

REPORT ID: **16227.00.T46.RP1**

Niagara Region Wind Farm – Turbine T46 IEC 61400-11 Edition 3.0 Measurement Report

Prepared for:

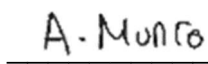
1021702 B.C. Ltd

as general partner for and on behalf of FWRN LP

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03 November 2017 – Revision 1



Revision History

Revision Number	Description	Date
1	Issued Edition 3.0 test report	November 03,2017

This report in its entirety, including appendices contains 81 pages.

Statement Qualifications and Limitations

This report was prepared by Aeroustics Engineering Limited in accordance with International Standard IEC 61400-11 (Edition 3.0, released 2012-11), “Wind turbine generator systems – Part 11: Acoustic noise measurement techniques”. This report is specific only to the Wind Turbine identified in this report.

Aeroustics Engineering Limited shall not be responsible for any events or circumstances that may have occurred since the date on which the Wind Turbine was tested and/or this report was prepared, or for any inaccuracies contained in information that was provided to Aeroustics Engineering Limited. Further, Aeroustics Engineering Limited agrees that this report represents test data analysed as per the above described standard for the specific Wind Turbine described in this report, but Aeroustics Engineering Limited makes no other representations with respect to this report or any part thereof.

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This Statement of Qualifications and Limitations is attached to and forms part of this report.

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1 Introduction

Aercoustics Engineering Limited (Aercoustics) was retained by 1021702 B.C. Ltd as a general partner for and behalf of Niagara Region Wind Farm (“FWRN”) to conduct an acoustic measurement of turbine T46 at the Niagara Region Wind Farm. The purpose of the measurement was to provide verification of the maximum noise emission of the turbine. The measurement was carried out in accordance with International Standard IEC 61400-11 (Edition 3.0, released 2012-11), “Wind turbine generator systems – Part 11: Acoustic noise measurement techniques”. This report is specific only to Turbine T46.

2 Wind Turbine Information

2.1 Wind turbine equipment specific information

Wind turbine specific equipment information for turbine T46 was provided by FWRN and is summarized in Tables 1 – 5.

Table 1 - Wind Turbine Details

Wind Turbine Details	
Manufacturer	Enercon
Model Number	E-101
Turbine ID	1011199

Table 2 - Operating Details

Operating Details	
Vertical or Horizontal axis wind turbine	Horizontal
Upwind or downwind rotor	Upwind
Hub height	124 m
Horizontal distance from rotor centre to tower axis	6 m
Diameter of rotor	101 m
Tower type (lattice or tube)	Tube
Passive stall, active stall, or pitch controlled turbine	Pitch Controlled
Constant or variable speed	Variable Speed
Power curve	Please see Figure B.01
Rotational speed at each integer standardised wind speed	Please see Figure B.02
Rated power output	2900 kW
Control software version	5.20 (main board), 5.87 (pitching system)

Table 3 - Rotor Details

Rotor Details	
Rotor control devices	Electric Pitch
Presence of vortex generators, stall strips, serrated trailing edges	Tip bows (winglet type devices)
Blade type	Composite (Epoxy Resin, Balsa)
Serial number	N/A
Number of blades	3

Table 4 - Gearbox Details

Gearbox Details	
Manufacturer	N/A
Model number	N/A
Serial number	N/A

Table 5 - Generator Details

Generator Details	
Manufacturer	Enercon
Model number	G4 Annular Generator
Serial number	N/A

2.2 Wind Turbine Location

Turbine T46 is located in the county of Haldimand near the town of Dunnville, approximately 450 m South of Feeder Canal Road, and 970 m East of Bird Road. The coordinates of Turbine T46 are 17T 622737 m Easting and 4748968 m Northing. The area surrounding T46 is flat and consists primarily of farmland.

A general layout of the area in which the turbine is located is provided in the site plan (Figure A.01).

3 Measurement Details

3.1 Measurement Equipment

3.1.1 Acoustic Measurement Equipment

A summary of acoustic equipment utilized by Aercoustics for the measurement of turbine T46 is summarized in Table 6.

Table 6 - Acoustic Measurement Equipment

Equipment	Manufacturer Name & Model	Serial Number
Acoustic Data acquisition system	LMS SCADA Mobile	22163146†
Microphone	B&K 4189	3060528‡ 2625417*
Pre-amplifier	B&K 2671	2369795‡ 2614900*
Acoustic calibrator	B&K 4231	2053016‡ 1807640*

†Instrument used on both days of testing

‡Instruments used on Aug 18, 2017

* Instruments used on August 31, 2017

Calibration of the measurement setup was carried out before and after Aercoustics set of measurements.

3.1.2 Meteorological Equipment

Wind speed for Turbine ON was derived from the power curve (as per procedures outlined in IEC 61400-11). Wind direction for turbine ON measurements was utilized from the nacelle anemometer located at hub height (124 m high) from turbine T46. Data for background measurements was obtained from a 10m high anemometer, which was placed as per guidelines outlined in IEC-61400-11.

The meteorological equipment is summarized in Table 7.

Table 7 – Meteorological Measurement Equipment

Equipment	Manufacturer Name & Model	Serial Number
Anemometer	VAISALA WXT520	G4420002
Serial to Analog Converter	NOKEVAL 7470	A159784

3.2 Measurement Setup

3.2.1 Microphone Placement

The measurement microphone was setup 179.5 m from the base of the turbine in 'Position 1', (i.e. downwind of the turbine, as per IEC 61400-11) at an elevation of 0m relative to the

base of T46. The microphone was placed in the centre of a circular, acoustically reflective board.

During the measurement period only data points for which the microphone was within 15 degrees of downwind from the turbine were used. The microphone position relative to downwind of the turbine was monitored via the yaw angle output provided from the turbine system (discussed further in Section 3.5). During placement of the microphone the turbine was parked and the reference yaw angle for that measurement logged.

When measurements of T46 were taken, the surrounding land was planted with soy beans crop. The crop was short and as such the influence on the measurement was considered negligible. There were no nearby reflecting surfaces (houses, barns etc.); as such the influence from reflecting surfaces was considered to be negligible.

Photos of the measurement setup are provided in Figure A.02, Appendix A.

3.2.2 Double Windscreen Setup

A double windscreen setup was not utilized.

3.3 Measurement Schedule

Table 8 provides a summary of the test date and times. Data was logged in 10 second intervals for post-processing (as per the measurement standard).

Table 8 - Measurement Schedule Summary

Date	Test Type	Start Time	Finish time
Aug 18, 2017	Turbine ON	12:56 pm	1:16 pm
	Background	1:37 pm	2:07 pm
	Turbine ON	2:19 pm	2:59 pm
	Background	3:05 pm	3:15 pm
	Turbine ON	3:34 pm	3:46 pm
Aug 31, 2017	Turbine ON	2:33 pm	4:00 pm
	Background	4:03 pm	5:05 pm

3.4 Meteorological Conditions

Detailed meteorological data relevant to the measurement is provided in Appendix E.

As previously mentioned, wind speed for Turbine ON was derived from T46's power curve (as per the standard), while wind direction was provided by T46's nacelle anemometer (located at hub height). Background data was obtained from an anemometer located 10m above ground level near T46.

Temperature and pressure readings during the measurement period were provided by the 10m anemometer, located near turbine T46 for the duration of Aeroacoustics measurements.

3.5 Turbine operational information

Output data from the turbine (Power, yaw, RPM, pitch angle, and nacelle wind speed) were obtained as analog output signals that were simultaneously acquired with the acoustic and anemometer measurement data using Aercoustics data acquisition system.

4 Measurement Results

4.1 Deviations from IEC-61400-11 Edition 3.0

Due to Electromagnetic Interference affecting microphone signal in the test cabling at 1/3 octave frequency bands at 6.3 kHz and above, the analysis excludes these affected frequency bands. As wind turbines do not generate sound of notable levels at high frequencies, this has a negligible impact on the conclusions of the analysis.

4.2 Special Notes & Considerations

Turbines T45 and T47 are located in the immediate vicinity of T46. During the measurements, Turbines T45 and T47 are parked and not in operation. As such, they do not have any contributions to the results.

4.3 Analysis Details

The following section outlines analysis of the measurement data acquired for T46. The data presented is exclusive of transient events such as vehicle traffic, wildlife, air traffic etc. The site has been assessed to have a roughness length of 0.05m, representative of farmland with some vegetation.

4.3.1 Double Windscreen Adjustment

As previously mentioned, no double wind screen was used, as such the measurement data did not require adjustment.

4.3.2 Wind Speed Correction

The wind speed for each measurement data point for Turbine ON was derived through the power curve (as per Section 8.2.1.1 of IEC-61400-11). For data points during Turbine ON that were outside the allowed range of the power curve, the wind speed was derived from the nacelle anemometer wind speed (as specified in Section 8.2.1.2 of IEC-61400-11).

Background wind speed was derived utilizing data acquired with the 10m anemometer and normalizing the wind speed (as per Section 8.2.2 of IEC-61400-11).

4.4 Type B uncertainties

Type B uncertainties were obtained through interpretation of information provided in Annex C of IEC-61400-11, and instrument uncertainties obtained from the calibration certificate. A summary of Type B uncertainties is provided in Table 9, while detailed information (including data in 1/3 octave) is provided in Appendix C.

Table 9 - Summary of Type B uncertainties

Component	Typical (dB)	Used (dB)
Calibration	0.2	0.2
Board	0.3	0.3
Distance & direction	0.1	0.1
Air absorption	0	0
Weather conditions	0.5	0.5
Wind speed measured	0.7	0.7
Wind speed derived	0.2	0.2
Wind speed from power curve	0.2	0.2

4.5 Sound Pressure Level Measurements

Sound pressure level measurements are summarized in Table 10. Detailed 1/3 Octave band spectrum data, respective uncertainties, and analysis plots are provided in Appendix C. A copy of the measurement data used for analysis is provided in Appendix E and includes meteorological and turbine operational data.

Table 10 - Summary of Sound Pressure Level Measurements

Wind Speed (m/s)	Turbine ON		Background		Turbine ON, Background adjusted L_{eq} , (dBA)
	L_{eq} , (dBA)	# of data pts	L_{eq} , (dBA)	# of data pts	
8.5	48.2	13	39.8	24	47.5
9	50.1	12	40.5	15	49.6
9.5	50.9	17	42.1	10	50.2
10	50.5	18	42.2	11	49.8
10.5	51.0	31	41.9	19	50.4
11	51.2	35	41.4	16	50.7
11.5	51.2	16	42.5	13	50.6
12	51.2	12	41.0	15	50.8
12.5	52.0	22	42.5	16	51.4
13	51.9	23	42.4	15	51.4
13.5	51.4	20	42.5	12	50.8
14	51.8	12	42.6	14	51.3

4.6 Sound Power Level of Turbine

The calculated sound power level of the turbine T46 (as per IEC 61400-11) is summarized in Table 11 (hub height) and Table 12 (10m height). Detailed 1/3 Octave band spectrum data and respective uncertainties are provided in Appendix C.

Table 11 - $L_{WA, K}$ at each integer wind speed

Wind Speed (m/s)	Apparent L_{WA} , (dBA)	Uncertainty (dB)
8.5	99.5	0.9
9	101.6	1.0
9.5	102.2	0.9
10	101.8	1.0
10.5	102.4	0.9
11	102.7	0.8
11.5	102.5	1.0
12	102.7	0.9
12.5	103.4	0.9
13	103.4	0.9
13.5	102.7	0.8
14	103.2	0.9

Table 12 - $L_{WA, 10m, K}$ at each integer wind speed

Wind Speed (m/s)	Apparent L_{WA} , (dBA)	Uncertainty (dB)
5	96.0	1.0
6	100.6	0.9
7	102.3	0.8
8	102.8	0.8
9	103.2	0.8
10	103.1	0.8

4.7 Tonality Analysis

The tonality analysis for Turbine T46 is summarized in Table 13, while plots of narrow band spectra at each wind speed are provided in Appendix D. The ΔL_{tn} and ΔL_a values reported represent the energy average of all data points with an identified tone that falls within the same frequency origin (as specified in Section 9.5.8 in IEC-61400-11).

The narrow band spectra provided in the plots represents an energy average of all data points in the given wind speed bin for both Turbine ON and Background.

Table 13 - Tonality Assessment Summary

Wind Speed (m/s)	Frequency (Hz)	Tonality, ΔL_{tn} (dB)	Tonal audibility, ΔL_a (dB)	FFT's with tones	Total # of FFT's	Presence (%)
No Reportable Tones						

5 Closure

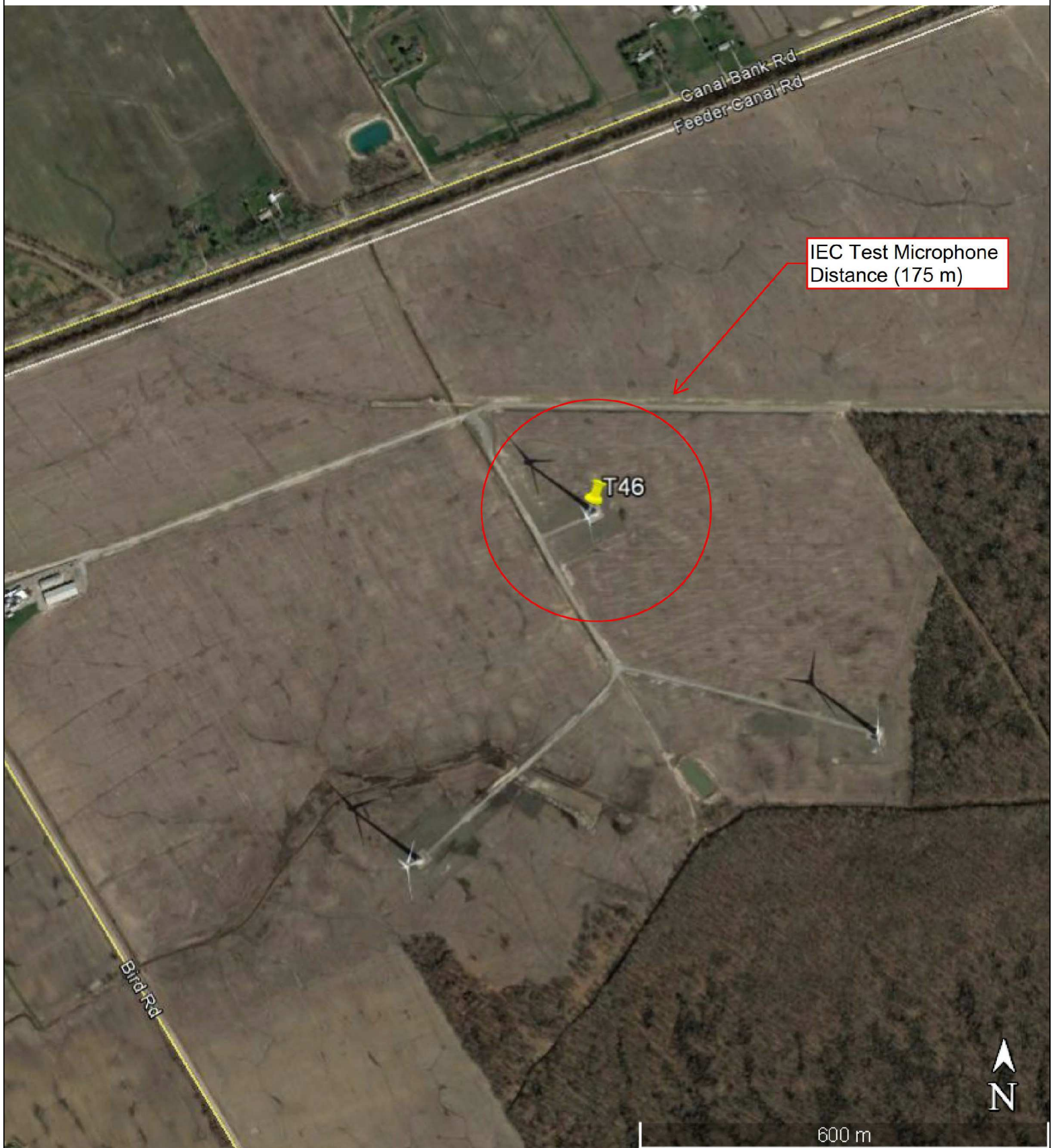
Measurements and analysis were carried on Turbine T46 of the Niagara Region Wind Farm, located in the county of Haldimand as per International IEC 61400-11 (Edition 3.0, released 2012-11), "Wind turbine generator systems – Part 11: Acoustic noise measurement techniques".

Should you have any questions or comments please do not hesitate to contact the authors of this report.

6 References

1. International Standard IEC 61400-11 (Edition 3.0, released 2012-11), "Wind turbine generator systems – Part 11: Acoustic noise measurement techniques".

Appendix A Site Details





16227.00.T46.RP1

Scale: NTS
 Drawn by: NT
 Reviewed by: PA
 Date: Sept 8, 2017
 Revision: 1

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Niagara Region Wind Farm - IEC 61400-11 Edition 3.0 - Turbine T46

Figure Title

Site Photos

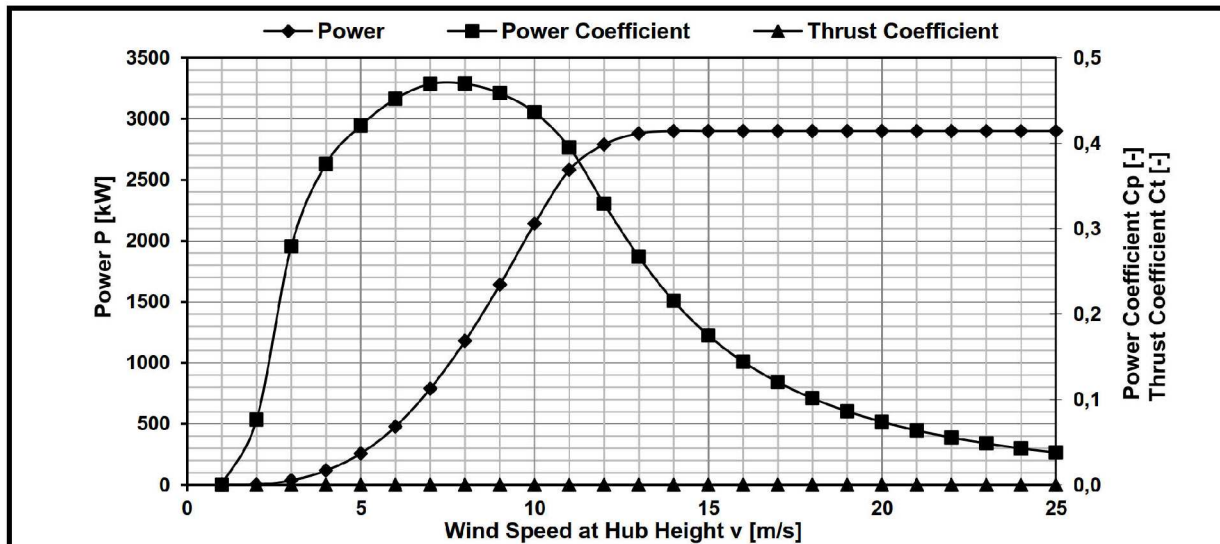
Figure A.02

Appendix B

Turbine Information

Rated Power Output: 3050 kW
Operation Mode: OMII 2900 kW
Designation: PC_E-101_3050_kW_OMII_2900_kW_calculated_V1.0
Standard Air Density: 1.225 kg/m³

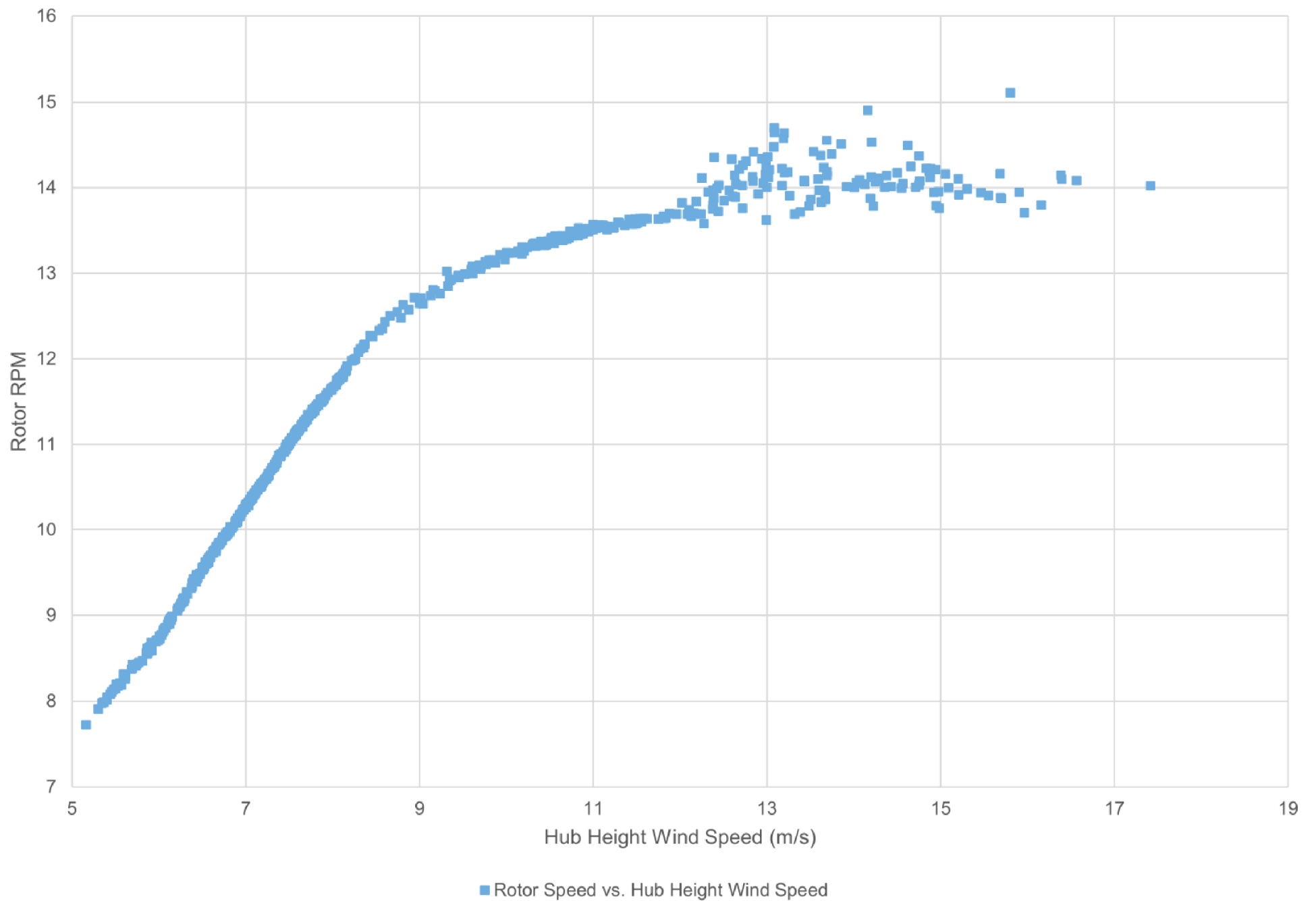
Wind Speed v [m/s]	Power P [kW]	Power Coefficient C_p [-]	Thrust Coefficient C_t [-]
1	0	0.00	-
2	3	0.08	-
3	37	0.28	-
4	118	0.38	-
5	258	0.42	-
6	479	0.45	-
7	790	0.47	-
8	1180	0.47	-
9	1640	0.46	-
10	2140	0.44	-
11	2580	0.40	-
12	2790	0.33	-
13	2880	0.27	-
14	2900	0.22	-
15	2900	0.18	-
16	2900	0.14	-
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Document Information:

Author: Benjamin Ahrens
Department: WRD Power Performance
Date: 15.09.2015

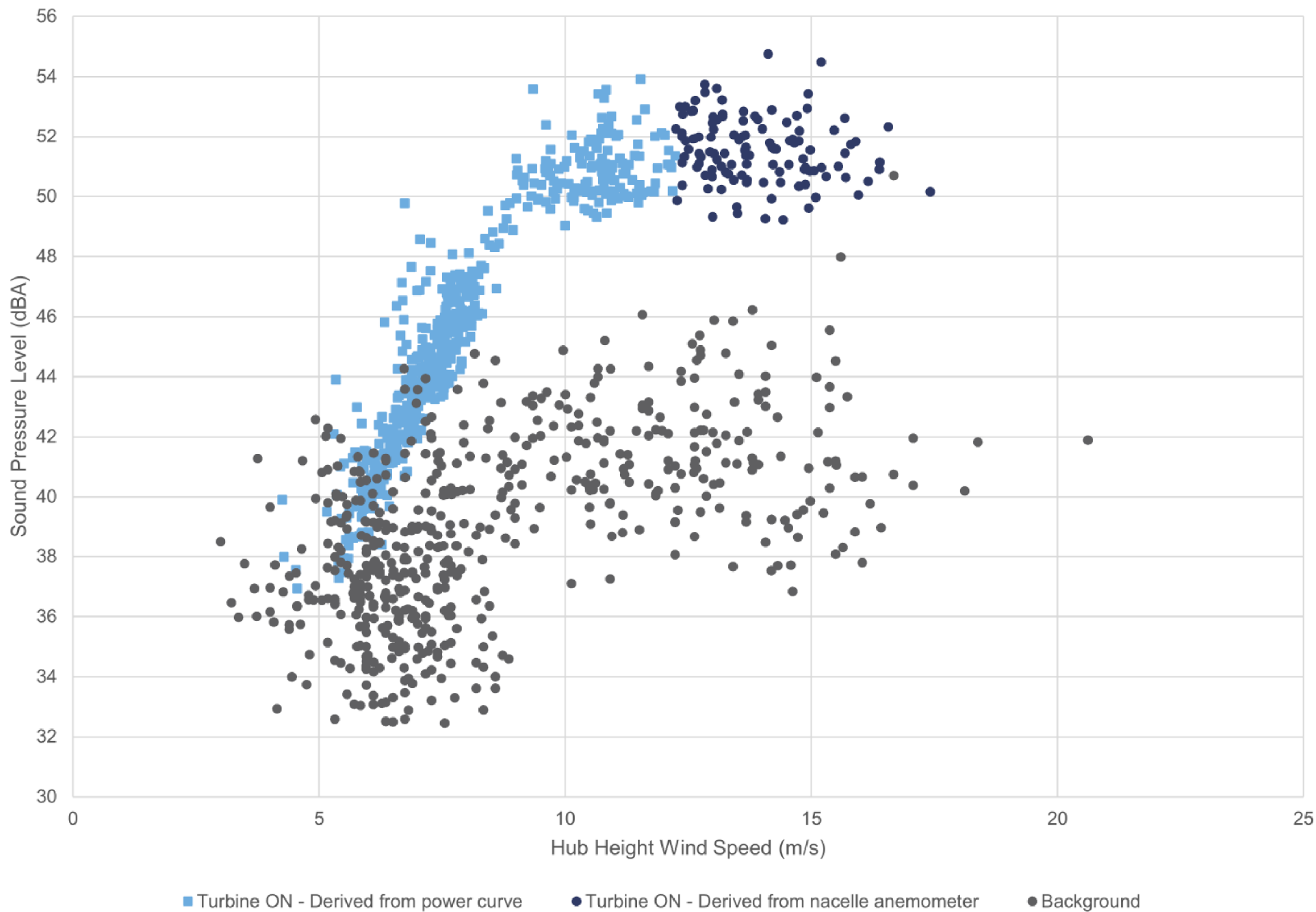
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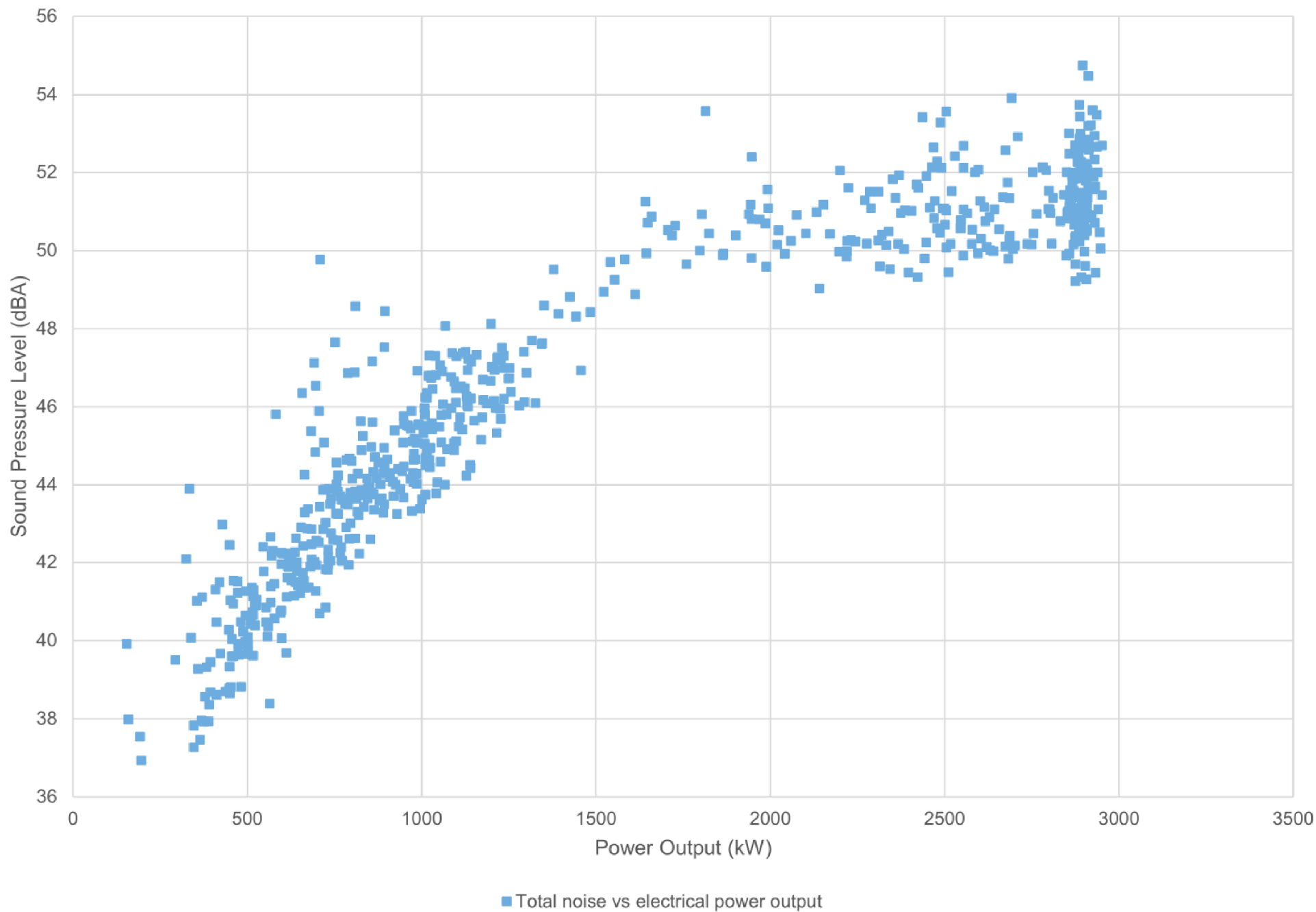
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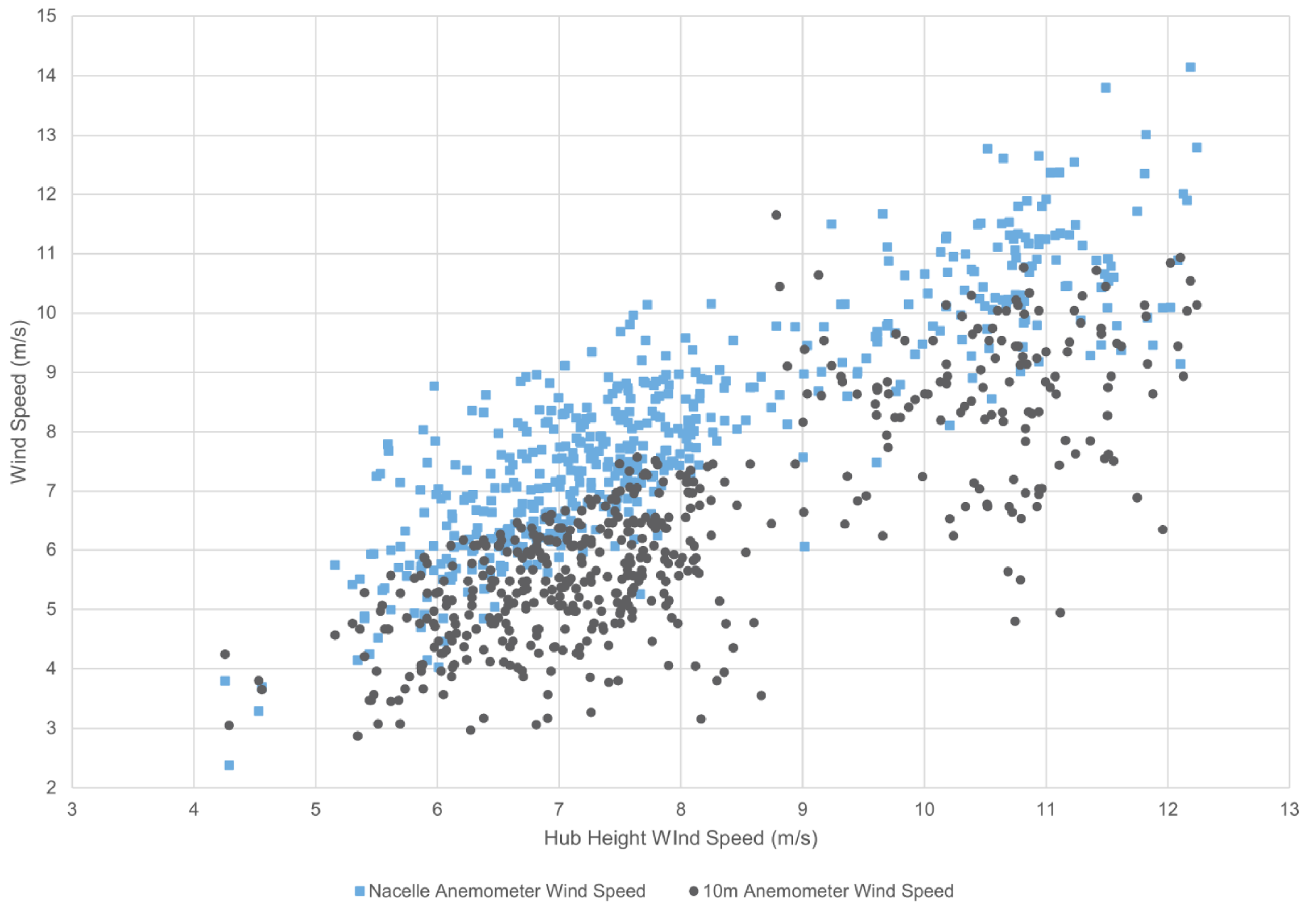


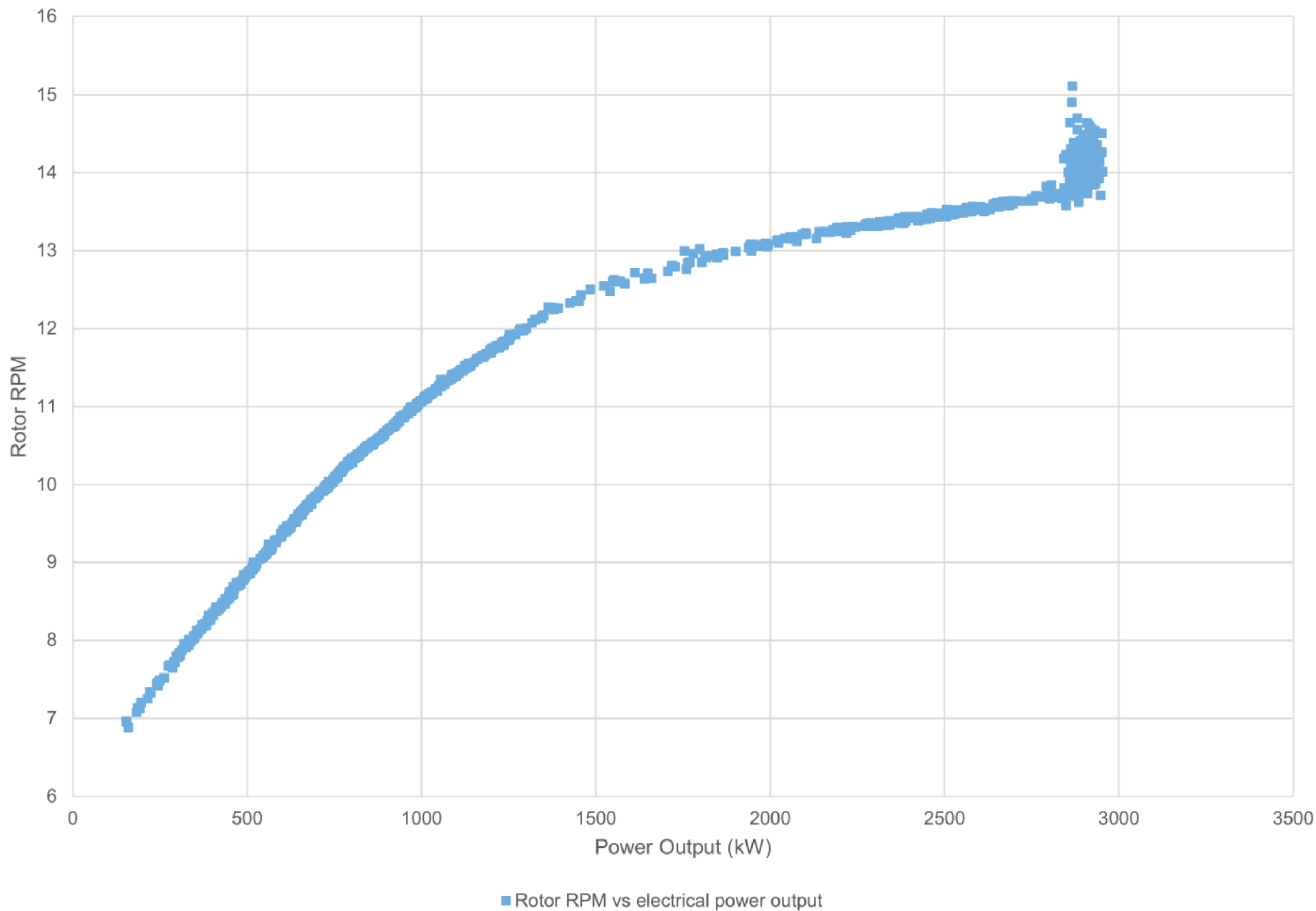
Appendix C

Apparent Sound Power Level

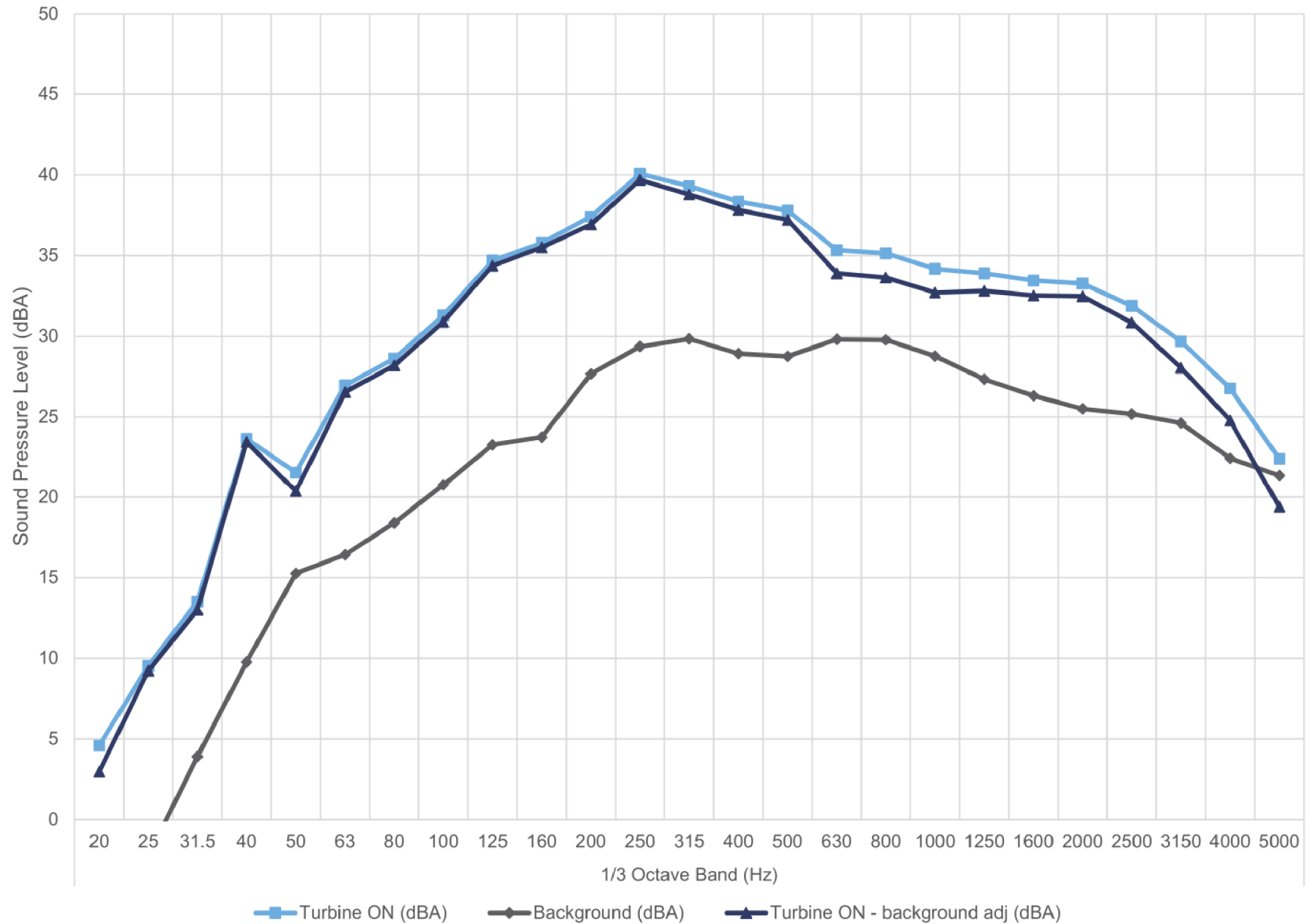








8.5 m/s - Hub Height



■ Turbine ON (dBA)
 ◆ Background (dBA)
 ▲ Turbine ON - background adj (dBA)



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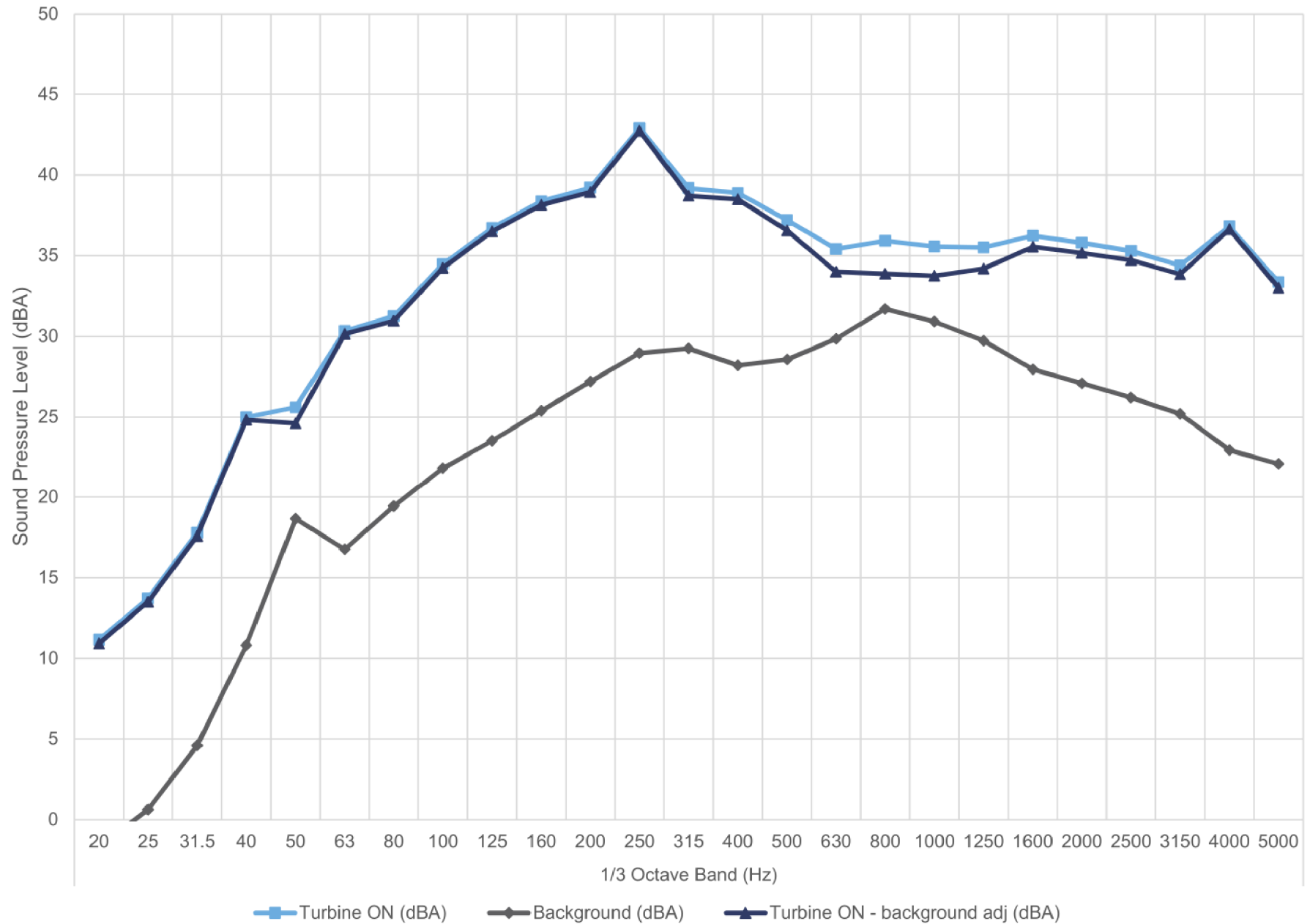
Niagara Region Wind Farm - IEC 61400-11 Edition 3.0 - Turbine T46

Figure Title

Plot of sound pressure spectrum in 1/3 Octave at 8.5 m/s

Figure C.05

9.0 m/s - Hub Height



■ Turbine ON (dBA)
 ◆ Background (dBA)
 ▲ Turbine ON - background adj (dBA)



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 Date: Nov 1, 2017
 Revision: 1

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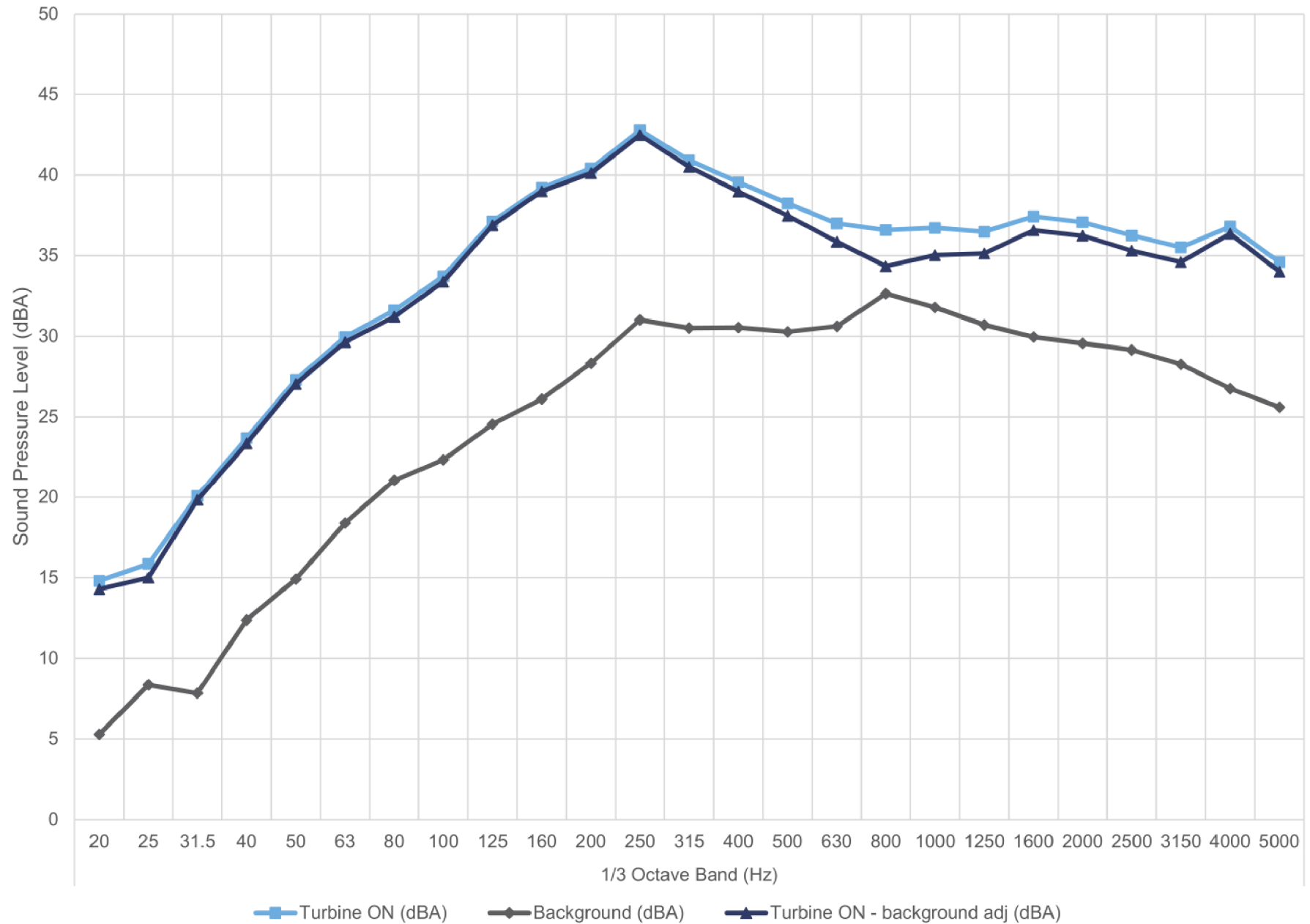
Niagara Region Wind Farm - IEC 61400-11 Edition 3.0 - Turbine T46

Figure Title

Plot of sound pressure spectrum in 1/3 Octave at 9 m/s

Figure C.06

9.5 m/s - Hub Height



■ Turbine ON (dBA)
 ◆ Background (dBA)
 ▲ Turbine ON - background adj (dBA)



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Project Name

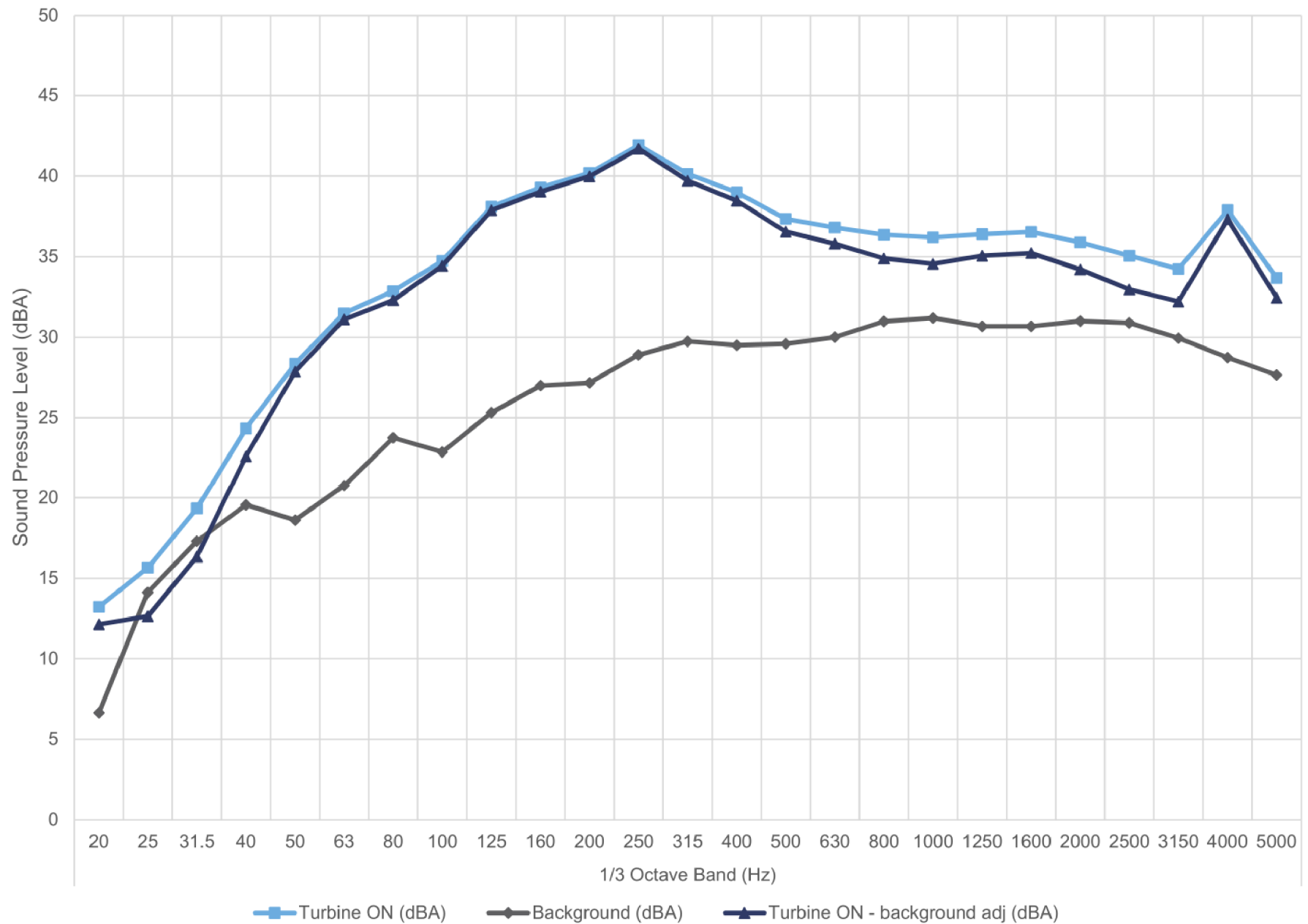
Niagara Region Wind Farm - IEC 61400-11 Edition 3.0 - Turbine T46

Figure Title

Plot of sound pressure spectrum in 1/3 Octave at 9.5 m/s

Figure C.07

10.0 m/s - Hub Height



■ Turbine ON (dBA)
 ◆ Background (dBA)
 ▲ Turbine ON - background adj (dBA)



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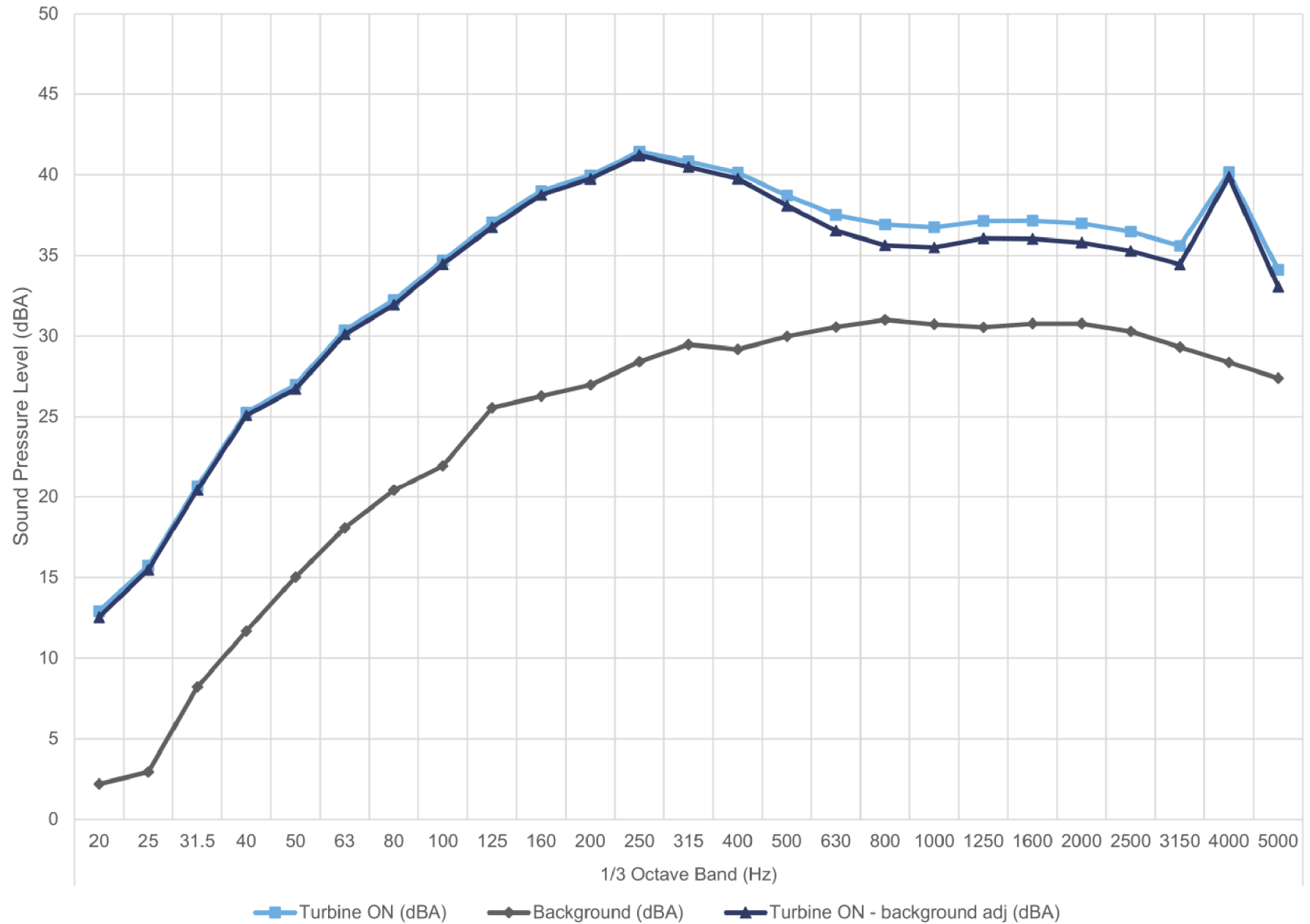
Niagara Region Wind Farm - IEC 61400-11 Edition 3.0 - Turbine T46

Figure Title

Plot of sound pressure spectrum in 1/3 Octave at 10 m/s

Figure C.08

10.5 m/s - Hub Height



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Project Name

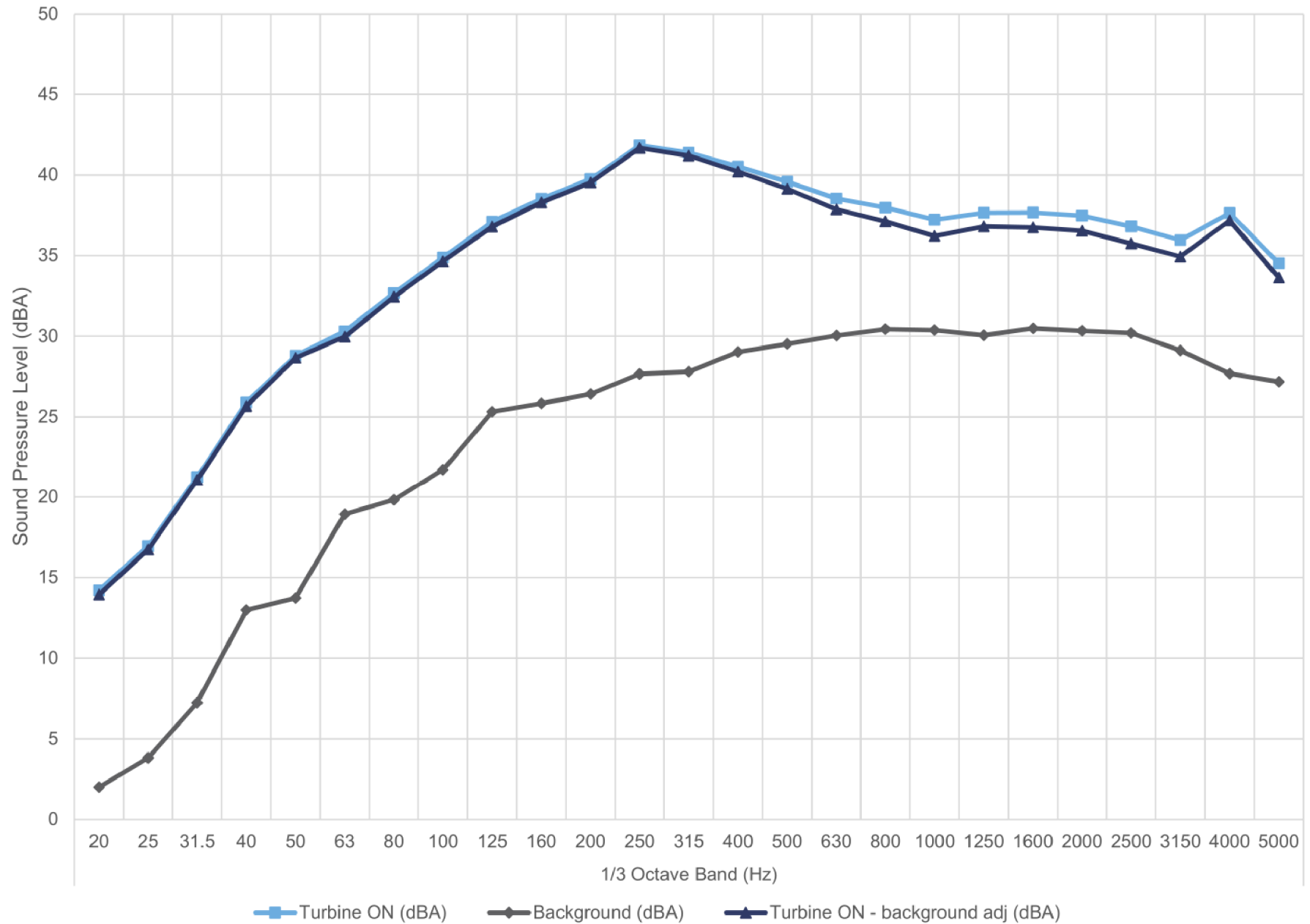
Niagara Region Wind Farm - IEC 61400-11 Edition 3.0 - Turbine T46

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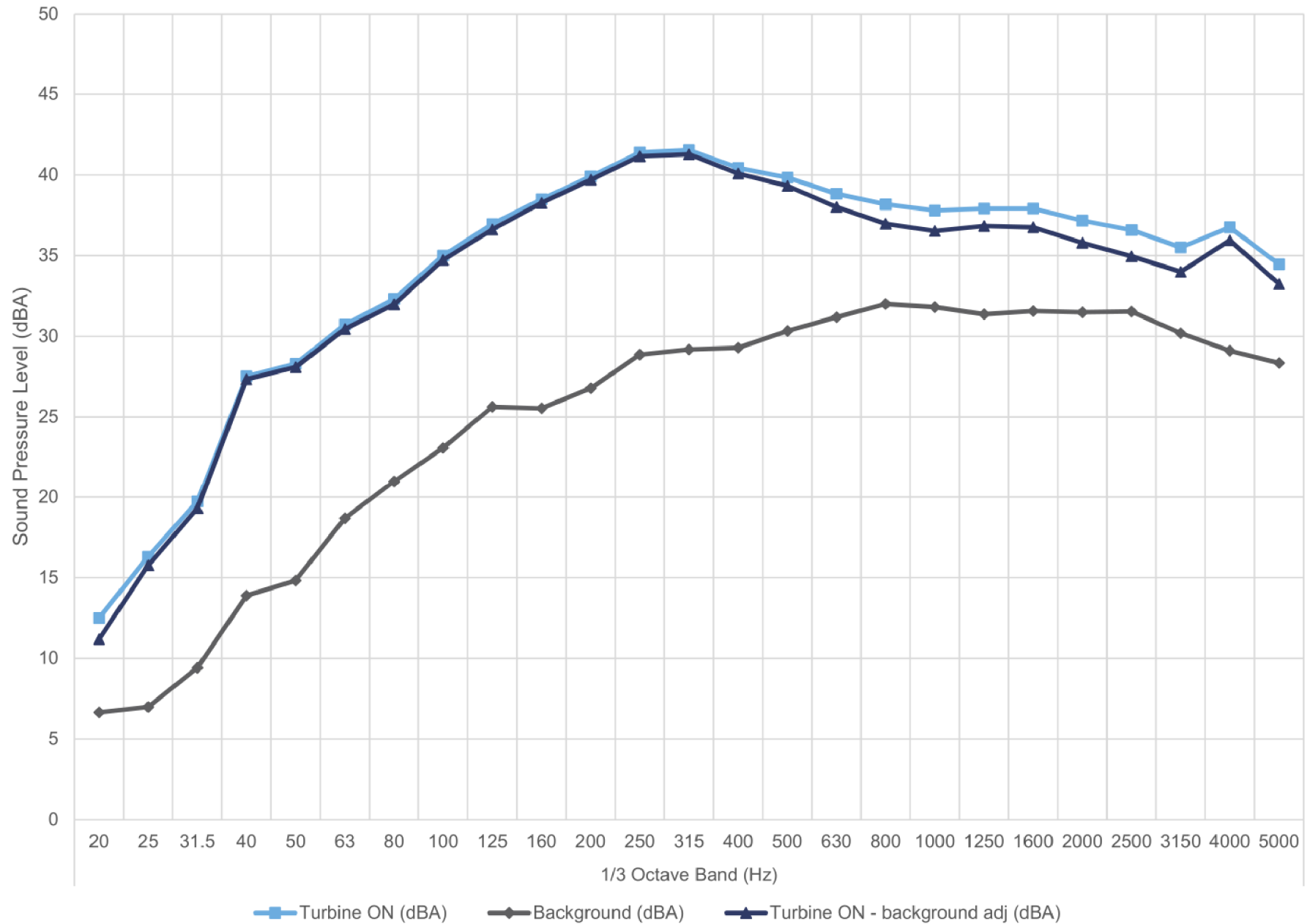
Plot of sound pressure spectrum in 1/3 Octave at 10.5 m/s

Figure C.09

11.0 m/s - Hub Height



11.5 m/s - Hub Height



■ Turbine ON (dBA)
 ◆ Background (dBA)
 ▲ Turbine ON - background adj (dBA)



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Project Name

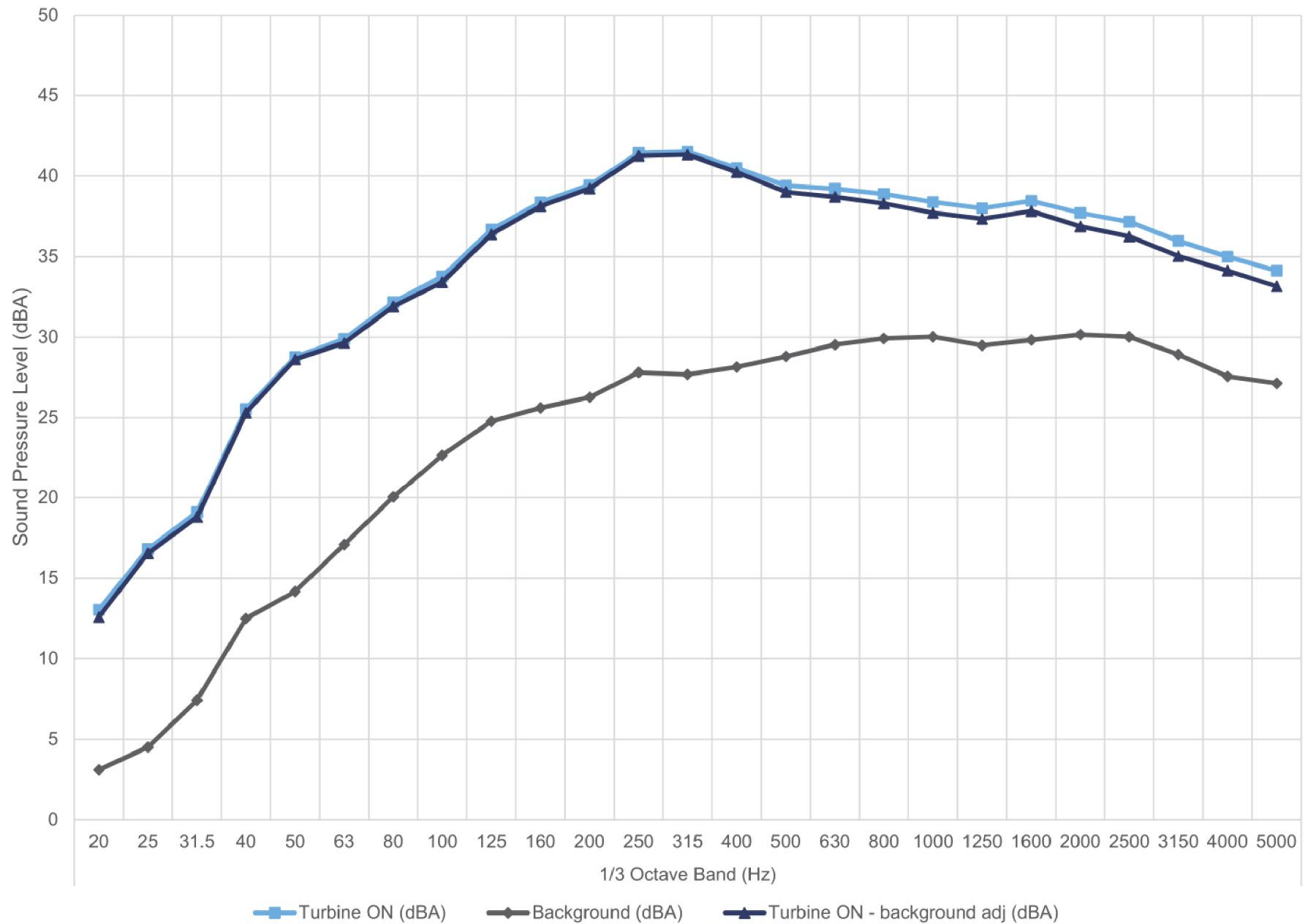
Niagara Region Wind Farm - IEC 61400-11 Edition 3.0 - Turbine T46

Figure Title

Plot of sound pressure spectrum in 1/3 Octave at 11.5 m/s

Figure C.11

12.0 m/s - Hub Height



■ Turbine ON (dBA)
 ◆ Background (dBA)
 ▲ Turbine ON - background adj (dBA)



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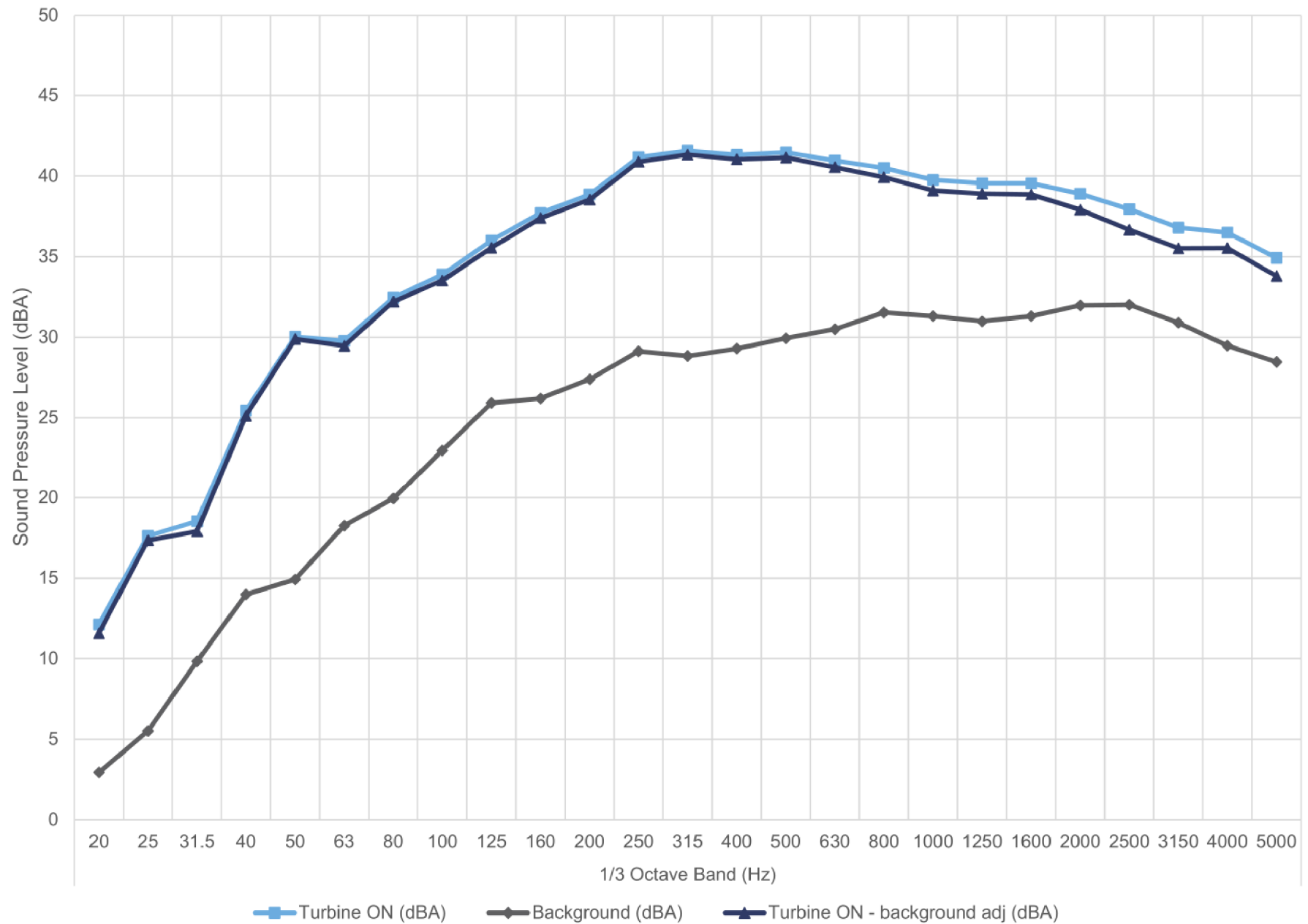
Niagara Region Wind Farm - IEC 61400-11 Edition 3.0 - Turbine T46

Figure Title

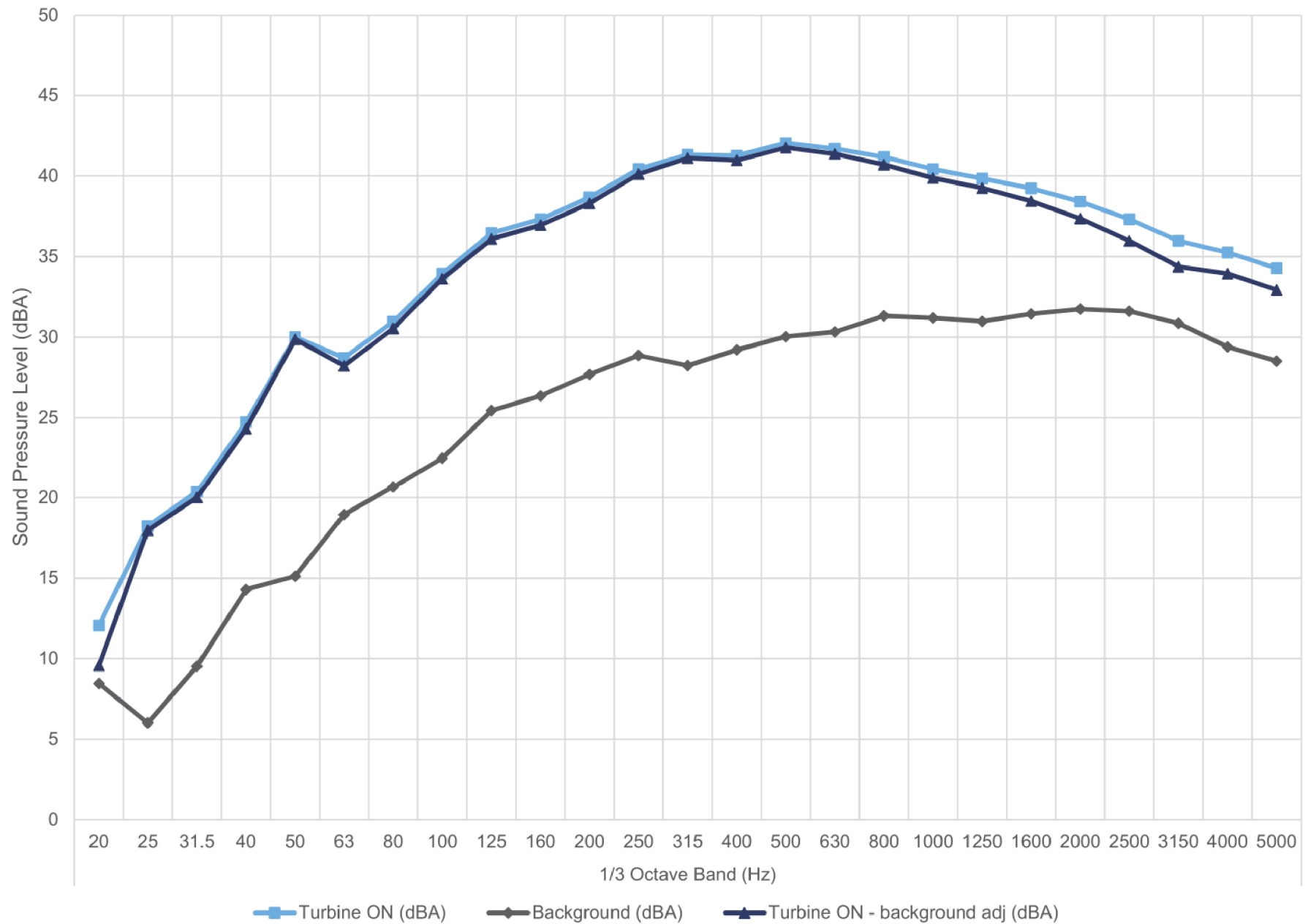
Plot of sound pressure spectrum in 1/3 Octave at 12 m/s

Figure C.12

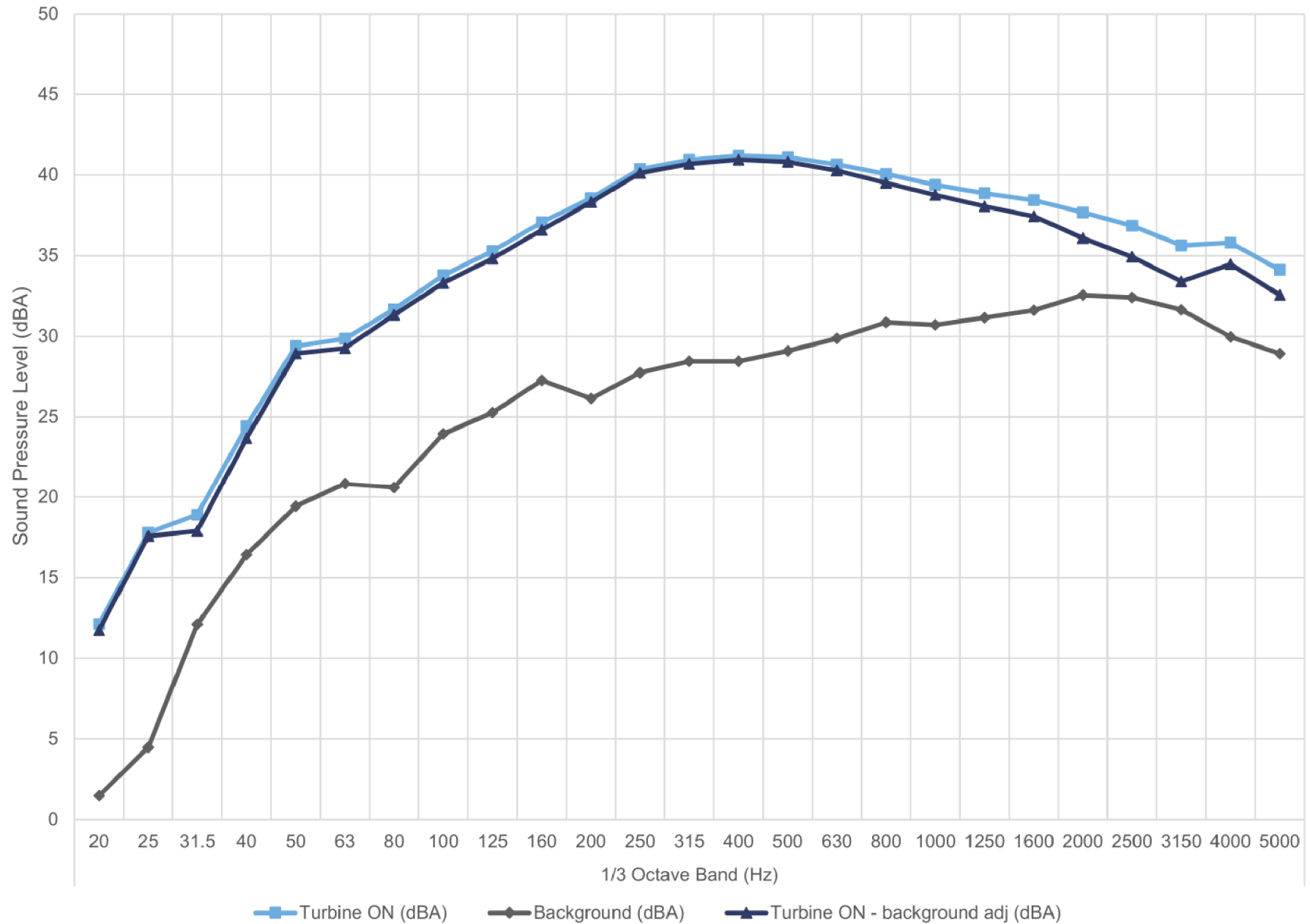
12.5 m/s - Hub Height



13.0 m/s - Hub Height



13.5 m/s - Hub Height



■ Turbine ON (dBA)
 ◆ Background (dBA)
 ▲ Turbine ON - background adj (dBA)



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Project Name

Niagara Region Wind Farm - IEC 61400-11 Edition 3.0 - Turbine T46

Figure Title

Plot of sound pressure spectrum in 1/3 Octave at 13.5 m/s

Figure C.15

14.0 m/s - Hub Height

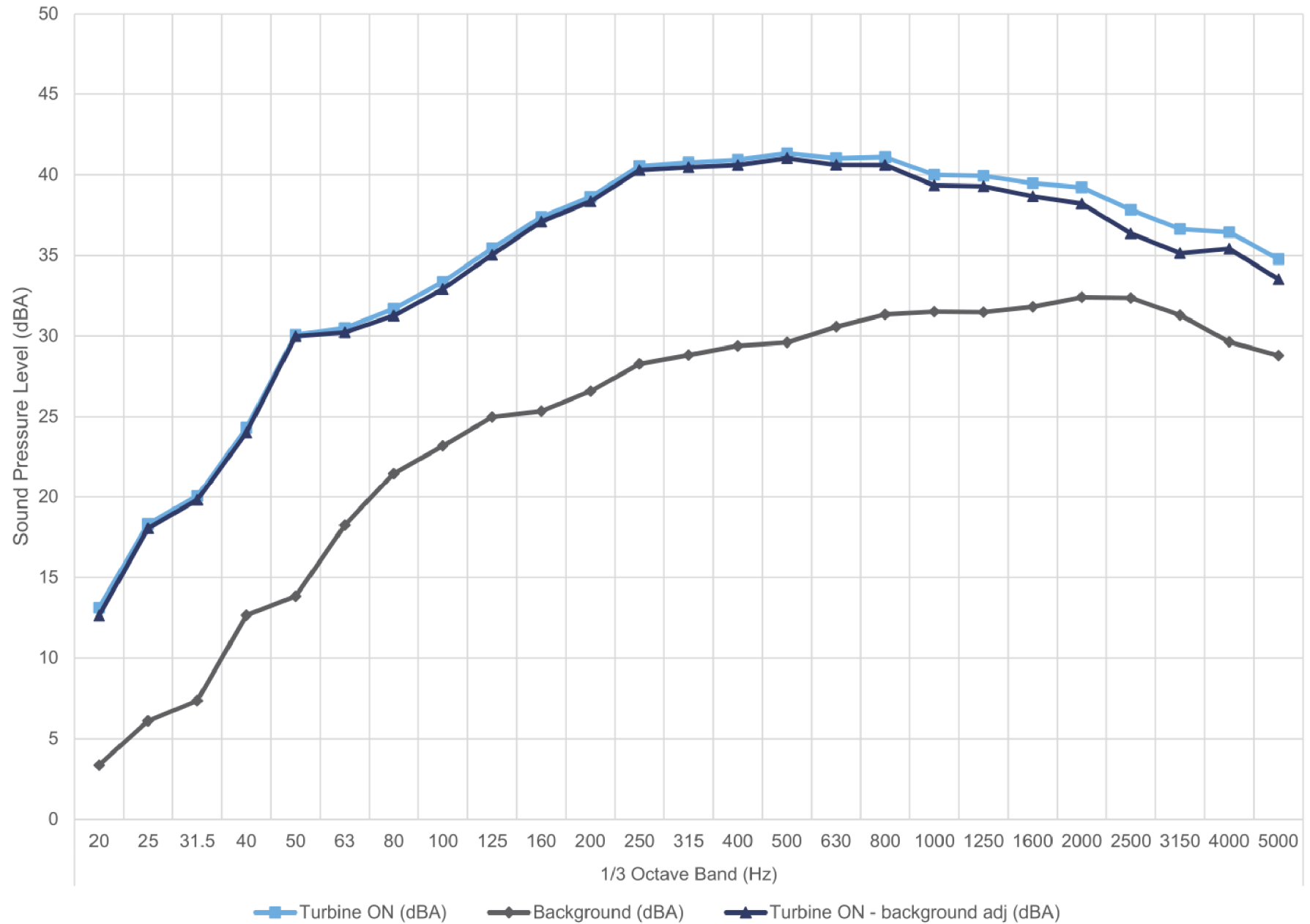


Table C.03 Type B measurement uncertainty summary

Project: Niagara Region Wind Farm - Turbine T46 - IEC 61400-11 Measurement
Report ID: 16227.00.T46.RP1

Page 1 of 1
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Overall Equipment Uncertainties		
	Typical values	Used values
Calibration	0.2 dB	0.2 dB
Board	0.3 dB	0.3 dB
Distance	0.1 dB	0.1 dB
Air absorption	0 dB	0 dB
Weather	0.5 dB	0.5 dB

1/3 Octave Band Uncertainties		
Frequency (Hz)	Microphone Uncertainty	Overall (including overall equipment Uncertainties)
20	0.8 dB	1 dB
25	0.8 dB	1 dB
31.5	0.5 dB	0.8 dB
40	0.5 dB	0.8 dB
50	0.5 dB	0.8 dB
63	0.5 dB	0.8 dB
80	0.5 dB	0.8 dB
100	0.5 dB	0.8 dB
125	0.5 dB	0.8 dB
160	0.5 dB	0.8 dB
200	0.3 dB	0.7 dB
250	0.3 dB	0.7 dB
315	0.3 dB	0.7 dB
400	0.3 dB	0.7 dB
500	0.3 dB	0.7 dB
630	0.3 dB	0.7 dB
800	0.3 dB	0.7 dB
1000	0.3 dB	0.7 dB
1250	0.3 dB	0.7 dB
1600	0.3 dB	0.7 dB
2000	0.3 dB	0.7 dB
2500	0.5 dB	0.8 dB
3150	0.5 dB	0.8 dB
4000	0.5 dB	0.8 dB
5000	0.5 dB	0.8 dB
6300	0.5 dB	0.8 dB
8000	0.5 dB	0.8 dB
10000	1.3 dB	1.4 dB

Table C.04 Detailed measruement uncertainty at hub height

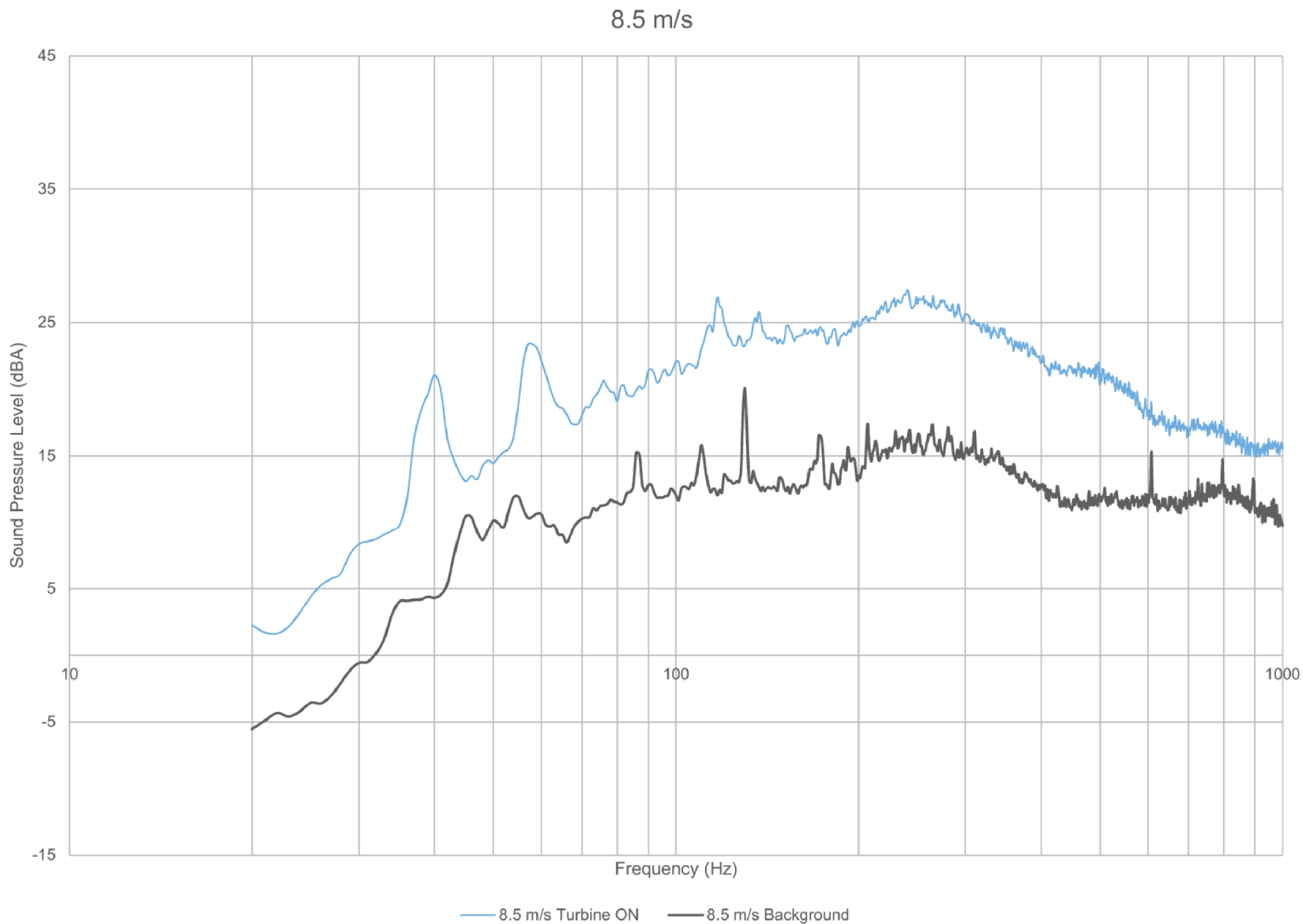
Project: Niagara Region Wind Farm - Turbine T46 - IEC 61400-11 Measurement

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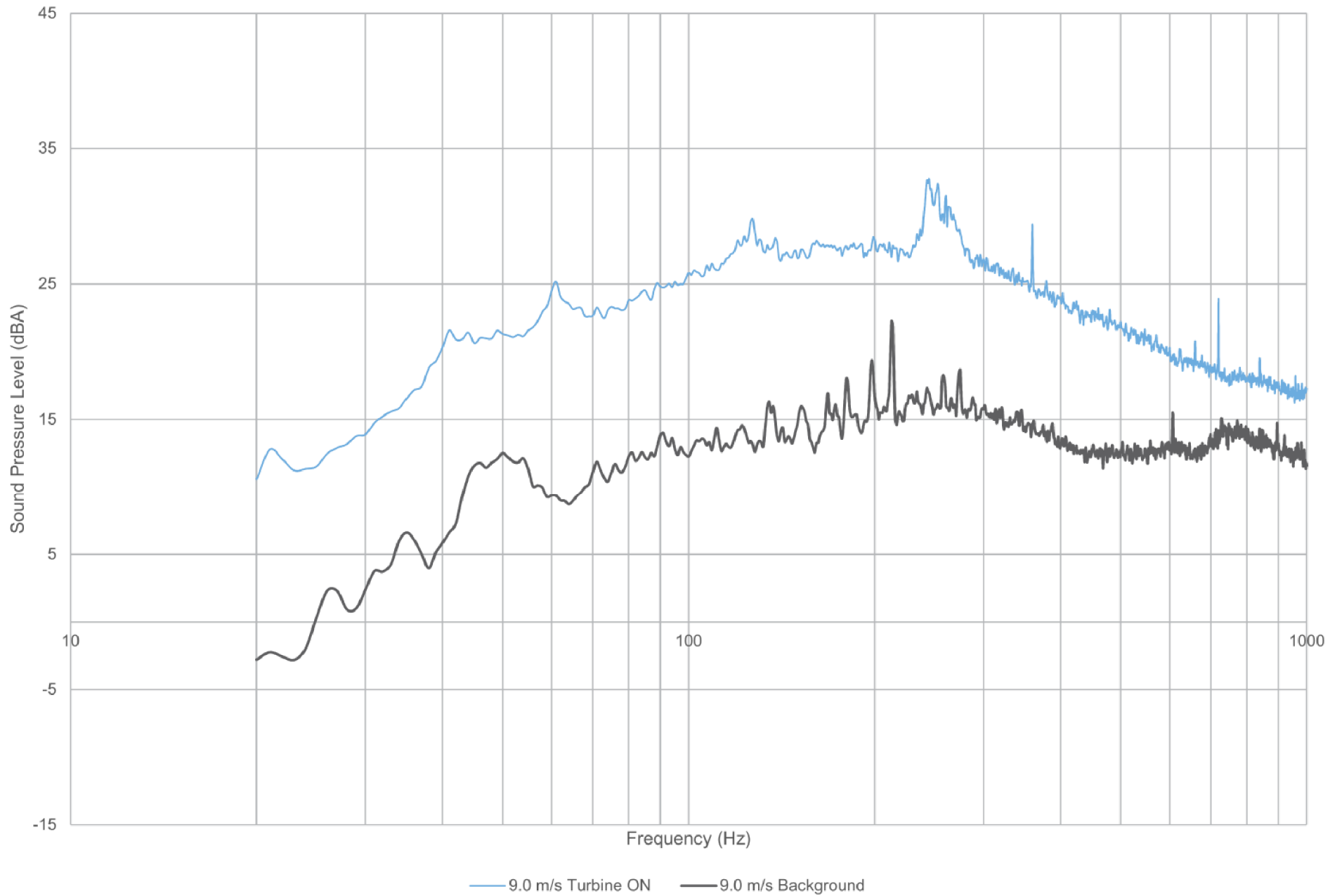
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Created on: 11/3/2017

Wind Bin (m/s)	Parameter	Average Wind Speed (m/s)	# of data points	Parameter	20	25	31.5	40	50	63	80	100	125	160	200	1/3 Octave Band (Hz)																Overall
					20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000			
13.0	Turbine ON	13.02	23	Average (dBA)	12.1	18.3	20.5	24.7	30.0	28.7	30.9	34.0	36.5	37.3	38.7	40.4	41.3	41.3	42.1	41.7	41.2	40.5	39.9	39.2	38.4	37.3	35.9	35.2	34.2	52.0		
				Uncertainty A (dB)	0.8	0.6	0.8	0.6	0.5	0.5	0.4	0.5	0.5	0.4	0.4	0.5	0.3	0.4	0.4	0.3	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.3		
				Uncertainty B (dB)	1.0	1.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8		
				Combined Uncertainty (dB)	1.3	1.2	1.2	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	1.0	0.8	
	Background	12.91	15	Average (dBA)	9.8	6.3	9.0	13.9	14.3	18.6	20.7	22.2	25.5	26.2	28.0	29.1	28.2	29.4	30.2	30.4	31.4	31.3	31.0	31.4	31.6	31.5	30.7	29.3	28.4	42.4		
				Uncertainty A (dB)	2.8	1.3	0.9	1.0	0.6	0.7	0.9	0.6	0.4	0.4	0.8	0.6	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.6	0.5	0.6	0.7	0.8	0.9	0.9	0.6	
				Uncertainty B (dB)	1.0	1.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	
				Combined Uncertainty (dB)	3.0	1.7	1.2	1.2	1.0	1.1	1.2	1.0	0.9	0.9	1.0	0.9	0.8	0.9	0.9	0.9	0.9	1.0	0.9	0.9	0.9	1.0	1.1	1.2	1.2	1.0		
13.5	Turbine ON	13.56	20	Average (dBA)	12.1	17.7	18.7	24.4	29.3	30.0	31.8	33.8	35.1	37.0	38.6	40.4	40.9	41.2	41.0	40.5	39.9	39.3	38.7	38.3	37.6	36.8	35.6	35.9	34.1	51.3		
				Uncertainty A (dB)	0.4	0.8	0.7	0.6	0.6	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.4	0.3	0.4	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.5	0.2		
				Uncertainty B (dB)	1.0	1.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8		
				Combined Uncertainty (dB)	1.1	1.3	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.8	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	1.0	0.8	
	Background	13.47	12	Average (dBA)	1.4	4.4	12.4	16.6	19.7	21.0	20.6	24.0	25.3	27.4	26.1	27.7	28.4	28.4	29.1	29.8	30.8	30.7	31.1	31.6	32.6	32.4	31.7	30.0	28.9	42.5		
				Uncertainty A (dB)	0.9	1.0	2.2	1.6	2.4	1.6	0.9	0.8	0.6	0.9	0.7	0.6	0.6	0.5	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.0	0.8			
				Uncertainty B (dB)	1.0	1.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8		
				Combined Uncertainty (dB)	1.3	1.4	2.4	1.7	2.5	1.8	1.2	1.2	1.0	1.2	1.0	0.9	0.9	0.9	0.9	1.0	1.1	1.1	1.1	1.1	1.2	1.3	1.4	1.3	1.1			
14.0	Turbine ON	14.10	12	Average (dBA)	13.4	18.5	20.4	24.3	30.3	30.6	31.7	33.3	35.5	37.5	38.6	40.6	40.7	40.9	41.4	41.2	41.4	40.2	40.2	39.8	39.6	38.1	36.9	36.6	34.9	52.0		
				Uncertainty A (dB)	1.3	0.6	1.0	0.7	0.9	1.0	1.0	0.6	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.7	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.6			
				Uncertainty B (dB)	1.0	1.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8		
				Combined Uncertainty (dB)	1.6	1.2	1.2	1.1	1.2	1.3	1.3	1.0	1.0	1.0	0.9	0.9	0.8	0.8	0.8	0.8	1.0	0.9	0.9	0.9	1.0	1.1	1.1	1.2	1.0			
	Background	13.99	14	Average (dBA)	3.4	6.1	7.4	12.6	13.8	18.3	21.5	23.2	25.0	25.4	26.6	28.3	28.9	29.4	29.7	30.6	31.4	31.6	31.5	31.9	32.5	32.4	31.4	29.7	28.8	42.6		
				Uncertainty A (dB)	1.4	1.3	1.0	0.9	0.7	0.7	1.0	0.8	0.6	0.5	0.5	0.7	0.5	0.6	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.1	1.1	1.0	0.7			
				Uncertainty B (dB)	1.0	1.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8		
				Combined Uncertainty (dB)	1.7	1.6	1.2	1.2	1.1	1.1	1.3	1.1	1.0	1.0	0.9	1.0	0.9	0.9	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.3	1.4	1.3	1.1			

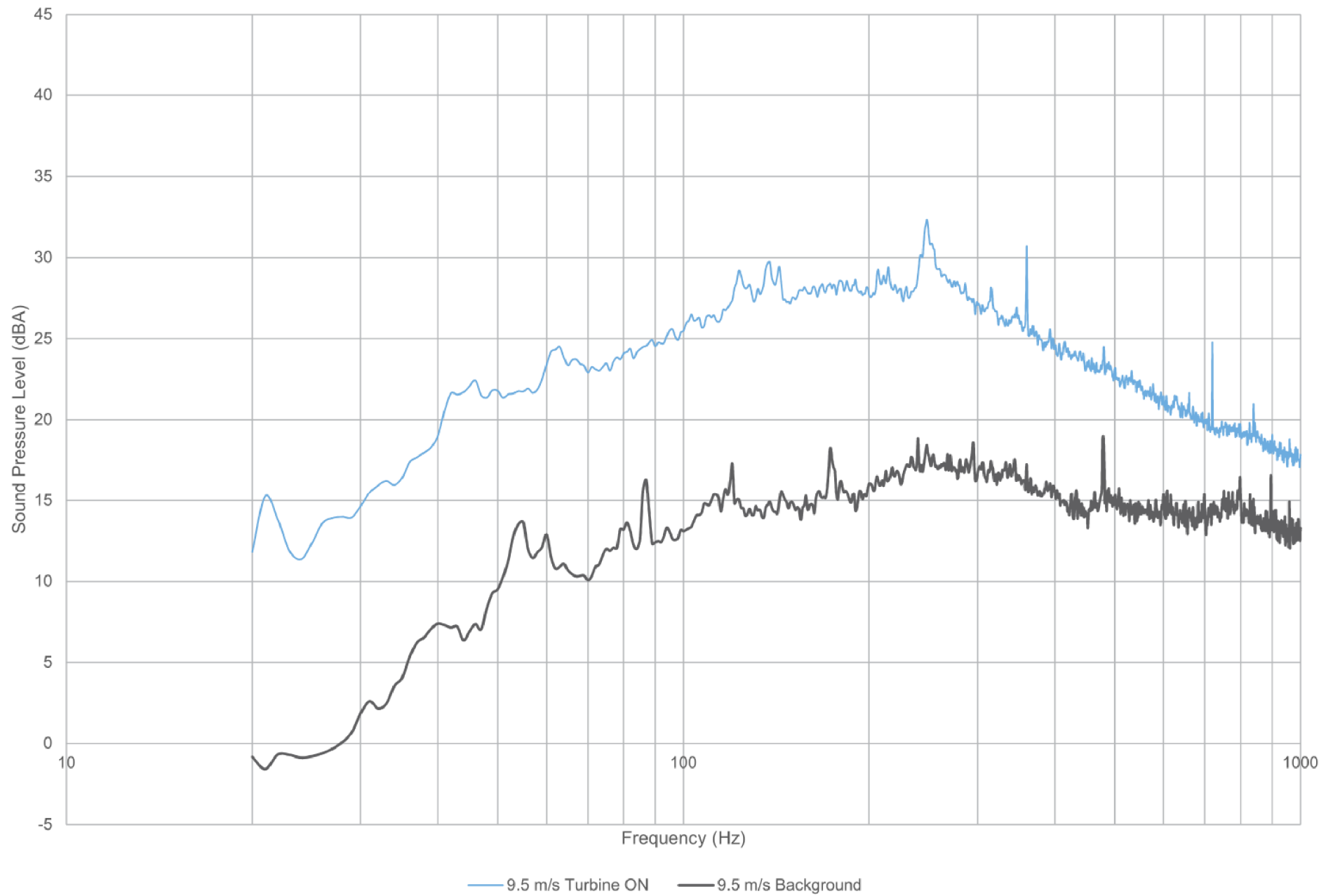
Appendix D Tonality Assessment



9.0 m/s



9.5 m/s



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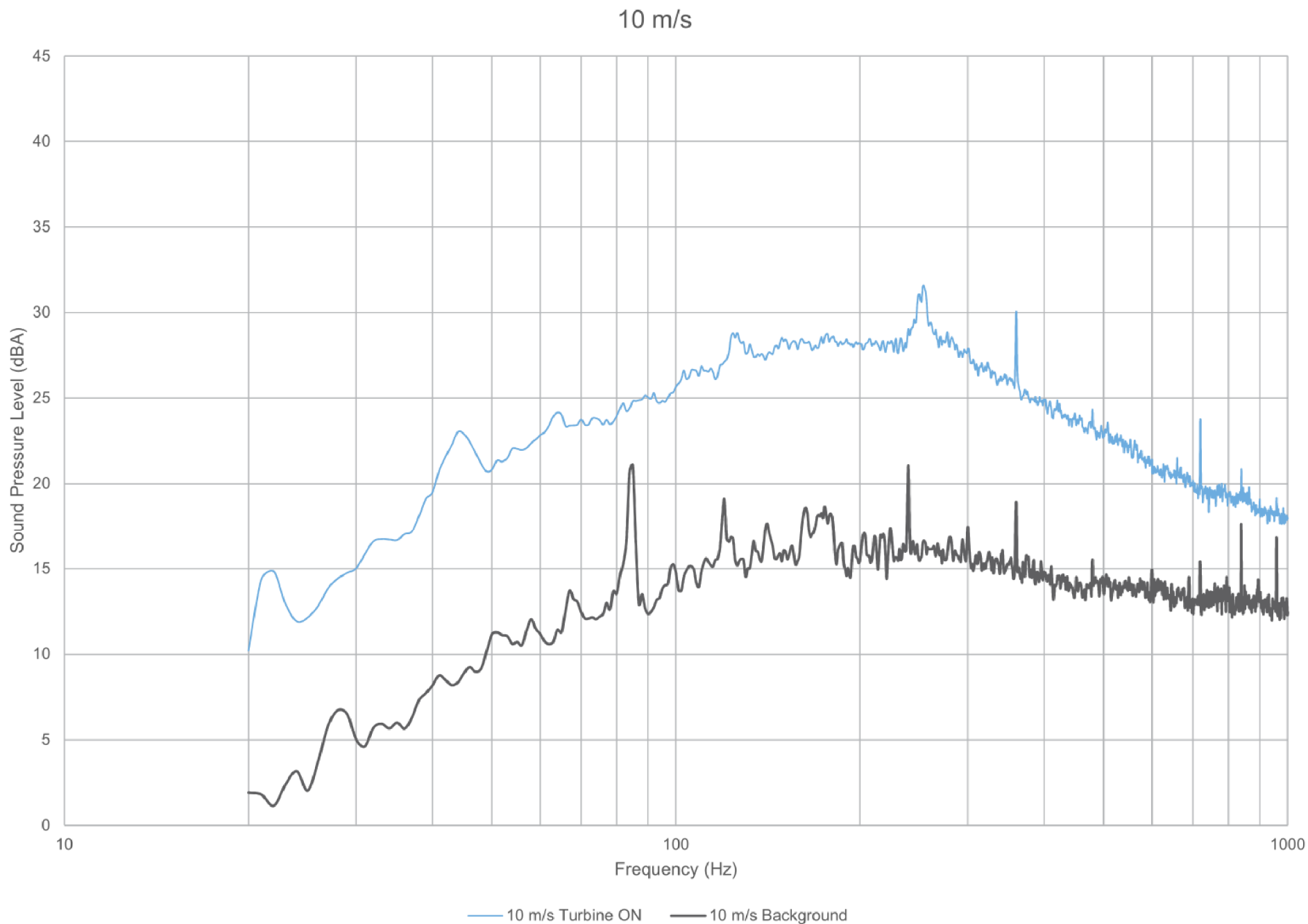
Project Name

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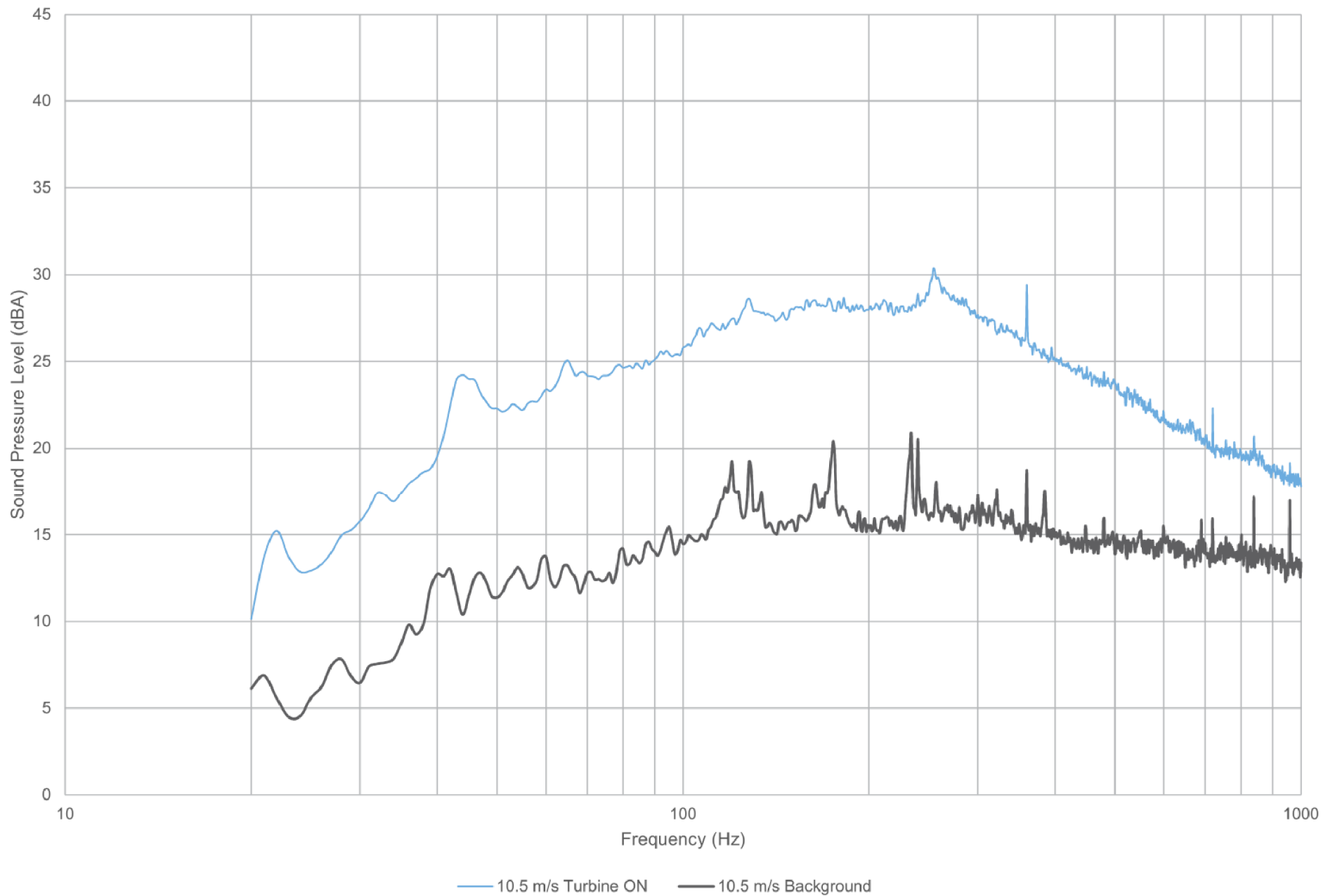
Figure Title

Plot of narrow band spectra - Turbine ON vs. Background at 9.5 m/s

Figure D.03



10.5 m/s



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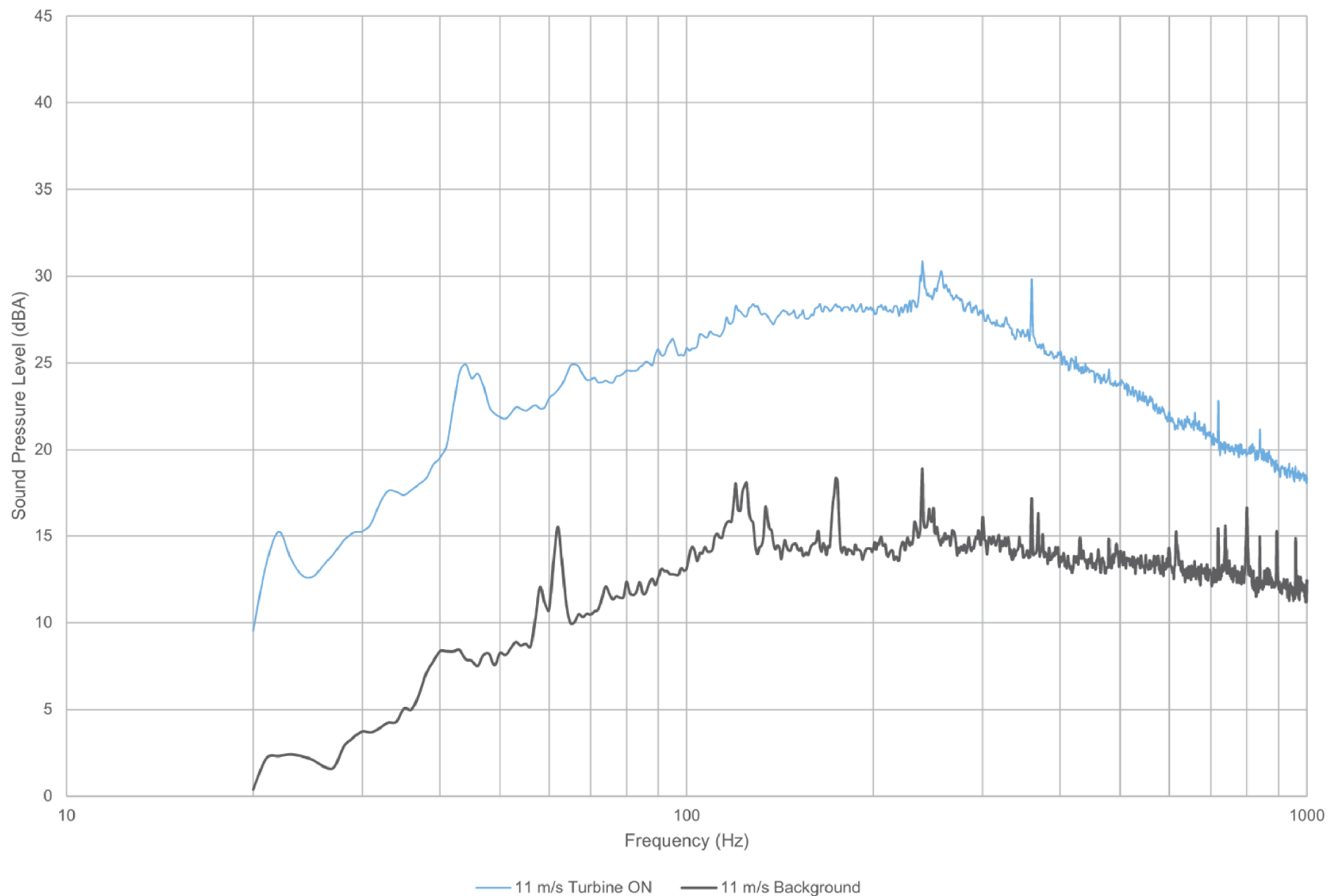
Niagara Region Wind Farm - IEC 61400-11 Edition 3.0 - Turbine T46

Figure Title

Plot of narrow band spectra - Turbine ON vs. Background at 10.5 m/s

Figure D.05

11 m/s



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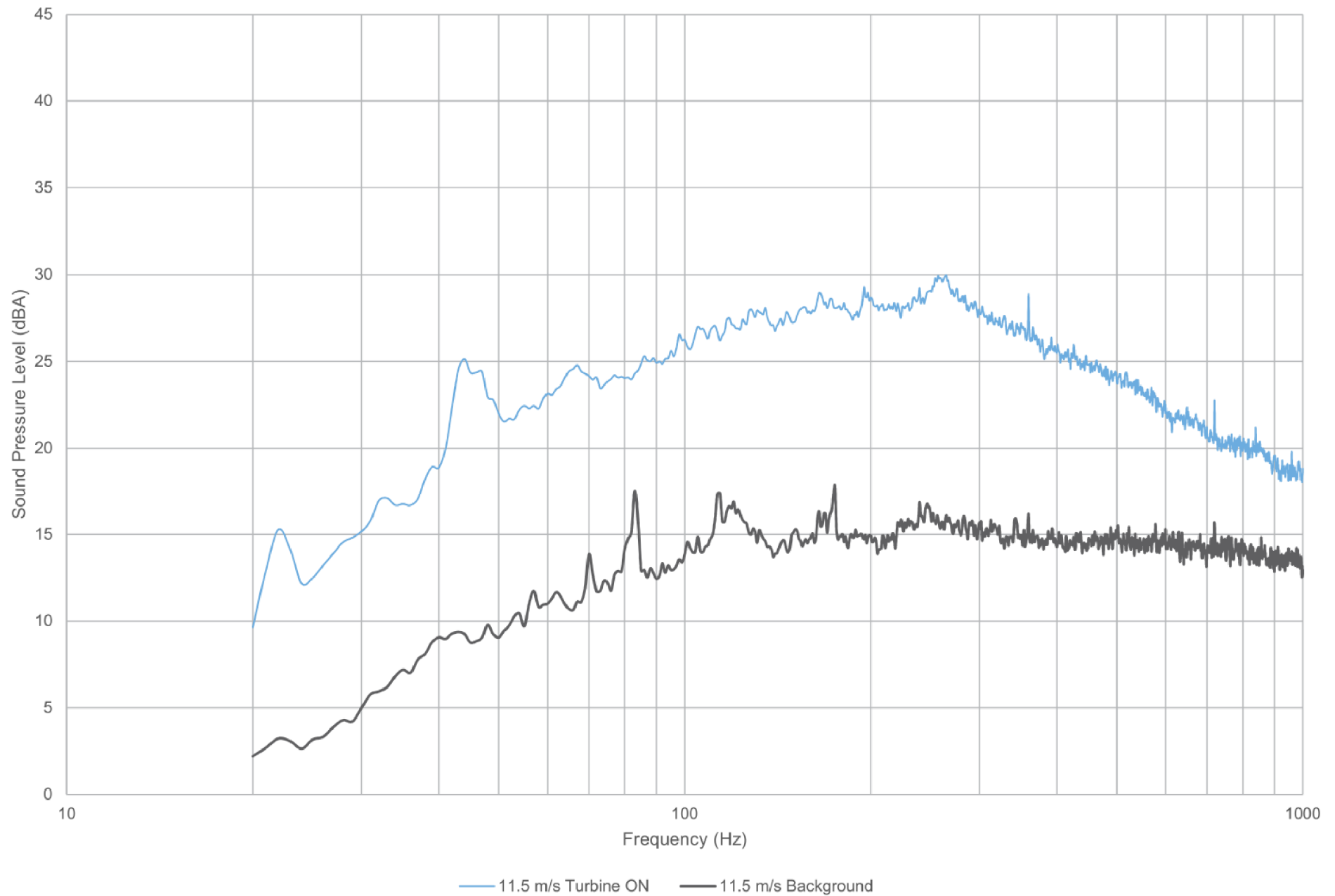
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Figure Title

Plot of narrow band spectra - Turbine ON vs. Background at 11 m/s

Figure D.06

11.5 m/s



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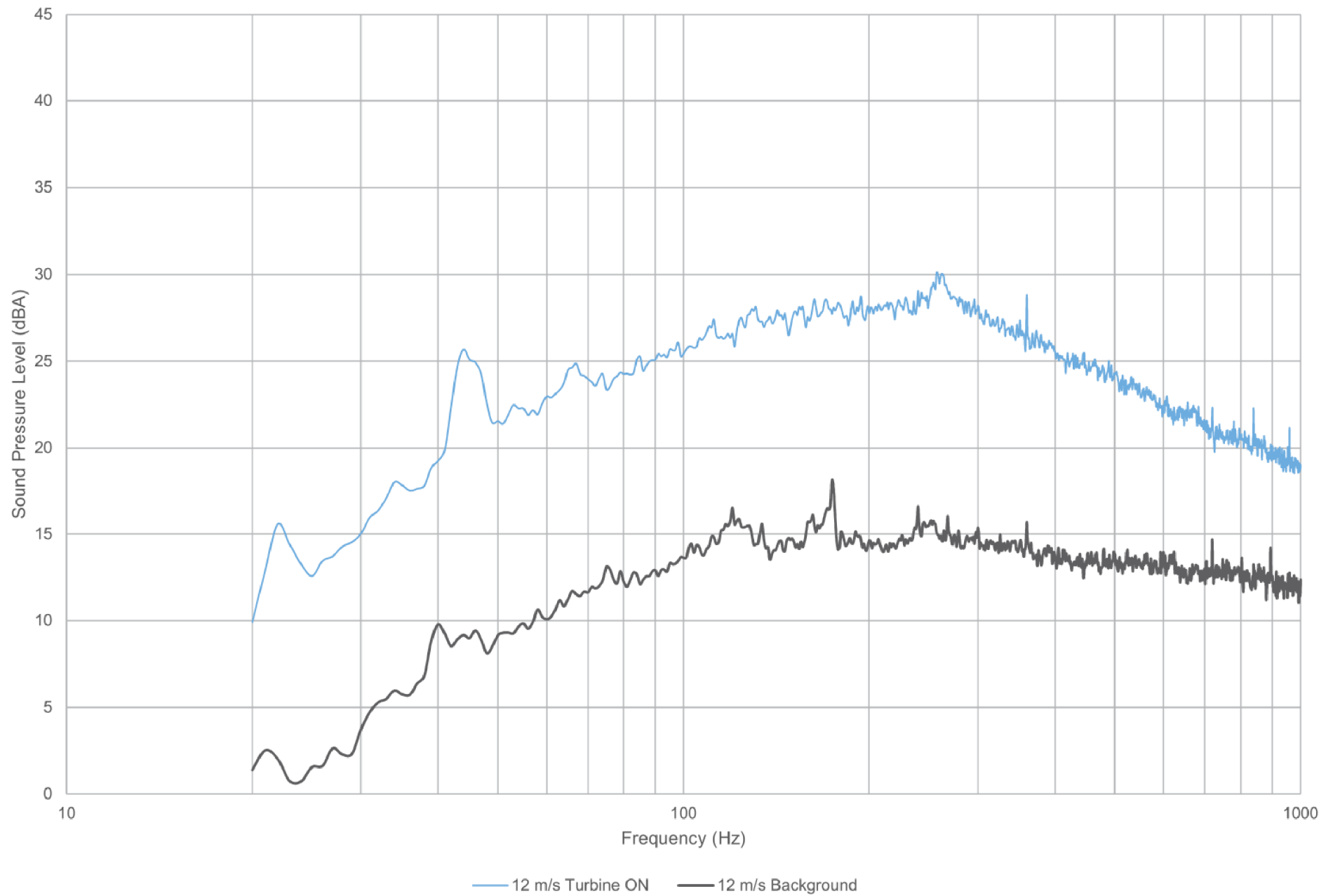
Niagara Region Wind Farm - IEC 61400-11 Edition 3.0 - Turbine T46

Figure Title

Plot of narrow band spectra - Turbine ON vs. Background at 11.5 m/s

Figure D.07

12 m/s



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Date: Nov 1, 2017
Revision: 1

Project Name

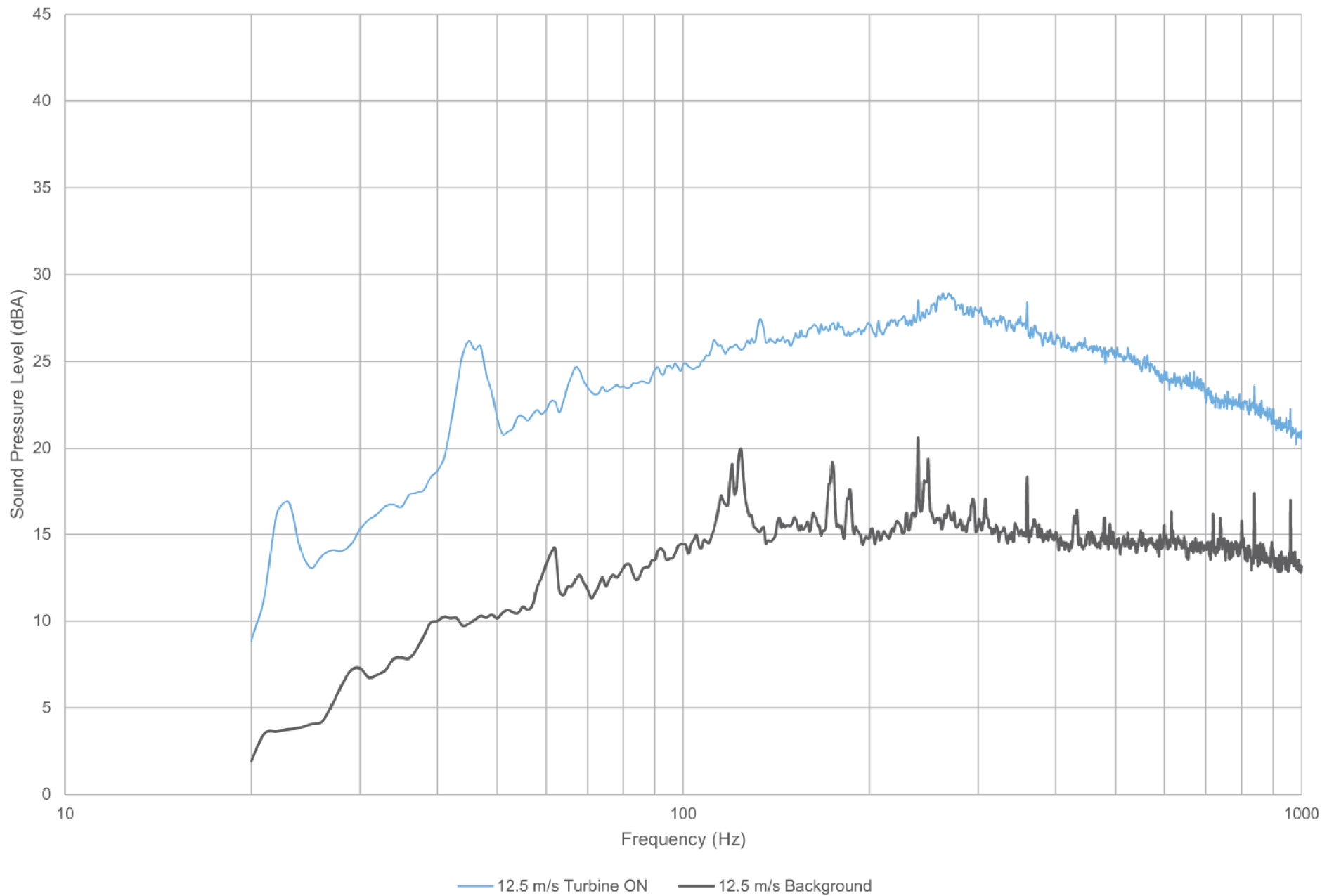
Niagara Region Wind Farm - IEC 61400-11 Edition 3.0 - Turbine T46

Figure Title

Plot of narrow band spectra - Turbine ON vs. Background at 12 m/s

Figure D.08

12.5 m/s



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Scale: NTS
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 Date: Nov 1, 2017
 Revision: 1

Project Name

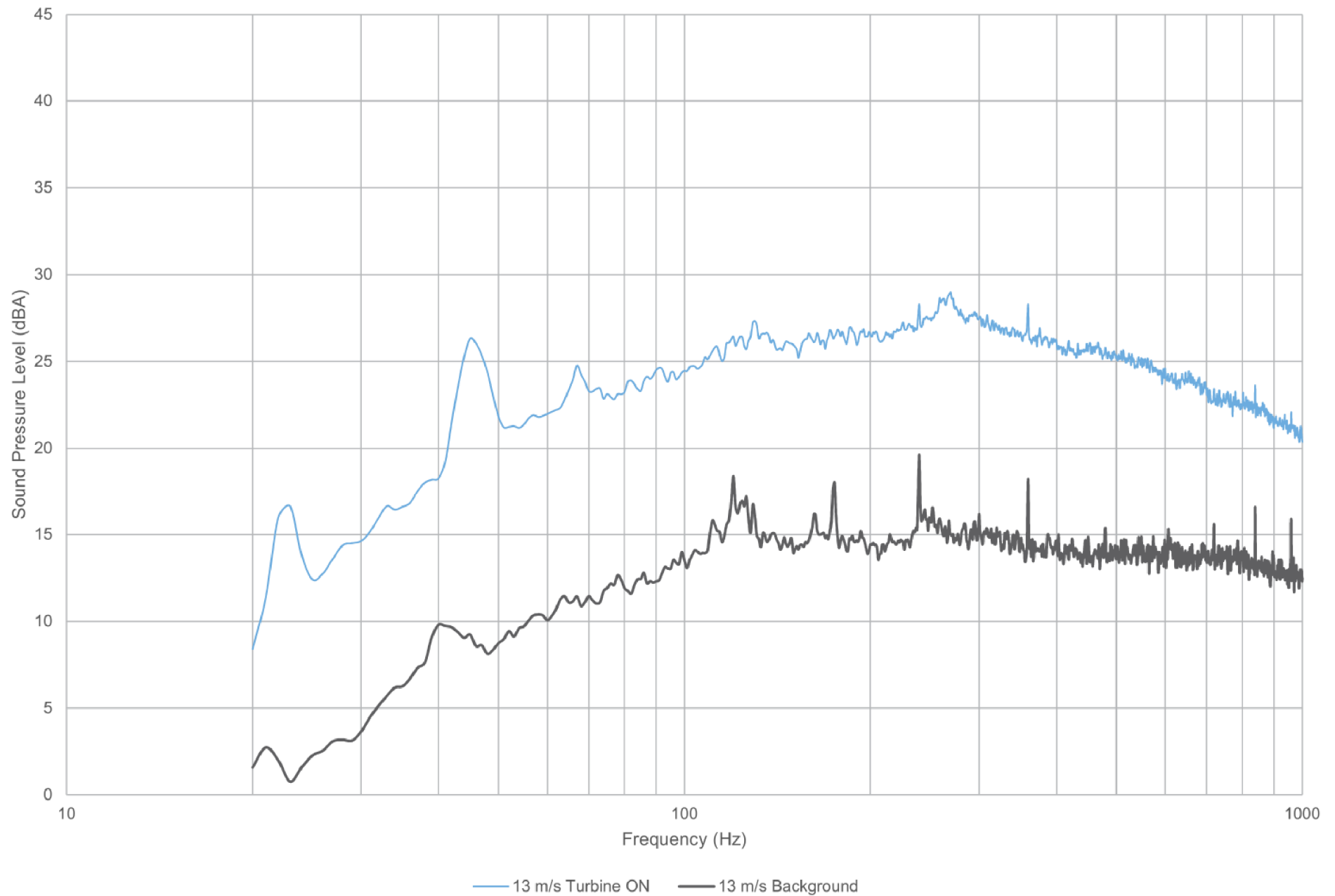
Niagara Region Wind Farm - IEC 61400-11 Edition 3.0 - Turbine T46

Figure Title

Plot of narrow band spectra - Turbine ON vs. Background at 12.5 m/s

Figure D.09

13 m/s



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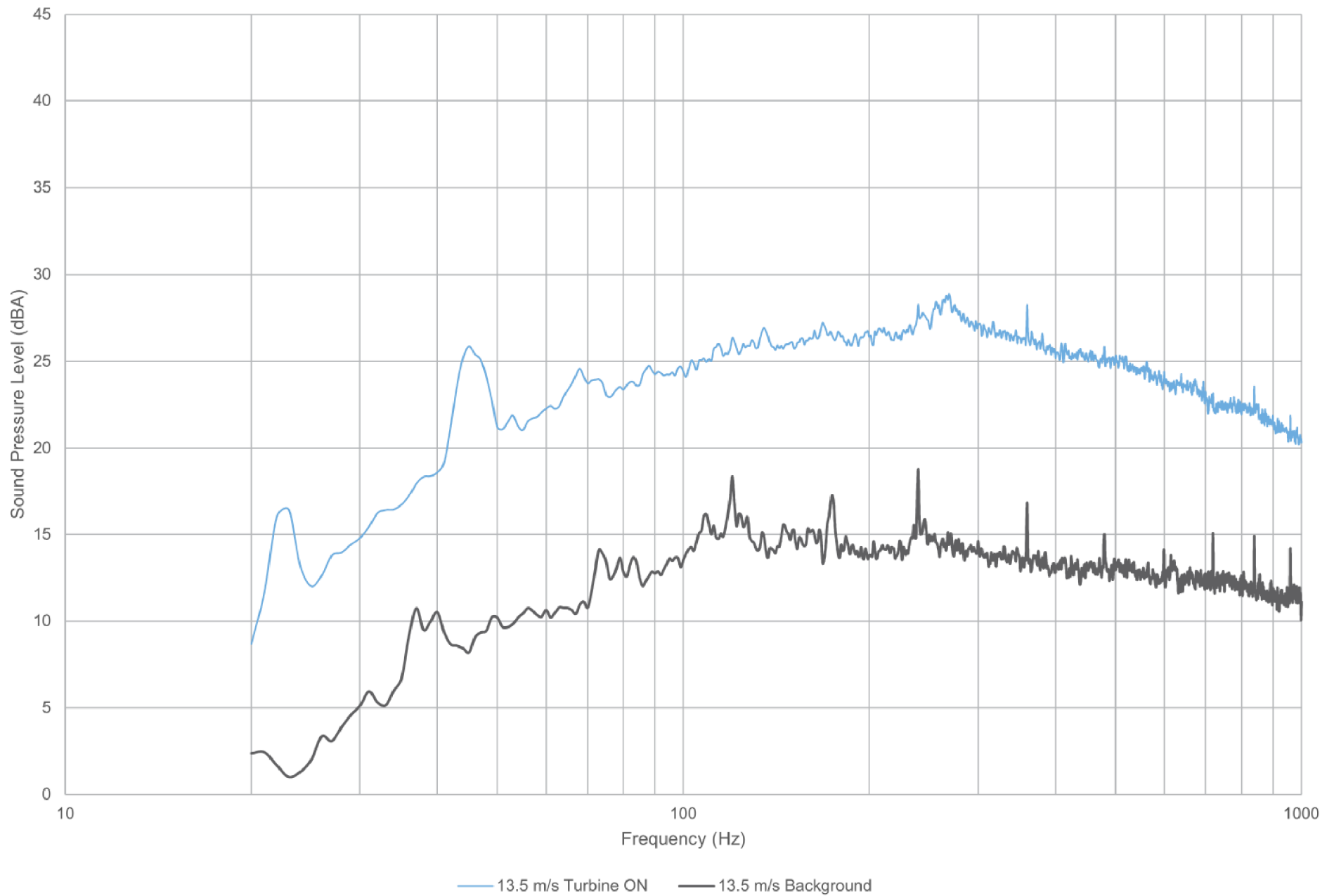
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Figure Title

Plot of narrow band spectra - Turbine ON vs. Background at 13 m/s

Figure D.10

13.5 m/s



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 Reviewed by: PA
 Date: Nov 1, 2017
 Revision: 1

Project Name

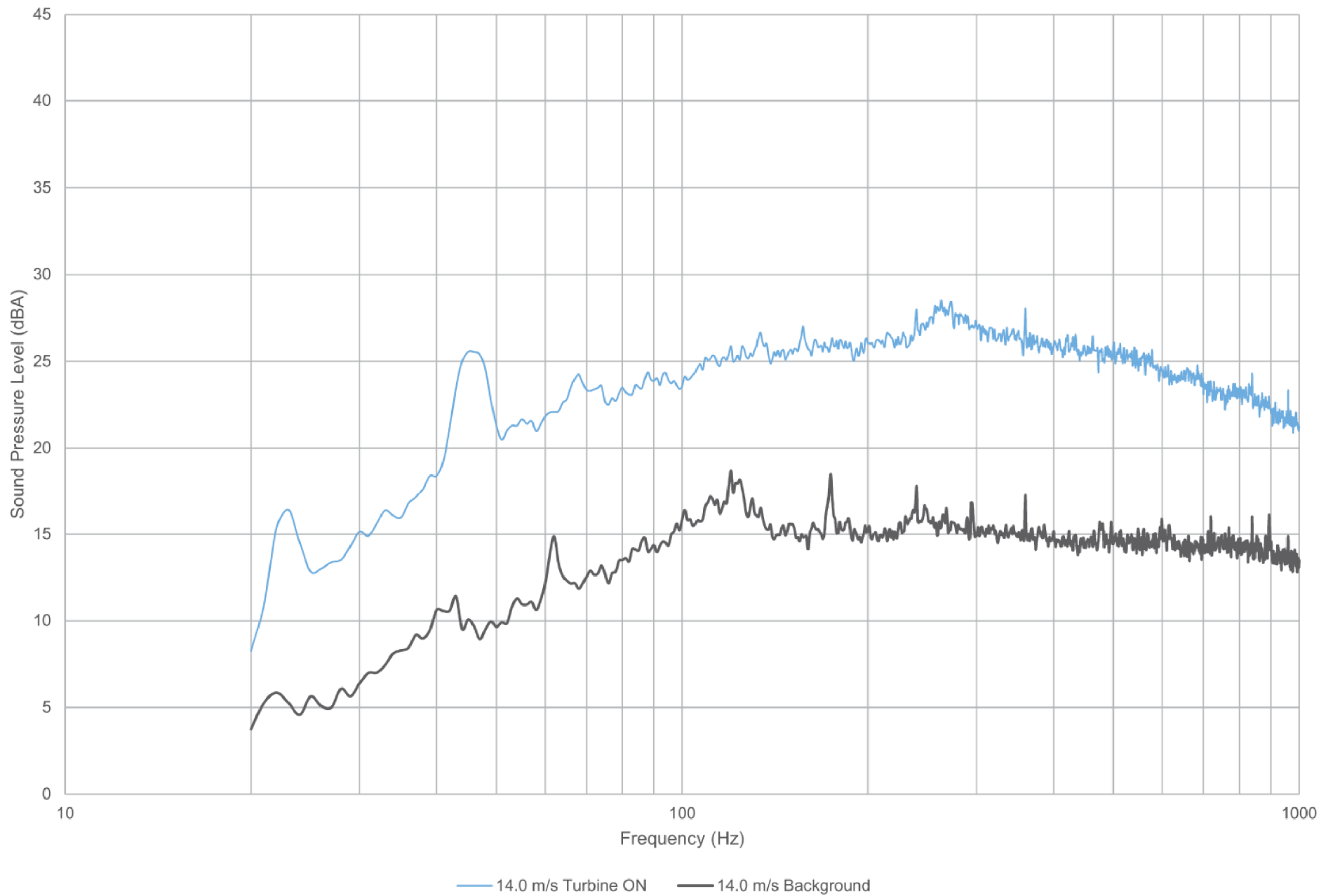
Niagara Region Wind Farm - IEC 61400-11 Edition 3.0 - Turbine T46

Figure Title

Plot of narrow band spectra - Turbine ON vs. Background at 13.5 m/s

Figure D.11

14 m/s



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Project Name

Niagara Region Wind Farm - IEC 61400-11 Edition 3.0 - Turbine T46

Figure Title

Plot of narrow band spectra - Turbine ON vs. Background at 14 m/s

Figure D.12

Table D.01 Tonality Assessment Table - 8.5 m/s

Project: Niagara Region Wind Farm- Turbine T46 - IEC 61400-11 Measurement

Report ID: 16227.00.T46.RP1

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Created on: 11/1/2017

Measurement #	Centre frequency (Hz)	Energy average of all masking lines (dB)	Background (dB)	Background adjusted criterion level (dB)	Masking level (dB)	Tone level (dB)	Determination of tonality (dB)	Frequency dependent audibility criterion (dB)	Tonal Audibility (dB)
No Reportable Tones									

Table D.02 Tonality Assessment Table - 9 m/s

Project: Niagara Region Wind Farm- Turbine T46 - IEC 61400-11 Measurement

Report ID: 16227.00.T46.RP1

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Created on: 11/1/2017

Measurement #	Centre frequency (Hz)	Energy average of all masking lines (dB)	Background (dB)	Background adjusted criterion level (dB)	Masking level (dB)	Tone level (dB)	Determination of tonality (dB)	Frequency dependent audibility criterion (dB)	Tonal Audibility (dB)
No Reportable Tones									

Table D.03 Tonality Assessment Table - 9.5 m/s

Project: Niagara Region Wind Farm- Turbine T46 - IEC 61400-11 Measurement

Report ID: 16227.00.T46.RP1

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Created on: 11/1/2017

Measurement #	Centre frequency (Hz)	Energy average of all masking lines (dB)	Background (dB)	Background adjusted criterion level (dB)	Masking level (dB)	Tone level (dB)	Determination of tonality (dB)	Frequency dependent audibility criterion (dB)	Tonal Audibility (dB)
No Reportable Tones									

Table D.04 Tonality Assessment Table - 10 m/s

Project: Niagara Region Wind Farm- Turbine T46 - IEC 61400-11 Measurement

Report ID: 16227.00.T46.RP1

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Created on: 11/1/2017

Measurement #	Centre frequency (Hz)	Energy average of all masking lines (dB)	Background (dB)	Background adjusted criterion level (dB)	Masking level (dB)	Tone level (dB)	Determination of tonality (dB)	Frequency dependent audibility criterion (dB)	Tonal Audibility (dB)
No Reportable Tones									

Table D.05 Tonality Assessment Table - 10.5 m/s

Project: Niagara Region Wind Farm- Turbine T46 - IEC 61400-11 Measurement

Report ID: 16227.00.T46.RP1

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Created on: 11/1/2017

Measurement #	Centre frequency (Hz)	Energy average of all masking lines (dB)	Background (dB)	Background adjusted criterion level (dB)	Masking level (dB)	Tone level (dB)	Determination of tonality (dB)	Frequency dependent audibility criterion (dB)	Tonal Audibility (dB)
No Reportable Tones									

Table D.06 Tonality Assessment Table - 11 m/s

Project: Niagara Region Wind Farm- Turbine T46 - IEC 61400-11 Measurement

Report ID: 16227.00.T46.RP1

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Created on: 11/1/2017

Measurement #	Centre frequency (Hz)	Energy average of all masking lines (dB)	Background (dB)	Background adjusted criterion level (dB)	Masking level (dB)	Tone level (dB)	Determination of tonality (dB)	Frequency dependent audibility criterion (dB)	Tonal Audibility (dB)
No Reportable Tones									

Table D.07 Tonality Assessment Table - 11.5 m/s

Project: Niagara Region Wind Farm- Turbine T46 - IEC 61400-11 Measurement

Report ID: 16227.00.T46.RP1

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Created on: 11/1/2017

Measurement #	Centre frequency (Hz)	Energy average of all masking lines (dB)	Background (dB)	Background adjusted criterion level (dB)	Masking level (dB)	Tone level (dB)	Determination of tonality (dB)	Frequency dependent audibility criterion (dB)	Tonal Audibility (dB)
No Reportable Tones									

Table D.08 Tonality Assessment Table - 12 m/s

Project: Niagara Region Wind Farm- Turbine T46 - IEC 61400-11 Measurement

Report ID: 16227.00.T46.RP1

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Created on: 11/1/2017

Measurement #	Centre frequency (Hz)	Energy average of all masking lines (dB)	Background (dB)	Background adjusted criterion level (dB)	Masking level (dB)	Tone level (dB)	Determination of tonality (dB)	Frequency dependent audibility criterion (dB)	Tonal Audibility (dB)
No Reportable Tones									

Table D.09 Tonality Assessment Table - 12.5 m/s

Project: Niagara Region Wind Farm- Turbine T46 - IEC 61400-11 Measurement

Report ID: 16227.00.T46.RP1

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Created on: 11/1/2017

Measurement #	Centre frequency (Hz)	Energy average of all masking lines (dB)	Background (dB)	Background adjusted criterion level (dB)	Masking level (dB)	Tone level (dB)	Determination of tonality (dB)	Frequency dependent audibility criterion (dB)	Tonal Audibility (dB)
No Reportable Tones									

Table D.10 Tonality Assessment Table - 13 m/s

Project: Niagara Region Wind Farm- Turbine T46 - IEC 61400-11 Measurement

Report ID: 16227.00.T46.RP1

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Created on: 11/1/2017

Measurement #	Centre frequency (Hz)	Energy average of all masking lines (dB)	Background (dB)	Background adjusted criterion level (dB)	Masking level (dB)	Tone level (dB)	Determination of tonality (dB)	Frequency dependent audibility criterion (dB)	Tonal Audibility (dB)
No Reportable Tones									

Table D.11 Tonality Assessment Table - 13.5 m/s

Project: Niagara Region Wind Farm- Turbine T46 - IEC 61400-11 Measurement

Report ID: 16227.00.T46.RP1

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Created on: 11/1/2017

Measurement #	Centre frequency (Hz)	Energy average of all masking lines (dB)	Background (dB)	Background adjusted criterion level (dB)	Masking level (dB)	Tone level (dB)	Determination of tonality (dB)	Frequency dependent audibility criterion (dB)	Tonal Audibility (dB)
No Reportable Tones									

Table D.12 Tonality Assessment Table - 14 m/s

Project: Niagara Region Wind Farm- Turbine T46 - IEC 61400-11 Measurement

Report ID: 16227.00.T46.RP1

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Created on: 11/1/2017

Measurement #	Centre frequency (Hz)	Energy average of all masking lines (dB)	Background (dB)	Background adjusted criterion level (dB)	Masking level (dB)	Tone level (dB)	Determination of tonality (dB)	Frequency dependent audibility criterion (dB)	Tonal Audibility (dB)
No Reportable Tones									

Appendix E Measurement Data

End of Report
