HGC ENGINEERING

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DETERMINATION OF SOUND POWER LEVEL OF A TRANSFORMER

Prepared for:

McLean's Mountain Wind GP Inc.
30 St. Clair Avenue West, 12th Floor
Toronto, ON
M4V 3A1

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1 INTRODUCTION

HGC Engineering was retained by McLean's Mountain Wind GP Inc. to complete acoustic measurements of the project transformer to satisfy Condition G of the Renewable Energy Approval ("REA") (Number 7733-8XUNS5) issued to the site by the Ontario Ministry of the Environment ("MOE").

The audit condition in the REA requires the determination of the sound power level of the transformer for comparison to the specification included in the Environmental Noise Impact Assessment Report, dated August 15, 2012 [1], completed by others. The sound power level of the transformer was measured on July 11, 2014 utilizing methods from C57.12.90, IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers [2].

2 SOUND SOURCE UNDER TEST

The transformer, manufactured by ABB, is located within the transformer station at the McLean's Mountain Wind Project. The unit is nominally rated at 70 mVA. Overall dimensions are approximately 5.6 metres wide, 6.1 metres in length and 4.5 metres in height. Photos of the transformer are provided in Figures 1 and 2. The unit does not include forced air cooling.

Acoustically, the transformer was tonal. A tonal sound is defined as one which has a "pronounced audible tonal quality such as a whine, screech, buzz or hum". A/C transformers and inverters typically exhibit a humming character at twice the line frequency (120 Hz) and harmonics thereof, as a result of magnetostrictive forces in the windings and semiconductors. The sound level measurements indicated tones at 120 Hz and harmonics thereof.

The unit was operating normally during the test period.

3 ACOUSTIC ENVIRONMENT

The measurements were conducted outdoors at the McLean's Mountain Wind Project near Little Current, Ontario. The sound from the transformer was steady, such that sound pressure measurements could be used to determine the sound emission levels of the transformer assembly, utilizing methods from IEEE Standard, C57.12.90.

Weather conditions during the test period remained relatively constant with a mainly clear sky, air temperature of 20° Celsius, and winds from the south at 3 to 5 m/s.

4 INSTRUMENTATION

The sound level measurements were conducted using a Brüel & Kjær PULSE model 3560-B-010 Real Time Frequency Analyzer (S/N 2516092) equipped with a Brüel & Kjær model ZH 0632 Sound Intensity Probe and a Brüel & Kjær matched intensity microphone pair. The instrumentation was calibrated before and after the measurements using a Brüel & Kjær model 4231 sound level calibrator with a dual microphone coupler. Laboratory calibration certificates for the equipment are included as Appendix A.

5 MEASUREMENT PROCEDURE

A sketch of the measurement setup is appended as Figure 3. As per the IEEE C57.12.90 standard, measurements were conducted at 1/3 and 2/3 height of the transformer at 1 meter intervals around all four sides of the unit. Measurements were conducted at 0.3 meters away from the transformer surfaces (mainly the cooling radiators).

6 MEASUREMENT RESULTS

Table I provides the average octave band sound pressure levels of the transformer measured at 42 unique locations, as described in the previous section.

Table I: Transformer (70 mVA) Sound Pressure Level [dB]

Octave Band Centre Frequency [Hz]	31.5	63	125	250	500	1k	2k	4k	8k	Overall [dBA]
Sound Pressure Level [dB]	58	59	74	59	63	49	40	33	24	63

Appendix B contains the detailed one-third octave band sound pressure level results.

The conversion from sound pressure level to sound power level is based on the area of the imaginary surface enclosing the source, at the specified reference distance from the equipment. In this case, the enclosing surface area for the transformer is 165 m^2, including the top.
The sound power level of the transformer is presented in Table II below and is also shown graphically in Figure 4.

Table II: Measured Transformer Sound Power Level [dB re 10^{-12} Watts], Calculated Using Sound Pressure

Octave Band Centre Frequency [Hz]	31.5	63	125	250	500	1k	2k	4k	8k	Overall [dBA]
Sound Power Level [dB]	80	81	96	81	85	72	62	55	49	85

Table III shows the sound power level utilized in the Environmental Noise impact Assessment Report.

Table III: Specified Transformer Sound Power Level [dB re 10^{-12} Watts]

Octave Band Centre Frequency [Hz]	31.5	63	125	250	500	1k	2k	4k	8k	Overall [dBA]
Sound Power Level [dB]	86	92	94	90	89	83	79	73	66	90

The sound pressure level measurements at 0.3 m indicate the overall, A-weighted sound power level of the transformer is 5 dBA less than specified and generally, in all but one octave band, the sound levels are 5 to 15 dB less than specified. However at 125 Hz the measured sound level is 2 dB higher than the specification.

Recent research into methods of measuring sound levels from electrical transformers indicates that measurements completed utilizing sound intensity methods provide more accurate results [3]. Therefore, as a supplement to the above measurements, they were repeated using sound intensity methods and instrumentation. Unlike a simple sound level meter with an omni-directional microphone, sound intensity instrumentation utilizes a highly directional probe and sophisticated analyzer to measure both the magnitude and direction of sound. This approach therefore has excellent immunity to background noise and cross-interference from sources located close together. Methods from ISO 9614-2 "Acoustics - Determination of sound power levels of noise sources using sound intensity - Part 2: Measurement by scanning" [4] were employed in this regard. Table IV provides the sound power level determined using sound intensity methods.

Table IV: Measured Transformer Sound Power Level [dB re 10^{-12} Watts], Calculated Using Sound Intensity

Octave Band Centre Frequency [Hz]	31.5	63	125	250	500	1k	2k	4k	8k	Overall [dBA]
Sound Power Level [dB]	83	86	91	78	82	70	52	<50	<50	81

The sound level measurements completed using sound intensity methods indicate the transformer sound power level meets the specified sound power level in all octave bands, and A-weighted sum.

7 CONCLUSIONS

HGC Engineering completed an Acoustic Audit of the electrical transformer located at the McLean's Mountain Wind Project, near Little Current, Ontario. Sound level measurements were completed on July 11, 2014, utilizing methods from C57.12.90, IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers and methods from ISO 9614-2.

The sound level measurements and calculations indicate the overall transformer sound level is less than the specified sound level in the Environmental Noise Impact Assessment.

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20-Nov-14
PROVINCE OF ONTARIO

Reviewed by

Corey Kinart, PEng

REFERENCES

[1] Aercoustics Engineering Limited, "Environmental Noise Impact Assessment, McLean's Mountain Wind Farm", May 3, 2013.

[2] IEEE Standard C57.12.90, "IEEE Standard Test Code for Liquid-Immersed Distribution, Power and Regulating Transformers." The Institute of Electrical and Electronics Engineers, Inc. New York, 2007.

[3] Andrew Dobson, "Addressing the Complexities, Limitations and Benefits Involved in Conducting Near-Field Sound Power Measurements of Large Electrical Transformers", Internoise Innsbruck, September 2013.

[4] ISO Standard 9614-2, "Acoustics – Determination of sound power levels of noise sources using sound intensity – Part 2: Measurement by scanning," International Organization for Standardization, 1996.

Figure 1: Transformer

Figure 2: Transformer

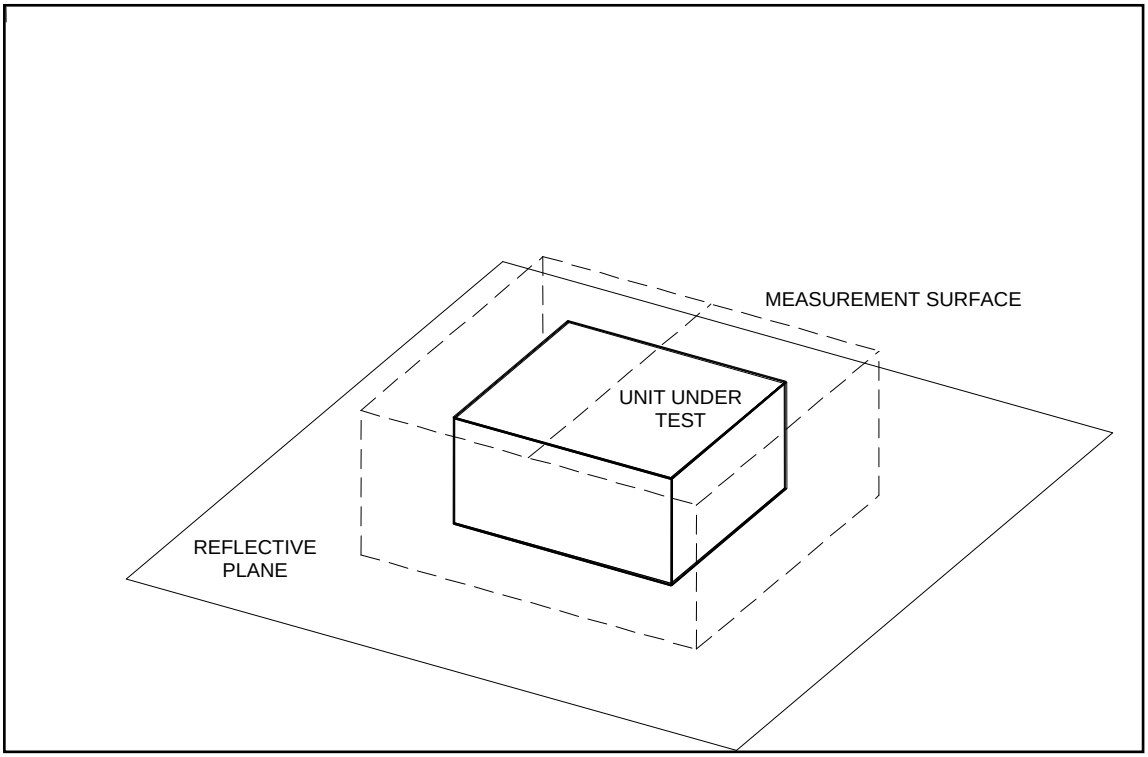
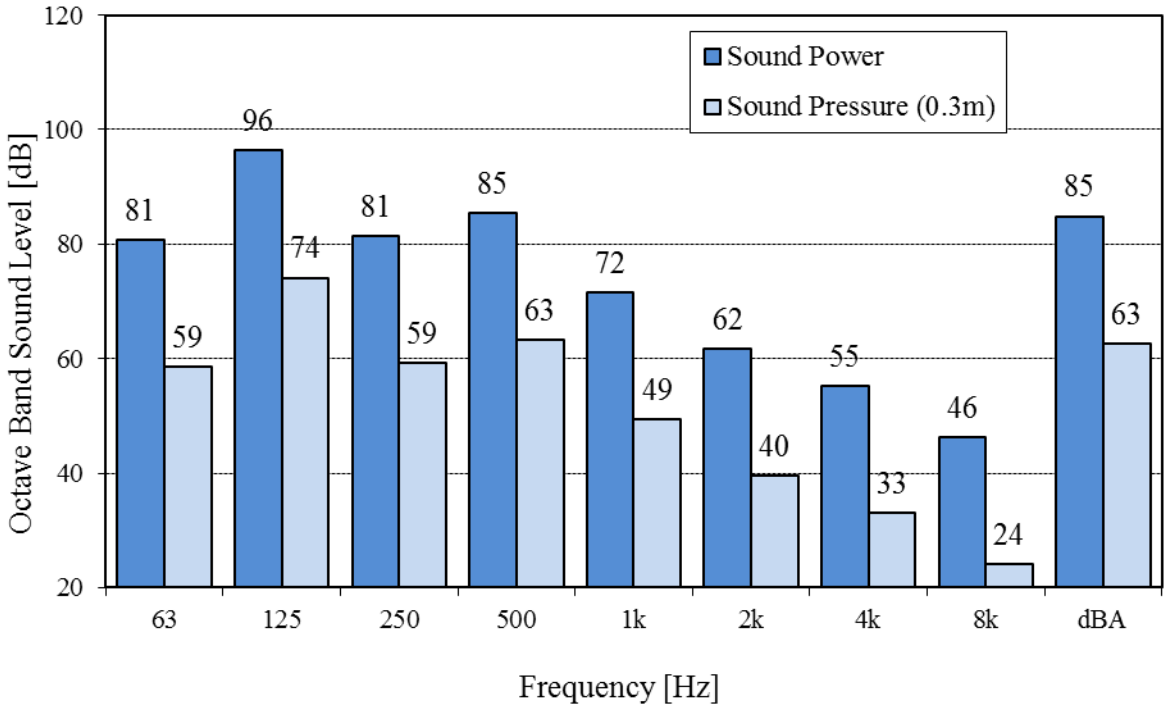


Figure 3: Sketch of Measurement Surface

Figure 4: Sound Power and Sound Pressure Levels
Transformer, Measured July 11, 2014



APPENDIX A
Instrument Calibration Certificates

CERTIFICATE of CALIBRATION

Make :	Bruel & Kjaer	Reference # :	133208
Model :	3560-B-010	Customer :	HGC Engineering Mississauga, ON
Descr. :	Measuring System 5 ch		
Serial # :	2476771	P. Order :	Sean Richardson
Asset # :	NAN		

Cal. status : Received in spec's, no adjustment made.

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 : Jan 20, 2014 By : JB (per ZR)

Cal. Due : Jan 20, 2015 J. Raposo

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

Standards used : J-129 J-216 J-303

Navair Technologies

REPAIR AND CALIBRATION TRACEABLE TO NRC AND NIST

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APPENDIX B
Detailed Measurement Results

One-Third Octave Frequency [Hz]	Measured Transformer Sound Pressure Level [dB] Microphone Location																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
25	64	56	55	57	63	58	57	52	46	45	42	51	47	46	53	56	53	57	62	57	50
31.5	62	57	54	58	63	58	56	49	45	43	40	46	44	44	52	55	52	57	60	53	51
40	62	58	55	58	63	57	58	56	54	51	41	49	46	46	52	57	59	58	60	54	51
50	61	58	57	60	62	57	58	59	58	54	45	54	51	51	54	60	63	60	58	56	53
63	59	53	50	56	59	54	53	47	46	46	57	50	49	49	51	51	50	53	57	51	47
80	57	51	51	54	56	53	52	45	44	47	40	45	47	47	48	50	46	52	55	51	44
100	61	59	55	55	60	61	61	58	58	63	57	58	52	53	61	62	62	62	64	64	55
125	74	73	68	65	73	76	75	72	72	77	72	72	61	64	76	76	77	76	77	78	68
160	52	50	44	51	51	52	51	50	50	52	45	47	43	43	50	52	50	49	52	52	43
200	48	46	40	50	47	49	47	49	48	47	41	44	45	42	44	48	41	48	46	43	38
250	49	54	51	50	46	58	52	54	56	58	55	57	60	56	58	61	53	62	55	48	44
315	55	54	56	55	53	56	55	52	59	49	52	56	50	48	56	57	61	51	55	55	52
400	59	58	60	59	57	60	60	57	63	56	57	61	55	53	61	61	65	56	59	59	56
500	50	52	61	62	56	57	61	60	59	63	58	50	58	59	55	57	62	64	57	49	51
630	53	53	46	44	45	60	56	51	56	52	51	60	56	55	55	55	61	54	49	55	39
800	34	37	41	41	39	40	42	42	50	51	42	39	38	39	35	43	46	50	42	41	33
1000	36	35	36	31	34	41	40	46	57	54	46	38	40	47	36	39	41	44	43	37	33
1250	29	29	32	30	34	34	37	42	52	51	40	32	33	38	30	39	34	37	41	32	31
1600	27	29	33	28	33	35	35	39	44	46	36	31	32	33	30	36	35	37	42	35	29
2000	30	31	32	33	34	32	32	35	40	41	33	32	32	30	28	34	34	36	37	32	30
2500	25	26	26	25	27	27	29	33	35	41	29	27	28	28	27	30	29	30	35	28	27
3150	25	26	25	26	27	27	29	31	34	42	32	28	28	28	27	29	27	29	35	27	26
4000	25	29	28	30	29	28	27	27	30	37	31	25	26	25	26	28	27	29	32	29	28
5000	24	26	24	23	25	23	25	26	28	34	37	23	23	23	23	26	23	25	27	25	24
6300	23	25	23	21	24	22	22	24	26	29	30	21	21	21	21	25	21	22	24	22	22
8000	26	27	24	24	26	24	21	21	26	26	24	22	20	20	19	24	23	19	22	23	23
10000	23	25	25	21	24	22	19	18	23	25	19	18	18	18	17	23	20	18	18	20	21
Height	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
A-Weighted	61	60	61	61	60	64	63	61	65	65	61	62	59	59	63	64	66	64	63	63	56
C-Weighted	75	74	70	69	73	76	75	73	73	78	72	73	66	67	76	77	77	76	78	78	69

One-Third Octave Frequency [Hz]	Measured Transformer Sound Pressure Level [dB] Microphone Location																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
25	43	54	52	50	66	60	51	47	47	54	42	45	44	41	42	44	48	53	63	57	60
31.5	42	49	49	45	66	57	49	45	46	51	40	41	42	40	39	43	48	52	59	55	60
40	40	48	47	42	68	57	49	44	45	52	41	42	41	39	38	42	46	49	60	57	59
50	46	48	46	45	66	55	51	46	49	52	45	43	40	41	41	45	46	49	57	53	57
63	43	46	48	50	65	56	53	53	61	59	57	48	45	44	51	51	46	47	55	51	55
80	41	45	45	44	62	51	45	40	44	48	40	41	39	40	38	42	42	44	54	50	52
100	61	59	54	57	63	55	59	61	59	60	57	55	56	53	54	59	63	56	65	65	58
125	75	74	68	71	70	67	73	75	74	74	72	70	71	68	69	74	77	70	80	80	72
160	48	47	43	45	56	48	46	48	47	48	45	43	44	42	42	47	50	44	55	53	47
200	38	39	42	35	55	47	42	44	47	40	41	43	39	42	41	46	43	40	50	45	42
250	48	35	55	42	59	55	54	57	60	47	55	56	50	57	55	60	56	49	58	55	47
315	60	52	60	53	56	54	43	56	53	54	52	50	58	57	57	61	63	45	59	55	52
400	65	56	64	58	58	58	49	61	57	59	57	55	62	62	62	65	67	50	63	60	57
500	52	52	44	56	48	58	58	55	54	53	58	53	53	54	54	58	58	62	63	58	53
630	50	45	40	47	52	52	56	59	58	52	51	52	54	48	52	51	61	58	58	50	39
800	36	37	34	37	42	42	41	46	48	51	42	41	40	33	37	42	40	49	47	43	35
1000	33	37	35	34	41	43	44	48	52	57	46	44	47	35	41	48	44	49	42	37	36
1250	29	32	31	31	35	37	38	41	44	49	40	38	39	31	34	39	36	39	36	33	30
1600	28	30	32	27	32	36	37	38	42	46	36	35	35	28	29	34	36	35	36	33	29
2000	27	31	32	29	30	34	35	37	37	41	33	31	31	27	27	33	35	34	34	32	29
2500	25	25	26	24	27	27	29	32	33	38	29	28	27	23	25	28	28	29	29	27	26
3150	25	24	26	24	24	25	27	29	31	38	29	29	27	23	25	28	28	28	29	26	26
4000	23	25	25	23	24	25	30	28	30	36	26	26	26	23	24	27	27	29	29	28	26
5000	23	24	25	25	24	22	22	22	25	31	23	24	22	21	22	24	24	25	25	26	25
6300	21	23	22	20	21	19	19	20	22	25	20	21	20	20	20	22	22	23	23	24	23
8000	20	23	22	21	21	19	19	19	21	24	19	20	19	18	18	19	20	20	20	21	21
10000	18	21	22	18	19	16	17	18	18	25	17	18	17	17	17	17	17	18	17	18	19
Height	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
A-Weighted	63	60	61	59	60	60	61	63	62	63	60	58	61	60	60	64	67	62	67	65	58
C-Weighted	76	74	70	72	73	69	73	76	75	75	72	70	72	70	70	75	78	71	80	80	72