOE# 124272, 108603, 108604.
- Calibration was performed at a temperature of 23°C and Relative Humidity of 41%
- Uncertainty of Nominal Values = ± 0.02°C, k = 2.

Calibrated By: Reda
Date: 7/20/2012

Approved By: Preston
Date: 7/20/2012

Figure B7. Calibration sheet for the temperature sensor

Wind Vane Calibration Report

Calibration Laboratory:
National Wind Technology Center - Cert. Team
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401

Customer:
National Wind Technology Center - Certification Team
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401

Calibration Location:
National Wind Technology Center
Cert Lab

Calibration Date: **13-Sep-12**

Report Number: W5515-120913

Page: 1 of 1

Procedure:
NWTC-CT: C104 Calibrate Wind Vane_091209.docx

Deviations from procedure:
Output of Wind vane was set for 5 Volts.

Item Calibrated:

Manufacturer	Met One Instruments, Inc
Model	020C
Serial Number	**W5515**
Vane Material	Aluminum
Condition	Refurbished

Results:

Slope:	**71.63**	**deg/V**
Offset to boom:	**97.81**	**deg**
Max error:	1.70	deg

Estimated Uncertainty:

Inclinometer Uncertainty (deg)	Total Uncertainty (deg)
0.10	1.22

Traceability:

	Mfg & Model	Serial Number	Cal Date
Inclinometer:	Spi-Tronic	31-038-3	5-Oct-11
Voltmeter:	HP 3458A	2823A05145	15-Sep-11

Calibration by: Mark Murphy

13-Sep-12
Date

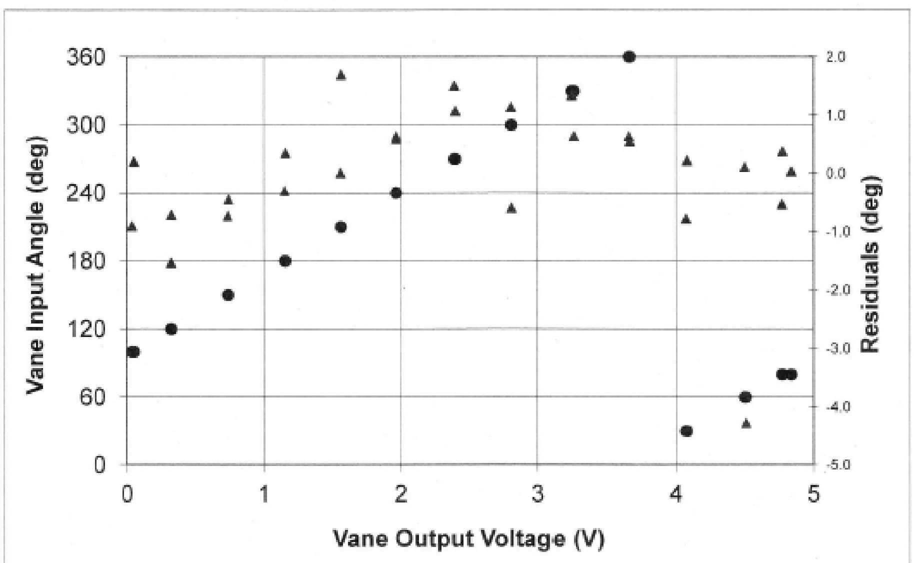

Figure B8. Calibration sheet for the wind vane

Dynamic Technology, Inc.

A Trescal Company

17025 Accredited Certificate of Calibration

Certificate #: 2225020003 F

DOE# 04373 C

Calibration Laboratory Certificate #: 2516.01

Acct #:	101320
Customer:	National Renewable Energy Laboratory
Shipper #:	1861169
Address:	16253 Denver West Parkway Golden, CO, 80401
Contact:	NI RMA
PO #:	

Manufacturer:	National Instruments
Model:	9205
Description:	32 Channel Analog Input Module
Serial Number:	14DA726
Asset Number:	14DA726
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	X
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	06/27/2012
Due Date:	06/27/2014
Temperature:	70.30 deg. F
Humidity:	44.00 %
Baro. Press.:	
Procedure:	DCN 09381
Reference:	manufacturer's manual

Incoming Remarks:

ndo.

Domestic Accredited Calibration. w/antistatic bag

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
2182620002	Fluke	5700A	Multifunction Calibrator	05/09/2012	08/07/2012

Checked, Rd 7/12/12

The above identified unit was calibrated in our laboratory at the address shown below.

This report applies only to the item(s) identified above and shall not be reproduced, except in full, without the written approval of Dynamic Technology, Inc. This unit has been calibrated utilizing standards with a Test Uncertainty Ratio (TUR) of greater than 4:1 approximating a 95 % confidence level with a coverage factor of k=2 unless otherwise stated above or as stated on the Report of Calibration. The calibration was performed using references traceable to the SI through NIST or other recognized national laboratory, accepted fundamental or natural physical constants, ratio type of calibration, or by comparison to consensus standards. Dynamic Technology's calibration program is in compliance with:

ISO/IEC 17025:2005, ANSI/NCSL Z540-1:1994, ANSI/NCSL Z540.3:2006, MIL STD 45662A, QD-4000 2011

Dynamic Technology warrants all material and labor performed for ninety (90) days unless covered under a separate policy.

* Any number of factors may cause the calibrated item to drift out of tolerance before the interval has expired.

Technician Name/Date: James Nimri, 06/27/2012 Signatory: [signature] QA Approved: DTI QA 22

3201 West Royal Lane, Suite 150, Irving, TX 75063 (214) 723-5600 FAX (214) 723-5601

Page 1 of 1

Figure B9. Calibration sheet for the 9205 signal conditioning module 14DA726

Dynamic Technology, Inc.

A Trescal Company

17025 Accredited Certificate of Calibration

Certificate #: *2225020002* *F*

DOE# 03891C

Calibration Laboratory Certificate #: 2516.01

ACCREDITED

Acct #:	101320
Customer:	National Renewable Energy Laboratory
Shipper #:	1861169
Address:	16253 Denver West Parkway Golden, CO, 80401
Contact:	NI RMA
PO #:	

Manufacturer:	National Instruments
Model:	9217
Description:	4 Channel 100ohm RTD Analog Input M
Serial Number:	12BFEE2
Asset Number:	12BFEE2
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	06/27/2012
Due Date:	06/27/2013
Temperature:	70.30 deg. F
Humidity:	44.00 %
Baro. Press.:	
Procedure:	DCN 09480
Reference:	manufacturer's manual

Incoming Remarks:

ndo.

Domestic Accredited Calibration. w/antistatic bag

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
2062190010	ESI	RS925	Decade Resistance Standard	01/05/2012	01/05/2013
2182620007	Agilent Technologi	3458A	DMM	05/23/2012	08/23/2012

checked, [signature] 7/11/12

The above identified unit was calibrated in our laboratory at the address shown below.

This report applies only to the item(s) identified above and shall not be reproduced, except in full, without the written approval of Dynamic Technology, Inc. This unit has been calibrated utilizing standards with a Test Uncertainty Ratio (TUR) of greater than 4:1 approximating a 95 % confidence level with a coverage factor of k=2 unless otherwise stated above or as stated on the Report of Calibration. The calibration was performed using references traceable to the SI through NIST or other recognized national laboratory, accepted fundamental or natural physical constants, ratio type of calibration, or by comparison to consensus standards. Dynamic Technology's calibration program is in compliance with

ISO/IEC 17025:2005, ANSI/NCSL Z540-1:1994, ANSI/NCSL Z540.3:2006, MIL STD 45662A, QD-4000:2011

Dynamic Technology warrants all material and labor performed for ninety (90) days unless covered under a separate policy

* Any number of factors may cause the calibrated item to drift out of tolerance before the interval has expired

Technician Name/Date: James Nimri, 06/27/2012 Signatory: [signature] QA Approved: [stamp]

3201 West Royal Lane, Suite 150, Irving, TX 75063 (214) 723-5600 FAX (214) 723-5601

Page 1 of 1

Figure B10. Calibration sheet for the 9217 signal conditioning module 12BFEE2

Dynamic Technology, Inc.

A Trescal Company

17025 Accredited Certificate of Calibration

Certificate #: 2225020001 F

DOE# 038926

ilac-MRA ACCREDITED Calibration Laboratory Certificate #: 2516.01

Acct #:	101320
Customer:	National Renewable Energy Laboratory
Shipper #:	1861169
Address:	16253 Denver West Parkway Golden, CO, 80401
Contact:	NI RMA
PO #:	

Manufacturer:	National Instruments
Model:	9229
Description:	4 Channel Analog Input Module
Serial Number:	12A2037
Asset Number:	12A2037
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	06/27/2012
Due Date:	06/27/2013
Temperature:	70.00 deg. F
Humidity:	44.00 %
Baro. Press.:	
Procedure:	DCN 09375
Reference:	manufacturer's manual

Incoming Remarks:

ndo.

Domestic Accredited Calibration. w/antistatic bag

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
2182620002	Fluke	5700A	Multifunction Calibrator	05/09/2012	08/07/2012

Checked: [signature] 7/11/12

The above identified unit was calibrated in our laboratory at the address shown below.

This report applies only to the item(s) identified above and shall not be reproduced, except in full, without the written approval of Dynamic Technology, Inc. This unit has been calibrated utilizing standards with a Test Uncertainty Ratio (TUR) of greater than 4:1 approximating a 95 % confidence level with a coverage factor of k=2 unless otherwise stated above or as stated on the Report of Calibration. The calibration was performed using references traceable to the SI through NIST or other recognized national laboratory, accepted fundamental or natural physical constants, ratio type of calibration, or by comparison to consensus standards. Dynamic Technology's calibration program is in compliance with:

ISO/IEC 17025:2005, ANSI/NCSL Z540-1:1994, ANSI/NCSL Z540.3:2006, MIL STD 45662A, QD-4000:2011

Dynamic Technology warrants all material and labor performed for ninety (90) days unless covered under a separate policy

* Any number of factors may cause the calibrated item to drift out of tolerance before the interval has expired

Technician Name/Date: James Nimri, 06/27/2012 Signatory: [signature] QA Approved: DTI QA 22

3201 West Royal Lane, Suite 150, Irving, TX 75063 (214) 723-5600 FAX (214) 723-5601

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Figure B11. Calibration sheet for the 9229 signal conditioning module 12A2037