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ASSESSMENT REPORT - **Project: 16227.02**

Niagara Region Wind Farm
1st Transformer Acoustic Audit

REA Number 4353-9HMP2R
36 Rue Lajeunesse,
Kingsey Falls, Quebec, J0A 1B0

Prepared for:

1021702 B.C. Ltd
as general partner for and on behalf of FWRN LP

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Revision History

Version	Description	Author	Reviewed	Date
-	Initial Report	KC	AM	February 18, 2020
R1	First Revision to correct minor typo	AM	PA	February 11, 2020
R2	Second revision to include responses to MECP comments in as well as additional supporting documentation	KC	AM	March 19, 2020

Table of Contents

1 Introduction

Aercoustics Engineering Limited ("Aercoustics") has been retained by 1021702 B.C. Ltd as general partner for and on behalf of FWRN LP ("Boralex") to complete a post construction audit of the Niagara Region Wind Farm ("NRWF") transformer substation. NRWF operates under Renewable Energy Approval ("REA") #4353-9HMP2R, issued on November 6, 2014 [1] and further modified on November 23, 2015, May 6, 2016 and May 12, 2016.

The testing outlined in this report was conducted as per the latest version of the IEEE 57.12.90-2015 standard while the transformer was under a load representing more than 85% of the maximum turbine load. This report summarizes the results of the acoustic test on transformer ST1 conducted on October 17, 2019 as per IEEE 57.12.90-2015 standard.

2 Measurement Instrumentation

The following acoustic measurement equipment was utilized for the acoustic audit, equipment was field calibrated before site measurements:

<u>Near-field Intensity Measurements</u>

- Sound Level Meter: Larson Davis 2900 Integrating Sound Level Meter, SN 1054, Calibrated January 18, 2019;
- Microphones: G.R.A.S. Type 40 GK, SN 112784 and 104771, Calibrated February 11, 2018;
- Preamps: G.R.A.S. 26 CB, SN 104361 and 112774, Calibrated February 11, 2018

Calibration certificates are provided in Appendix A. Please note that the G.R.A.S. pre-amps are calibrated as a pair with the associated microphones; the calibration certificates for the G.R.A.S. microphones, included in Appendix A, are valid for both the microphones as well as the preamps.

3 Site Details

Aercoustics personnel completed a site visit on October 17, 2019 and observed transformer ST1 located in the substation yard located south of Canborough Road and west of Wellandport Road in the town of Wellandport, Ontario. A layout of the substation ST1 is included in Figure 1.

During the measurement period on October 17, 2019 the temperature was around 8°C with windy conditions with wind speeds of approximately 25-30 km/hr from the west. The IEEE 57.12.90-2015 requires testing under load conditions which necessitates the need for measurements to be conducted during windy conditions when the turbines would be operating and providing load to the transformer.

It should be noted that there was negligible wind interference at the measurement locations due to shielding provided by the surrounding acoustic barriers. Built according to REA number 4353-9HMP2R, 5-meter tall barriers surround transformer ST1 on all four sides.

4 Transformer Operation

The specifications of transformer ST1 are summarized in Table 1.

Table 1 Transformer Parameters

Parameter	Transformer ST1
Capacity	90/120/150 MVA
Rated Voltage	115 kV
Phase	3 Phase
Frequency	60 Hz
Manufacturer	Pennsylvania Transformer Tech. Inc.

During the testing period, the transformer ST1 was operating at rated voltage. Since the wind turbine farm was operational during the acoustic test, the load was noted as approximately 120MW for transformer ST1. With a maximum rated turbine load of 134.2 MW, the load present on the transformer during testing was greater than 85% of the maximum turbine load on the transformer. The threshold of 85% of maximum rated load has been agreed to by the MECP to represent the loaded condition prescribed in IEEE 57.12.90-2015 for acoustic measurements [2].

As per IEEE 57.12.90-2015 measurements were done in two conditions: with the external cooling fans operating (ONAF) and non-operational (ONAN). The transformer noise measured consisted of cooling fan noise and generator core hum. A four (4) sided 5.3m high acoustic barrier was in place (surrounding the transformer on all sides) during the measurement. It should be noted that the barrier height exceeds the height specified in the REA, for more detail please refer to the letter in Appendix B.

5 Near Field Measurements

5.1 Measurement Procedure

Sound level measurements were taken between 9:26 AM and 10:33 AM on October 17, 2019. Sound intensity levels were measured in accordance with ISO 9614-1 [3]. Sound power level was determined from the measured sound intensity in accordance with IEEE C57.12.90-2015 [2].

Measurement points were taken at intervals 1 m apart, 0.3 m from the surface of the transformer casing or 1 m near cooling fans, at 1/3rd and 2/3rd total height of the transformer, as stipulated by IEEE C57.12.90-2015. The sound power levels were then calculated in accordance with the procedures set out in IEEE C57.12.90-2015.

A summary of the measurement parameters is provided in Table 2. The transformer sits on a 0.3 m high concrete curb, the height of which has been considered accordingly. See Figure 2 for a picture of the installed transformer ST1. See Figure 3 for the plan view of transformer ST1, including source and measurement locations for ONAN and ONAF.

Table 2 Measurement Details

Parameter	Transformer ST1
Measurement Distance	0.3 m from non-fan surface, 1 m from cooling fans
Horizontal Spacing Between Measurement Locations	1 m
Height of Transformer (H)	4.6 m
Height of Microphone 1 above ground	1.8 m (0.3 m + 1/3H)
Height of Microphone 2 above ground	2.0 m (0.3 m + 2/3H)

5.2 Measurement Results

5.2.1 Sound Intensity Level Measurements

The average sound intensity measured for transformer ST1 for ONAN and ONAF operations was 66 dBA (Leq) and 75 dBA (Leq) respectively. Spectral data is summarized in Table 3, while overall data from each measurement location around the transformer is provided in Table 4 and Table 5.

Table 3 Measured Transformer Averaged Spectrum

	Octave Band Centre Frequency (Hz)									
	31.5	63	125	250	500	1000	2000	4000	8000	Total (dBA)
ONAN Transformer ST1 Sound Intensity Level (dB)	64	57	77	62	62	63	36	30	27	66
ONAF Transformer ST1 Sound Intensity Level (dB)	72	79	79	76	72	72	65	51	43	75

Table 4 Measured Sound Intensity Levels - ONAN

SiL (dBA), as per IEEE 57.12.90-2015/ ISO 9614-1		
	Transformer ST1	
Position*	**1/3 Height**	**2/3 Height**
1	68	65
2	63	67
3	61	62
4	66	66
5	64	68
6	62	65
7	59	65
8	61	63
9	63	61
10	66	64
11	66	68
12	63	67
13	65	64
14	61	64
15	62	61
16	65	63
17	69	64
18	67	68
19	66	61
20	62	60
21	65	60
22	66	60
23	65	69
24	65	64
25	65	66
26	67	63
27	63	70
28	70	67
29	65	68
30	67	70
31	67	70
32	70	72
TOTAL	**Total Energy Average SiL: 66 dBA**	

*Measurement locations are shown in Figure 3

Table 5 Measured Sound Intensity Levels - ONAF

SiL (dBA), as per IEEE 57.12.90-2015/ ISO 9614-1		
Transformer ST1		
Position*	**1/3 Height**	**2/3 Height**
1	70	71
2	70	69
3	70	69
4	76	75
5	80	78
6	79	78
7	77	78
8	76	75
9	78	75
10	80	75
11	79	76
12	76	76
13	75	74
14	76	75
15	78	75
16	78	77
17	77	77
18	75	76
19	74	75
20	72	74
21	71	71
22	75	71
23	76	72
24	76	74
25	74	72
26	74	72
27	74	69
28	69	71
29	68	70
30	72	68
31	72	71
32	73	72
TOTAL	**Total Energy Average SiL: 75 dBA**	

*Measurement locations are shown in Figure 3

5.2.2 Evaluation of Sound Power Level - ONAN

Based on the evaluation procedures outlined in IEEE C57.12.90:2015, the transformer ST1 had a sound power level of 90 dBA for ONAN. The parameters used to determine the overall sound power level are provided in Table 6. The calculated sound power spectra for ONAN are included in Table 7.

The primary noise source was the core hum of the transformer. Based on Aercoustics observations of the site and the subjective tonality assessment at the source measurement location, a 5dB tonal penalty has been applied to the transformer core calculated sound power level.

It is noted that the ONAF measurement locations indicated in Figure 3 were used for the ONAN measurements as well. The measurement surface *S* corresponding to these locations has been used in the determination of both the ONAF and ONAN sound power levels. The ONAF measurement locations, when used in the determination of sound power, are understood to be fully representative of the ONAN sound levels.

Table 6 Sound Power Calculations - ONAN

Parameter	Transformer ST1
Perimeter Area of Enclosing Measurement Surface	155 m^2
Top Area	61 m^2
Total Measurement Surface Area	216 m^2
Average Sound Intensity Level	66 dBA

Table 7 Calculated Transformer Sound Power Spectra - ONAN

	Octave Band Centre Frequency (Hz)									
	31.5	63	125	250	500	1000	2000	4000	8000	Total (dBA)
Transformer Core	88	80	101	85	85	87	59	53	50	90
Transformer Core Only [with +5 dB Penalty]	93	85	106	90	90	92	64	58	55	95

5.2.3 Evaluation of Sound Power Level - ONAF

Based on the evaluation procedures outlined in IEEE C57.12.90, the transformer ST1 had a sound power level of 100 dBA for ONAF. The parameters used to determine the overall sound power level are provided in Table 8. The calculated sound power spectra are included in Table 9.

For transformer ST1 the cooling fan noise is dominant and drives the overall sound power level of the transformer. As the tonal penalty is applicable to the tonal nature of the transformer core only (the cooling fan noise is broadband), the tonal penalty has been applied only to the transformer core noise and not to the overall sound power levels with the cooling fans running.

Table 8 Sound Power Calculations - ONAF

Parameter	Transformer ST1
Perimeter Area of Enclosing Measurement Surface	155 m^2
Top Area	61 m^2
Total Measurement Surface Area	216 m^2
Average Sound Intensity Level	75 dBA

Table 9 Calculated Transformer Sound Power Spectra - ONAF

	Octave Band Centre Frequency (Hz)									
	31.5	63	125	250	500	1000	2000	4000	8000	Total (dBA)
Transformer Core Only	88	80	101	85	85	87	59	53	50	90
Transformer Core Only [with +5 dB Penalty]	93	85	106	90	90	92	64	58	55	95
Transformer Fans Only [with Transformer Core Subtracted]	95	103	97	100	95	95	89	74	66	98
Transformer Substation* [Transformer Core + Cooling Fans]	97	103	106	100	96	96	89	75	67	100

*Sound Power Levels include the +5dB tonal adjustment applied to the transformer core

6 Assessment of Compliance

The following table compares the facility's Renewable Energy Approval (REA) defined sound power limits for the transformers with the measured values for transformer ST1.

Table 10 Assessment of Compliance – Transformer Sound Power Level

Parameter	Sound Power Level (dBA)
PWL: Transformer Substation* (ONAF) [Transformer Core + Cooling Fans]	100
PWL: used in REA permitted acoustic model	**103.2**

* Sound Power Level (PWL) includes +5db tonal adjustment for transformer core tonal hum

The acoustic emission testing indicates that the overall sound power level of the transformer substation ST1 satisfies the specified sound power level used in the REA permitted acoustic model.

7 Conclusion

Based on the acoustic audit conducted on October 17, 2019, the acoustic impact of the Niagara Region Wind Farm Transformer substation ST1, REA#4353-9HMP2R is in compliance with the sound level limits specified in MECP's NPC-232.

8 References

1. V. Schroter, "Renewable Energy Approval # 4353-9HMP2R", Ontario Ministry of the Environment, Toronto, ON, November 6, 2014.

2. IEEE Standard C57.12.90-2015, Test Code for Liquid Immersed Distribution Power and Regulating Transformers

3. ISO Standard 9614-1:1993, Acoustics -- Determination of sound power levels of noise sources using sound intensity -- Part 1: Measurement at discrete points

Appendix A
Instrument Calibration Certificates

West Caldwell Calibration Laboratories Inc.

Certificate of Calibration

for

REALTIME FREQUENCY ANALYZER SLM

Manufactured by:	LARSON DAVIS
Model No:	2900B
Serial No:	1045
Calibration Recall No:	29349

Submitted By:

Customer:

Company: Aercoustics Engineering LTD.
Address:

The subject instrument was calibrated to the indicated specification using standards traceable to the National Institute of Standards and Technology or to accepted values of natural physical constants. This document certifies that the instrument met the following specification upon its return to the submitter.

West Caldwell Calibration Laboratories Procedure No. 2900B LARS

Upon receipt for Calibration, the instrument was found to be:

Outside (X)

tolerance of the indicated specification. See attached Report of Calibration.
The information supplied relates to the calibrated item listed above.
West Caldwell Calibration Laboratories' calibration control system meets the requirements, ISO 10012-1 MIL-STD-45662A, ANSI/NCSL Z540-1, IEC Guide 25, ISO 9001:2008 and ISO 17025.

Note: With this Certificate, Report of Calibration is included.

Approved by:

James Zhu
Quality Manager
ISO/IEC 17025:2005

Calibration Date: 18-Jan-19

Certificate No: 29349 -1

QA Doc. #1051 Rev. 2.0 10/1/01

West Caldwell Calibration Laboratories, Inc.
uncompromised calibration
1575 State Route 96, Victor, NY 14564, U.S.A.

ACCREDITED
Calibration Lab. Cert. # 1533.01

West Caldwell
Calibration
Laboratories, Inc.
uncompromised calibration
1575 State Route 96, Victor NY 14564

ISO/IEC 17025: 2005
ACCREDITED
Calibration Lab. Cert. # 1533.01

REPORT OF CALIBRATION

for

Larson Davis Real Time Analyzer

Model No.: 2900B | **Serial No.:** 1045
Company: Aercoustics Engineering LTD. | **I. D. No.:** XXXX

Calibration results:

Before data: .... **After data:** ...X......

Before & after data same: ....

All tested parameters: Pass

For details see "Calibration Data Record"

Laboratory Environment:		
Ambient Temperature:	20.2	°C
Ambient Humidity:	29.6	% RH
Ambient Pressure:	99.225	kPa
Calibration Date:	18-Jan-2019	
Calibration Due:	18-Jan-2020	
Report Number:	29349 -1	
Control Number:	29349	

The above listed instrument meets or exceeds the tested manufacturer's specifications.
This Calibration is traceable through NIST test numbers listed below.
The absolute uncertainty of calibration: See last page. Unless otherwise noted, the reported values are both "as found" and "as left" data.

The above listed instrument was checked using calibration procedure documented in West Caldwell Calibration Laboratories Inc. procedure : Rev. 7.0 Jan. 24, 2014 Doc. # 1038 2900BLD
Calibration was performed by West Caldwell Calibration Laboratories Inc. under Operating Procedures intended to implement the requirements of ISO10012-1, IEC Guide 25, ANSI/NCSL Z540-1, (MIL-STD-45662A) and ISO 9001:2015, ISO 17025

NIST Traceable Instruments:			Date of Cal.	Traceability No.	Re-cal. Due Date
HP	34401A	S/N US361025	19-Jul-2018	,1010733	19-Jul-2019
HP	33120A	S/N SG400116	19-Jul-2018	,1010733	19-Jul-2019
Brüel & Kjær	4231	S/N 2205492	16-Jul-2018	683/290345-18	16-Jul-2019

Cal. Date: 18-Jan-2019

Measurements performed by: ...MS...

Calibrated on WCCL system type 9700

Matthew Smith

Rev. 7.0 Jan. 24, 2014 Doc. # 1038 2900BLD

West Caldwell Calibration Laboratories Inc.

1575 State Route 96, Victor NY 14564
Tel. (585) 586-3900 FAX (585) 586-4327

Calibration Data Record

for

Manufacturer: Larson Davis

Real Time Analyzer — Model No.: 2900B — S/N: 1045

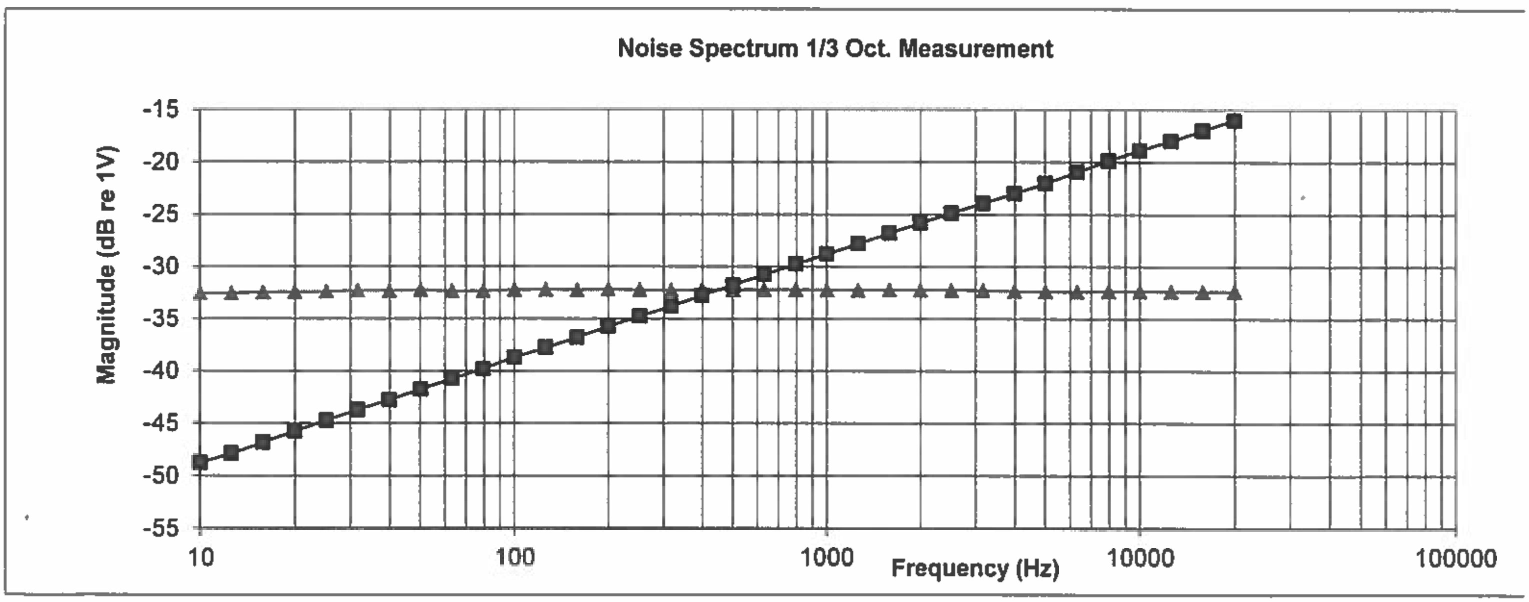
Preamp Model No.: PRM900B — S/N: 3887

Submitted by, — Company: Aercoustics Engineering LTD.

Test	Function		Tolerance Min	Tolerance Max		Measured values Before	Out	After	Out
,1.	Attenuator accuracy	FSD			READING				
	Ch.1	150dB	127.5	128.5	128	128.0		128.0	
		140dB	127.5	128.5	128	128.0		128.0	
		130dB	127.5	128.5	128	128.0		128.0	
		120dB	117.5	118.5	118	118.0		118.0	
		110dB	107.5	108.5	108	108.0		108.0	
		100dB	97.5	98.5	98	98.0		98.0	
		90dB	87.5	88.5	88	88.0		88.0	
		80dB	77.5	78.5	78	78.0		78.0	
		70dB	67.5	68.5	68	68.0		68.0	
		60dB	57.5	58.5	58	58.0		58.0	
		50dB	47.5	48.5	48	48.0		48.0	
		40dB	37.5	38.5	38	38.0		38.0	
		FSD			READING				
	Ch. 2	150dB	127.5	128.5	128	128.0		128.0	
		140dB	127.5	128.5	128	128.0		128.0	
		130dB	127.5	128.5	128	128.0		128.0	
		120dB	117.5	118.5	118	118.0		118.0	
		110dB	107.5	108.5	108	108.0		108.0	
		100dB	97.5	98.5	98	98.0		98.0	
		90dB	87.5	88.5	88	88.0		88.0	
		80dB	77.5	78.5	78	78.0		78.0	
		70dB	67.5	68.5	68	68.0		68.0	
		60dB	57.5	58.5	58	58.0		58.0	
		50dB	47.5	48.5	48	48.0		48.0	
		40dB	37.5	38.5	38	38.0		38.0	

Test	Function	Tolerance Min	Tolerance Max		Measured values Before	Out	Measured values After	Out
,2a	Frequency Response SLM Mode Ch. 1							
	A Weighting	0.0	90.4	16kHz	87.3		87.3	
		89.9	94.4	8kHz	92.8		92.8	
		94.0	96.0	4kHz	95.0		95.0	
		94.2	96.2	2kHz	95.2		95.2	
	Ref	93.0	95.0	1kHz	94.0		94.0	
		89.8	91.8	500Hz	90.8		90.8	
		84.4	86.4	250Hz	85.4		85.4	
		76.9	78.9	125Hz	77.9		77.9	
		66.8	68.8	63Hz	67.8		67.8	
		53.1	56.1	31.5Hz	54.5		54.5	
	C weighting	0.0	88.5	16kHz	85.4		85.4	
		88.0	92.5	8kHz	91.0		91.0	
		92.2	94.2	4kHz	93.2		93.2	
		92.8	94.8	2kHz	93.9		93.9	
	Ref	93.0	95.0	1kHz	94.0		94.0	
		93.0	95.0	500Hz	94.0		94.0	
		93.0	95.0	250Hz	94.0		94.0	
		92.8	94.8	125Hz	93.9		93.9	
		92.2	94.2	63Hz	93.3		93.3	
		89.5	92.5	31.5Hz	91.1		91.1	
,2b	Frequency Response SLM Mode Ch. 2							
	A Weighting	0.0	90.4	16kHz	87.2		87.2	
		89.9	94.4	8kHz	92.9		92.9	
		94.0	96.0	4kHz	94.9		94.9	
		94.2	96.2	2kHz	95.2		95.2	
	Ref	93.0	95.0	1kHz	94.0		94.0	
		89.8	91.8	500Hz	90.8		90.8	
		84.4	86.4	250Hz	85.4		85.4	
		76.9	78.9	125Hz	78.0		78.0	
		66.8	68.8	63Hz	68.0		68.0	
		53.1	56.1	31.5Hz	54.8		54.8	
	C weighting	0.0	88.5	16kHz	85.3		85.3	
		88.0	92.5	8kHz	90.9		90.9	
		92.2	94.2	4kHz	93.1		93.1	
		92.8	94.8	2kHz	93.8		93.8	
	Ref	93.0	95.0	1kHz	94.0		94.0	
		93.0	95.0	500Hz	94.0		94.0	
		93.0	95.0	250Hz	94.0		94.0	
		92.8	94.8	125Hz	93.8		93.8	
		92.2	94.2	63Hz	93.2		93.2	
		89.5	92.5	31.5Hz	91.1		91.1	

Test	Function	Tolerance Min	Tolerance Max	Measured values Before	Out	After	Out
3a	Ch.1 Noise			16.2		16.2	
	Ch.2 Noise			14.2		14.2	
3b	Mic. input						
	Ch. 1			Pass		Pass	
	Ch. 2			Pass		Pass	
4	Generator						
	White Noise			Pass		Pass	
	Pink Noise			Pass		Pass	
	Sine			Pass		Pass	



Ch .1	1/3 Octave Filters			
Filter Hz	85.5 to 93.0	93.5 to 94.5	85.5 to 93.0	Out
25	92.7	93.9	86.5	
31.5	92.6	93.9	87.2	
40	92.4	93.9	86.9	
50	92.4	93.9	87.7	
63	92.3	93.9	88.0	
80	92.2	94.0	88.1	
100	92.1	94.0	88.1	
125	92.2	94.0	88.6	
160	92.0	94.0	88.9	
200	91.8	94.0	89.3	
250	91.7	94.0	89.6	
315	91.6	94.0	89.9	
400	91.3	94.0	90.1	
500	91.3	94.0	90.4	
630	91.1	94.0	90.4	
800	91.0	94.0	90.8	
1K	90.8	94.0	90.7	
1.25K	90.9	94.0	90.9	
1.6K	90.7	94.0	91.3	
2K	90.4	94.0	91.4	
2.5k	90.3	94.0	91.5	
3.15k	90.0	94.0	91.9	
4k	89.6	94.0	91.9	
5k	89.6	94.0	91.9	
6.3k	89.3	93.9	92.1	
8k	89.1	93.9	92.3	
10k	88.8	93.9	92.0	
12.5k	88.9	93.8	92.4	
16k	88.5	93.8	92.6	
20k	88.2	93.8	92.3	

Ch .1	1/1 Octave Filters			
Filter Hz	85.5 to 93.0	93.5 to 94.5	85.5 to 93.0	Out
31.5	92.3	93.9	86.9	
63	92.1	94.0	88.3	
125	91.8	94.0	89.1	
250	91.6	94.0	89.7	
500	91.4	94.0	90.5	
1K	91.1	94.0	91.0	
2K	90.9	94.0	91.5	
4k	90.6	94.0	92.1	
8k	90.1	93.9	92.3	
16k	89.7	93.9	92.4	

Ch .2	1/3 Octave Filters			
Filter Hz	85.5 to 93.0	93.5 to 94.5	85.5 to 93.0	Out
25	92.9	94.0	86.5	
31.5	92.7	94.0	87.2	
40	92.5	94.0	87.0	
50	92.4	93.9	87.7	
63	92.3	94.0	88.0	
80	92.2	94.0	88.1	
100	92.1	94.0	88.2	
125	92.2	94.0	88.6	
160	92.0	94.0	88.9	
200	91.8	94.0	89.3	
250	91.8	94.0	89.6	
315	91.6	94.0	89.9	
400	91.3	94.0	90.1	
500	91.3	94.0	90.4	
630	91.1	94.0	90.4	
800	91.0	94.0	90.8	
1K	90.8	94.0	90.7	
1.25K	90.9	94.0	90.9	
1.6K	90.7	94.0	91.3	
2K	90.4	94.0	91.4	
2.5k	90.3	94.0	91.5	
3.15k	90.0	94.0	91.9	
4k	89.6	94.0	91.9	
5k	89.6	94.0	92.0	
6.3k	89.3	93.9	92.2	
8k	89.1	93.9	92.3	
10k	88.8	93.9	92.1	
12.5k	88.9	93.8	92.4	
16k	88.6	93.9	92.6	
20k	88.3	93.9	92.4	

Ch .2	1/1 Octave Filters			
Filter Hz	85.5 to 93.0	93.5 to 94.5	85.5 to 93.0	Out
31.5	92.4	94.0	86.9	
63	92.1	94.0	88.3	
125	91.8	94.0	89.2	
250	91.6	94.0	89.7	
500	91.4	94.0	90.5	
1K	91.1	94.0	91.0	
2K	90.9	94.0	91.5	
4k	90.6	94.0	92.1	
8k	90.1	93.9	92.3	
16k	89.7	93.9	92.4	

The expanded uncertainty of calibration at 95% confidence level with a coverage factor of k=2.

Parameter	Test Instrumentation Uncertainty	DUT Uncertainty	Total DUT Uncertainty
Reading with mic. @ 1 kHz:	0.11	0.1	0.21
Meter linearity:	0.46	0.1	0.56
Attenuator accuracy:	0.46	0.1	0.56
Electrical Freq. Resp.: 20 Hz to 20 kHz	0.024	0.1	0.12
Inherent noise level:	0.11	0.1	0.21
Overload:	0.11	0.1	0.21
Functions:	0.11	0.1	0.21
1/3 & 1/1 Filters:	0.024	0.1	0.12

Measurements performed by:

Calibration Date: 18-Jan-2019

Matthew Smith

CERTIFICATE of CALIBRATION

Make : G.R.A.S

Reference # : 151500

Model : 50GI

Customer : Aercoustics Engineering Ltd
Mississauga, ON

Descr. : CCP Intensity Probe

Serial # : 112774-112784, 104771-104781

P. Order : Visa-Iwona Stasiew

Asset # :

Cal. status : Received in spec's, no adjustment made.
System test 40GIs#112774/26CBs#104771 40GIs#112784/26CBs#104781

Navair Technologies certifies that the above listed instrument was calibrated on date noted and was released from this laboratory performing in accordance with the specifications set forth by the manufacturer.

Unless otherwise noted in the calibration report a 4:1 accuracy ratio was maintained for this calibration.

Our calibration system complies with the requirements of ISO-17025 standard, working standards used for calibration are certified by or traceable to the National Research Council of Canada or the National Institute of Standards and Technology.

Calibrated : Feb 11, 2018

By : J. Raposo

Cal. Due : Feb 11, 2019

Temperature : 23 °C ± 2 °C Relative Humidity : 30% to 70%

Standards used : J-163 J-216 J-333

Navair Technologies

REPAIR AND CALIBRATION TRACEABLE TO NRC AND NIST

6375 Dixie Rd. Mississauga, ON, L5T 2E7
Phone : 905 565 1584 Fax : 905 565 8325
http://www.navair.com
e-Mail: service@navair.com

NAVAIR TECHNOLOGIES
6375 Dixie Rd Unit# 7,
Mississauga, ON L5T 2E7
Tel: (905)565-1583
Fax: (905)565-8325

Form:50GI	Approved by:.	Jan-18	Ver 1.0

Calibration Report for Certificate : **151500**

Make			Model	Serial		Asset
G.R.A.S.			50GI	nsn		nan
G.R.A.S.			40GI	112774		nan
G.R.A.S.			40GI	112784		nan
G.R.A.S.			26CB	104771		nan
G.R.A.S.			26CB	104781		nan

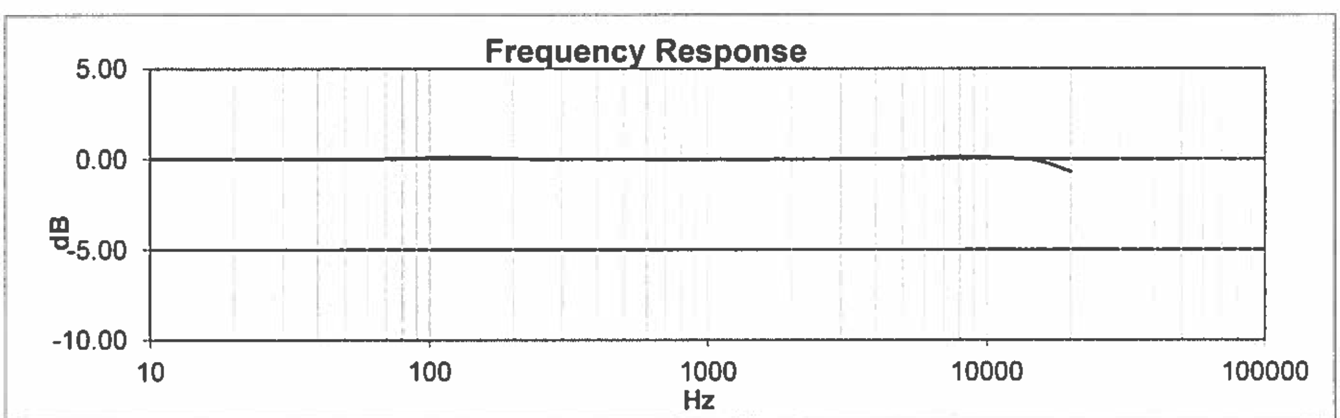
System test of microphone /preamp pairs
CH1 40GI s#112784 26CB S#104361
Sensitivity at 250Hz

Specs Nom	Unit	Min	Reading	Max	In/Out
10	mV/Pa	Nom	13.31	Non	Pass
-26.02	dB re 1V/Pa	Nom -40dB	-37.52	Nom -40dB	Pass
0	dB re 10mV/Pa	-2	-11.50	2	Pass

Ambient Conditions: Static Pressure 100.2 kPa Tem 23.4°C RH 20%

Frequency response

Freq	Actuator
Hz	dB
31.5	0.02
63.1	0.03
125.9	0.15
251.3	0.00
502.5	-0.01
1005.1	-0.03
1978.7	-0.03
3957.5	0.02
7914.9	0.15
12663	0.05
15830	-0.15
20000	-0.71



NAVAIR TECHNOLOGIES

6375 Dixie Rd Unit# 7,
Mississauga, ON L5T 2E7
Tel: (905)565-1583
Fax: (905)565-8325

System test of microphone /preamp pairs

CH2 40GI s#104771 26CB S#112774

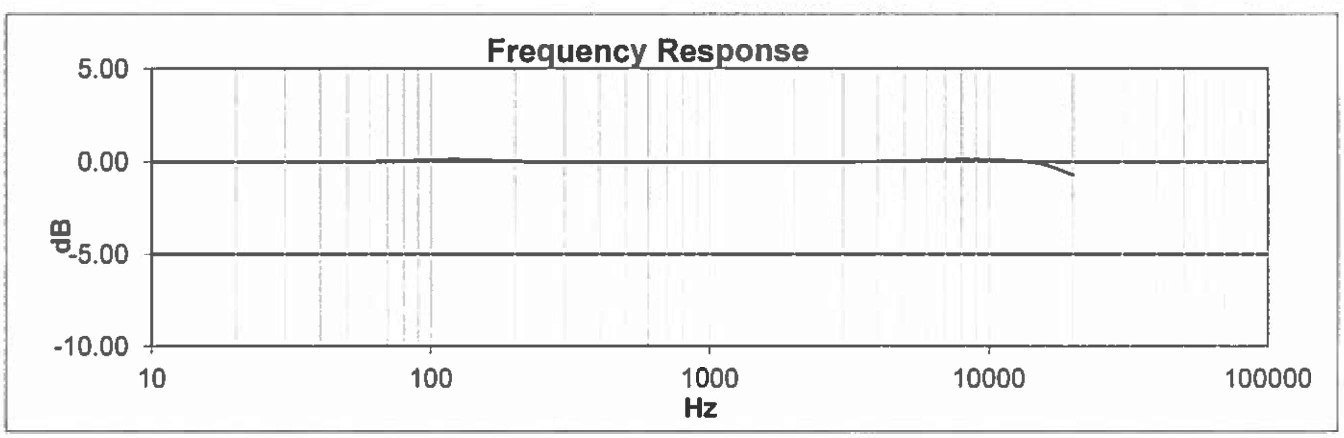
Sensitivity at 250Hz

Specs Nom	Unit	Min	Reading	Max	In/Out
10	mV/Pa	Nom	10.01	Non	Pass
-26.02	dB re 1V/Pa	Nom -40dB	-39.99	Nom -40dB	Pass
0	dB re 10mV/Pa	-2	-13.97	2	Pass

Ambient Conditions: Static Pressure 100.2 kPa
Temperature 23.4°C
Rel.Humidity 20.0%

Frequency response

Freq	Actuator	
Hz	dB	
31.5	0.02	
63.1	0.03	
125.9	0.15	
251.3	0.00	ref
502.5	-0.01	
1005.1	-0.03	
1978.7	-0.03	
3957.5	0.02	
7914.9	0.15	
12683	0.05	
15830	-0.15	
20000	-0.71	



Appendix B

Response Letter dated February 21, 2020

aercoustics

Aercoustics Engineering Ltd.
1004 Middlegate Road, Suite 1100
Mississauga, ON L4Y 0G1

Tel: 416-249-3361
Fax 416-249-3613
aercoustics.com

February 21, 2020

Aercoustics Project #: 16227.04

Niagara Region Wind Farm
REA# 4353-9HMP2R
36 Rue Lajeunesse,
Kingsey Falls, Quebec
J0A 1B0

ATTN: Stéphanie Bujold

Subject: Acoustic Transformer audit for Transformer ST1
Niagara Region Wind Farm
REA#4353-9HMP2R

Aercoustics Engineering Limited ("Aercoustics") has been retained by Niagara Region Wind Farm to complete the acoustic transformer audit for the North transformer substation ST1. Niagara Region Wind Farm operates under REA #4353-9HMP2R.

This letter contains responses to MECP comments received on February 5, 2020 for the Niagara Region Wind Farm ST1 Transformer acoustic audit report which are provided below. Original MECP comment is provided in black and Aercoustics' response is provided in purple.

1. Typographical oversight in Table 2

Parameter	Transformer ST1
Measurement Distance	0.3 m from non-fan surface, 1 m from cooling fans
Horizontal Spacing Between Measurement Locations	1 m
Height of Transformer (H)	4.6 m
Height of Microphone 1 above ground	1.8 m (0.3 m + 1/3H)
Height of Microphone 2 above ground	2.0 m (0.3 m + 2/3H)

Please confirm the height of microphone 2, in Table 2.

The microphone height of 2.0 meters noted in Table 2 was a typographical error. The correct height of 3.4 meters has been included in the revised report.

2. With reference to Figure 3 in the Report – measurement locations [ONAN and ONAF] and Figure 33 in the IEEE Std C57.12.90-2015 {standard} (Microphone location for measuring audible sound from transformers); please explain:

   a. Why was only one measurement contour used in place of one contour for ONAN (0.3 m from the reference sound producing surface) and one contour for ONAF, (2m from the reference sound producing surface);

   b. Why did the measurement contour not correlate, (have a similar path) with the reference sound producing surface (ref: Figure 33 in the Standard);

Transformer ST1 is enclosed by a barrier on all four sides which restricts the mobility of measurement personnel/ measurement equipment and the placement of the microphone measurement locations prescribed by the IEEE C57.12.90-2015 standard.

Alternate measurement location points were chosen to ensure that the measurement equipment/ personnel were not hampered by the nearby barrier and the sound intensity microphones were not in the flow from the fans during the ONAF measurement. In addition, a single contour was used for both measurement sets to conserve time in order to capture the measurements while the transformer was under the appropriate load. The window of time when the winds were appropriately high to sustain an 85% turbine load did not facilitate the establishment and use of a secondary contour.

The chosen alternate measurement locations are consistent with the intent of the IEEE C57.12.90-2015 standard and follows the methodology of ISO 3744 (Acoustics – Determination of sound power levels of noise sources using sound pressure – Engineering method in an essentially free field over a reflecting plane) i.e. the sound power of the transformer is the average normal intensity over a surface enclosing the source, multiplied by the surface area. The measurement surface chosen is simple to define and the planar surface makes averaging intensity over the surface simple while accounting for the site-specific constraints.

This slight deviation from the IEEE C57.12.90-2015 standard is not expected to affect the measured or calculated sound power level of Transformer ST1 as the measured surface area is accounted for in the calculation of the transformer sound power.

In addition, it should be noted that the measured sound power of transformer ST1 is 3dB below the maximum REA permitted level

3. With refence to Figure 3 in the Report and Figure 33 in Standard what is:

   a. The implication on the result/conclusions in the Report when using a contour that did not correlate with the reference sound producing surface (ref. Figure 33 in the Standard); and

   b. The implication on the result/conclusions in the Report of only using one contour for both ONAN and ONAF as opposed to one contour for ONAN and one contour for ONAF as stipulated in the Standard;

The deviation from the IEEE C57.12.90-2015 standard was necessary due to the aforementioned site-specific constraints. This deviation is considered minor and is not expected to affect the measured or calculated sound power level of Transformer ST1.

The measurement points used are consistent with the intent of the IEEE C.57.12.90-2015 standard and follows the methodology of ISO 3744 (Acoustics – Determination of sound power levels of noise sources using sound pressure – Engineering method in an essentially free field over a reflecting plane). The measurement surface area is accounted for in the calculation of the transformer sound power.

Therefore, the results and conclusion of the Report are expected to be fully representative of the sound power output of transformer ST1 and transformer ST1 is in compliance with the maximum REA sound power level.

Please do not hesitate to contact us should you have any questions or require anything further.

Sincerely,

AERCOUSTICS ENGINEERING LIMITED

A. Munro

Allan Munro, B.A.Sc., P.Eng

Payam Ashtiani, B.A.Sc., P.Eng

Appendix C
Response Letter dated March 19, 2020

aercoustics

Aercoustics Engineering Ltd.
1004 Middlegate Road, Suite 1100
Mississauga, ON L4Y 0G1

Tel: 416-249-3361
Fax 416-249-3613
aercoustics.com

March 19, 2020

Aercoustics Project #: 16227.04

Niagara Region Wind Farm
REA# 4353-9HMP2R
36 Rue Lajeunesse,
Kingsey Falls, Quebec
J0A 1B0

ATTN: Stéphanie Bujold

Subject: Acoustic Transformer audit for Transformer ST1
Niagara Region Wind Farm
REA#4353-9HMP2R

Aercoustics Engineering Limited ("Aercoustics") has been retained by Niagara Region Wind Farm to complete the acoustic transformer audit for the North transformer substation ST1. Niagara Region Wind Farm operates under REA #4353-9HMP2R.

This letter provides supporting evidence to assertions made in Aercoustics' attached response letter, dated February 21, 2020. This letter was provided to in response to MECP comments which were received February 6, 2020 related to the Niagara Region Wind Farm Transformer ST1 acoustic audit report.

During the acoustic audit, Aercoustics chose a set of measurement locations which differ from those provided in Figure 33 of the IEEE 57.12.90-2015 measurement standard. The in-situ (test) locations, shown in Figure 3 of the ST1 acoustic audit report, were chosen to ensure that the measurement equipment and personnel were not hampered by the acoustic barrier which surrounds Transformer ST1 on all four sides. Additionally, the in-situ measurement surface was used for both the ONAN and ONAF measurement sets to accommodate a limited window of time where the transformer was expected to be at the appropriate electrical load.

Figure A1, appended, illustrates the location of the surrounding barriers. This figure also illustrates the ONAN and ONAF measurement surfaces in accordance with IEEE 57.12.90-2015. Table 1 and Table 2 provide the relevant geometric parameters for the ONAN and ONAF measurement surfaces shown in Figure A1, as well as a comparison between these IEEE reference surfaces and the in-situ measurement surface.

Table 1: ONAN Measurement Surface Areas

Geometry Parameter (m^2)	Test Surface[1]	IEEE Reference Surface[2]	Delta (Test - Reference)
Perimeter of Enclosing Measurement Surface	34	28	-6
Perimeter Area of Enclosing Measurement Surface	155	128	-27
Top Area	61	51	-10
Total Measurement Surface Area	216	179	-37

1 Measurement surface shown in Figure 3 of Acoustic Audit Report

2 Measurement surfaces shown in Figure A1, Appended

Table 2: ONAF Measurement Surface Areas

Geometry Parameter (m^2)	Test Surface[1]	IEEE Reference Surface[2]	Delta (Test - Reference)
Perimeter of Enclosing Measurement Surface	34	39	5
Perimeter Area of Enclosing Measurement Surface	155	181	26
Top Area	61	107	46
Total Measurement Surface Area	216	288	72

1 Measurement surface shown in Figure 3 of Acoustic Audit Report

2 Measurement surfaces shown in Figure A1, Appended

As stated in Aercoustics' February 21 response letter, these deviations from the test protocol are considered minor. The sound power results calculated using these measurement locations, as presented in the acoustic audit report, are expected to be fully representative of the sound output from Transformer ST1.

To support the assertions presented above, the ONAN and ONAF measurement surfaces outlined in the IEEE standard have been used in an additional calculation of the transformer sound power output. The sound power levels determined using these alternative measurement surfaces have been compared to those determined using the in-situ (test) measurement surface. This comparison is provided in Table 3:

Table 3: Calculated Sound Power Output Comparison using Test surface and IEEE Reference Surface

Parameter	Test Surface[1] [dBA]	IEEE Reference Surface[2] [dBA]	Delta (Test - Reference) [dBA]
Sound Intensity: Transformer Core Only	66	66	0.0
PWL: Transformer Core Only	90	89	0.8
PWL: Transformer Core Only*	95	94	0.8
Sound Intensity: Transformer Core and Fans	75	75	0.0
PWL: Transformer Fans (core subtracted)	98	99	-1.0
PWL: Transformer Substation* (Transformer and Cooling Fans)	**100**	**100**	**-0.5**
REA Limit	**103.2**		

1 Measurement surface shown in Figure 3 of Acoustic Audit Report

2 Measurement surfaces shown in Figure A1, Appended

* Includes 5 dB Tonal Penalty

Table 3 illustrates that the use of the in-situ measurement test surface produces sound power levels that are representative of those calculated using the IEEE reference surfaces. Additionally, the audit results show a margin of compliance of approximately 3 dB. This wide margin further supports the use of the in-situ measurement surface as a valid and representative approach in this assessment of compliance.

Please do not hesitate to contact us should you have any questions or require anything further.

Sincerely,

AERCOUSTICS ENGINEERING LIMITED

Kohl Clark

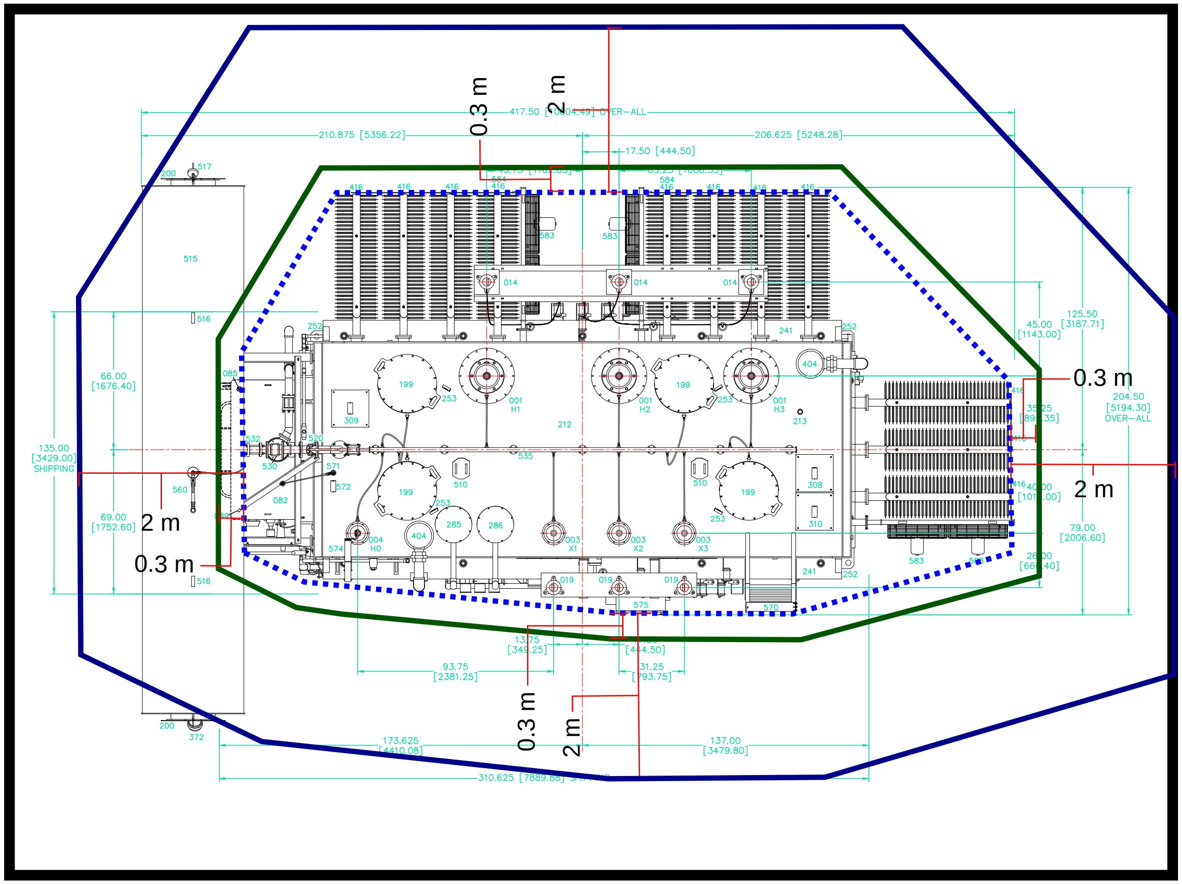
Kohl Clark, B.Eng

A. Munro

Allan Munro, B.A.Sc., P.Eng

P. Ashtiani

Payam Ashtiani, B.A.Sc., P.Eng



ONAF Measurement Surface*
ONAN Measurement Surface*
Reference Sound Producing Surface
ST1 Barrier

*Per Figure 33 of the IEEE C57.12.90-2015 Standard

Transformer ST1 - IEEE C57.12.90-2015 Measurement Surfaces with Transformer Barrier

Project: 16227.02 - Niagara Wind Farm Transformer Testing

Drawn By: KC
Reviewed By: AM
Scale: 1:92
Date: March 18, 2020

Figure A1

aercoustics