IN THE MATTER	Of the Resource Management Act 1991
AND	
IN THE MATTER	Of An Application For Resource Consent Under Section 88
BY	Meridian Energy Ltd.
TO	Wellington City Council Porirua City Council and Greater Wellington Regional council

Statement Of Evidence Of Richard Russell James.

Dated: 02 September, 2008

1 Introduction

1.0 Thank you for permitting me to submit my testimony on behalf of the Ohariu Preservation Society.

1.1 My name is Richard James. I am the Owner and Principal Consultant for E-Coustic Solutions, of Okemos, Michigan, USA. I have been a practicing acoustical engineer for over 35 years.

1.2 I obtained my Bachelor's Degree in Mechanical Engineering in 1971 in the sub-category of applied acoustical engineering. I have been a Full Member of the Institute of Noise Control Engineers. I first joined the Institute in 1973, shortly after its formation.

1.3 I have attached a narrative of my career as it relates to the topic of this hearing along with a detailed summary of my primary accomplishments to this testimony as Appendix A.

1.3.1 During my career I have been especially interested in the application of computers for modeling sound propagation, such as is commonly done when addressing community noise for new and existing industrial and commercial facilities.

1.3.2 I have also pursued my interest in the practical aspects of standardizing acoustical measurement procedures used when assessing the compatibility of a new industrial facility or process and the existing land-use of the community that would be affected by the facility or process. My interest in standardization of acoustical measurement procedures has also been applied to acoustical engineering tests for worker noise exposure and the purchasing of new and rebuilt industrial machines for use both inside and outside industrial facilities.

1.3.3 The combination of these two interests, computer modeling and measurement procedures leads to their application in evaluating the impact that sound emissions from industrial machines will have on the adjacent communities. My experience in this area ranges from the relatively simple cases of neighbors complaining about the sounds of dogs barking at neighboring animal kennels or of a noisy air-conditioning unit to the projects involving complete automotive manufacturing sites for US automobile manufacturer's in the USA, Canada, and Europe.

1.3.4 The construction of wind turbine projects is relatively new to the North-Central parts of the US where I live and practice. I first started hearing from people living near modern industrial scale wind turbines living on the US coasts in 2004 and received my first request for assistance from a farmer in Michigan in 2005. Since 2006, when the wind turbine project that was announced in 2005 submitted its permit application, I have done extensive personal research into wind turbine sound emissions and land-use questions related to locating them near homes, farms and businesses. The more I learned about the sound level criteria being used to guide wind project developers the more I became convinced that the criteria were inadequate.

1.3.5 From 2006 through 2007 I worked with communities and home owners in the north-central part of the USA to develop wind project siting criteria for county and township governments; I conducted studies of sound from operating wind turbines; I performed pre-construction background sound studies for the communities and home owners, and provided testimony at zoning hearings, trials, and public presentations. Much of this work focused on the states of Michigan, Ohio, Wisconsin, Illinois, West Virginia, and Pennsylvania. I also assisted clients in Oregon, Washington, and the U.K. with written testimony and reviews of studies conducted by noise consultants for the wind project developers. I am currently personally involved with wind turbine related work for clients in over 20 different communities.

1.4 During the past two years I have worked with Mr. George Kamperman to increase my perspective on this subject. Mr. Kamperman is a senior member and founder of the Institute of Noise Control Engineers. He started his consulting career in the early 1950's under Dr. Leo Beranek, founder of Bolt, Beranek and Neuman (BBN). Together we collaborated with other acoustical consultants in EU and the U.K. sharing information to better understand why certain wind farm projects resulted in complaints from people living near them and, in some cases, were said to aggravate existing health issues or create new ones in some of the people living near them while other wind projects did not cause problems.

1.4.1 In early 2008, Mr. Kamperman and I decided that our review of studies addressing wind farms with known complaints revealed a common failure in the process used to determine how close the wind project would be to people. We concluded that we had sufficient information[1] to formulate a statement of what factors we had come to see as the fundamental differences between the projects that were successful and those that resulted in complaints and to develop recommended criteria that could be used to locate wind projects that were compatible with the existing communities. We decided that we would make this statement by submitting a paper for presentation and publication at the forthcoming summer conference of the Institute of Noise Control Engineers, Noise-Con 2008. The title of the paper is: "Simple Guidelines for Siting Wind Turbines to Prevent Health Risks." It is available as part of the conference's published proceedings. I would like to have it included as part of my written

[1] A list of the studies and research that we found most useful and/or representative of a class of similar studies is included in Tables 1 through 4 of the Noise-Con paper in Appendix B.

testimony. A copy is provided in Appendix B.

1.4.2 Although our paper focused on information obtained by a review of published and private sound studies conducted by others, the criteria and recommendations we developed were also based on our own experience and knowledge, and were benchmarked against data we had collected for our clients.

1.5 In late winter of 2008, we were contacted by Dr. Nina Pierpont, M.D., Ph.D. a medical doctor living in the state of New York who is conducting research into the effects of wind turbine sound on people living in proximity to the modern industrial size wind turbines (1.5 MWatts and larger). She asked if we would expand upon our Noise-Con paper to provide additional background in support of our recommendations and also to provide the reader with a template for the language needed to use them as a community noise ordinance for wind turbines. We agreed to expand upon our earlier work for inclusion in her study. It is titled: "Wind Turbine Syndrome: A Report on a Natural Experiment" and is scheduled for publication in late September, 2008.

1.5.1 Our expanded manuscript covers many of the points I would like to make in my written testimony. Rather than repeating this material I would respectfully request that the manuscript be included as part of the record of my written testimony. I have provided this manuscript in Appendix C. It is titled the: "'How to' Guide to Siting Wind Turbines to Prevent Health Risks from Sound." The abstract for Dr. Pierpont's study is included in Appendix D[2].

1.6 At the risk of placing my conclusions before presenting my case for them, I would recommend that the criteria presented in this manuscript be considered, in their totality for the Mill Creek Wind Project. It is only by requiring proper methods of measurement and setting both dBA <u>and</u> dBC limits that public health can be protected from the effects of audible mid-to-high frequency sound from wind turbines and the low frequency acoustical energy that is often perceived as a non-auditory sensation or as a 'rumble' depending on each individual's sensitivity.

2 Opinions and Observations

2.0 I understand I may not be as familiar with the standards used in New Zealand as intimately as is Dr. Trevathan and other experts from New Zealand who have testified. But, I have been told that the New Zealand standards are under revision. Thus, I would like to present my views on some of the flaws I see in the current standard; especially in the methods and procedures used to assess pre-construction background sound levels and the limitations in computer modeling that should be disclosed when presenting the model's predicted sound levels for the purpose of siting wind turbines.

2.0.1 With respect to the details and specifics of the reports and testimony by the experts for Mill Creek, I will defer to Dr. Trevathan's testimony. I have had an opportunity to preview his testimony and found it to be accurate and in general conformance with my experience with wind turbine sound emissions, background sound studies, and limitations to computer modeling. Instead of repeating Dr. Trevathan's findings I will address several of the 'big theme' issues

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[2] For information see: http://www.windturbinesyndrome.com/?cat=3

that I have regarding the Mill Creek studies and also would like to comment on specifics of the current New Zealand standards.

2.1 To start, I will offer my opinion that the standard was written by people not concerned with standard acoustical measurement practice or instrumentation limitations, or else, such practices and limitations were ignored for reasons of expediency. I base this opinion not on the reputation or credentials of the people involved, but because the standards contain methods and procedures that deviate, in a significant manner, from what is considered to be proper measurement practice and instrumentation limits. Independent acoustical consultants, interested in measurement accuracy and maintaining a reasonable relationship between the accuracy of methods and procedures to be applied and way results are reported and the purposes for which they are used; would not have permitted expediency to be more important than accuracy. I do not see the influence of such a person in the NZ standards.

2.1.1 I will show how the deviations from commonly accepted acoustical measurement practice as standardized by US and international standards organizations that are permitted in the NZ standards have introduced bias and artifact into the results of the reports and testimony provided on behalf of Mill Creek.

2.2 I have confirmed during studies of wind farms that I have tracked from conception through operation that, where the recommended criteria are met, the community in general, and the people living closest to the turbines accept the sounds received on their property. Where the criteria are exceeded, the project results in complaints of annoyance and negative effects on sleep, health, and use of outdoor property for personal enjoyment. Individuals reporting medical symptoms tend to be parents speaking about their young children (6 and under), people with pre-existing medical conditions, including sleep problems, migraine headaches, autism, and the elderly.

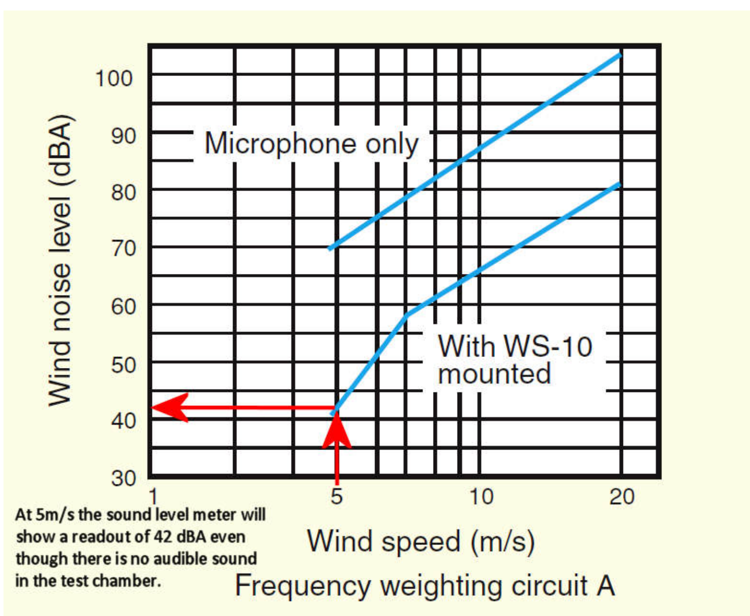
2.3 Measurement Artifacts Due To Windscreen Limitations

I would like to first address the methods for determining the long term background sound levels of a community. I will use as my example the report and testimony of Mr. Hayes which were identified as conforming to NZ standards.

2.3.1 I find that the data reported in his testimony and reports include measurements taken when the wind speed at the microphone position exceeds the 2 m/s upper limit commonly and appropriately used when measuring long term background sound levels. This low wind speed condition is especially necessary when assessing sound levels in a quiet community, as will be shown later. The measurements presented in the Hayes' report and testimony includes those taken when wind speeds at the microphone exceed 2 m/s and even 5 m/s. These would normally be discarded if commonly accepted acoustical measurement procedures, such as those provided in US standards set by the American National Standards Institute (ANSI) and corresponding ISO standards for outdoor sound measurements. That the NZ standard does not require similar strict procedures is one reason why I have concerns about the current proposal for Mill Creek.

2.3.2 It is a known limitation of sound level instruments that the windscreen used to reduce wind-artifacts fails at wind speeds of 5 m/s and above. Thus, the Hayes report and its conclusions about the long term background sound levels (L_{95}, L_{eq}, etc.) at the residential test sites may be contaminated by wind artifacts that will cause the readings to be higher than the true background sound level. This is not a debatable limitation based upon what is accepted in one country or another country by acoustic consultants. It is a limitation imposed by the instrument that we use and the accuracies that are required when taking measurements for legal or otherwise important purposes. Later, I will show how this artifact can be observed in the Mill Creek reports and testimony.

2.3.3 When a microphone is exposed to air movement reaching the microphone's diaphragm inside the windscreen, the pressure (not an audible sound) on the microphone's diaphragm results in spurious electrical signals being generated and included with the non-artifact signals by the circuitry in the instrument. This effect is often seen when watching a news reporter conduct an interview outside on a windy day. When the wind blows hard enough, the distortion heard on the television is due to wind screen failure. Acoustical measurements are restricted by the same problem. Current technology for wind screens designed to meet ISO and ANSI standards for acoustical measurement limit the maximum wind speed at the microphone to approximately 2 m/s or less if the goal is to measure background sound levels of less than 25 dBA. This limit is applicable when testing for long term background sound levels in a quiet community. There is a need for caution even when the tests are of situations in which the sound levels would be higher. As shown in the illustration below the absolute upper limit of the windscreen's effectiveness is usually set at approximately 5 m/s. At that speed the wind's pressure on the diaphragm produces a false reading of 42 dBA. If the windscreen was removed a reading of 70 dBA would be expected.



2.3.4 The wind speeds reported by Hayes were taken at the distances of 10 meters or more above the surface of the ground and are <u>not</u> suitable for determining the conditions at the microphone. The conditions on the ground are required documentation for outdoor acoustical measurements per ISO and ANSI measurement standards that were developed to assure accuracy and lack of bias in the measurements. The wind speeds reported for Mill Creek are from meteorological stations located at elevated heights above the ground. One of the standard distances being 10 meters above the grounds surface. The reports also refer to wind speeds from anemometers located at turbine hub height, which is 70 meters above ground. It is not known how much difference there is in the elevation of the ground where the meteorological equipment is located and the ground level at the test sites. But, this could also affect the relationships between the wind speeds at various elevations from the microphone. Readings from the elevated anemometers are not relevant to the data validation process set by standards for acoustic measurements and are particularly deficient for qualifying measurements used for determining compliance or for determining land-use compatibility in quiet communities. This may be permitted by the NZ standards, but it is not proper practice, and it allows artifacts to contaminate the data when the procedures of the standards are applied.

2.4 Evidence of Wind Artifact on Background Sound Tests Conducted for Mill Creek

2.4.1 My review of the data provided in Mr. Hayes' report and testimony for Mill Creek I find considerable evidence of these artifacts. At section 4.0.6 and 4.0.7 of his report Mr. Hayes alleges the background sound levels are between 38 and 42 dBA when winds at the hub are 16-17 m/s. Can this claim be supported or is there evidence that wind artifact may have contaminated the study's test results? I will start with the assertion that he cannot support such a claim if only data that meets commonly accepted practice is permitted for consideration.

2.4.2 In my opinion the data used to support this assertion was taken without using proper and commonly accepted procedures to assure that wind artifact does not affect results. I found no documentation that describes that precautions were taken to limit microphone input into the test instruments or in post-data collection review to exclude data when the wind speed at the microphone exceeds the 5 m/s limitation for the wind screen.

2.4.3 In light of my previous discussion on instrument limitations it is reasonable to conclude that the 38 to 40 dBA sound level range reported for the test sites are from data contaminated by wind artifacts and not an accurate measurement of <u>only the sounds present</u> during the measurement period. I must conclude that this deviation from proper practice is permitted under reasonable interpretation of NZ standards. Within that understanding, Mr. Hayes reports may meet the NZ standards but I do not believe they meet the generally accepted standards set by ISO and ANSI. This is one reason why I support the current review of the standards and trust that the review will include a correction for this deviation from proper measurement practice.

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4.0.6 The measured levels indicate that both measurement locations are relatively quiet during low wind speed conditions. The All data regression curves indicate that the prevailing background noise levels at both locations fall in the range 23 – 27 dB L_{A95} when the wind turbines will start to operate. Background noise levels show a trend to increase with increasing wind speed up to a level of between 38 – 42 dB L_{A95} for a hub height wind speed of 16 – 17 $m.s^{-1}$, a wind speed above the rated power output wind speed for the wind turbines.

4.0.7 During night-time periods, prevailing background noise levels lie between 20 – 25 dB L_{A95} during low wind speed conditions and again rise with increasing wind speeds to a level of 38 – 40 dB L_{A95} at a wind speed of 16 – 17 $m.s^{-1}$.

4.0.8 Table 4.1 below details the prevailing background noise levels obtained for each of the measurement locations. Wind speeds have been provided for the hub height wind speed of the wind turbines based upon the integer wind speed at 10m agl, the reference height for wind turbine sound power level measurements.

Table 4.1 detailing prevailing background noise levels at two representative noise measurement locations

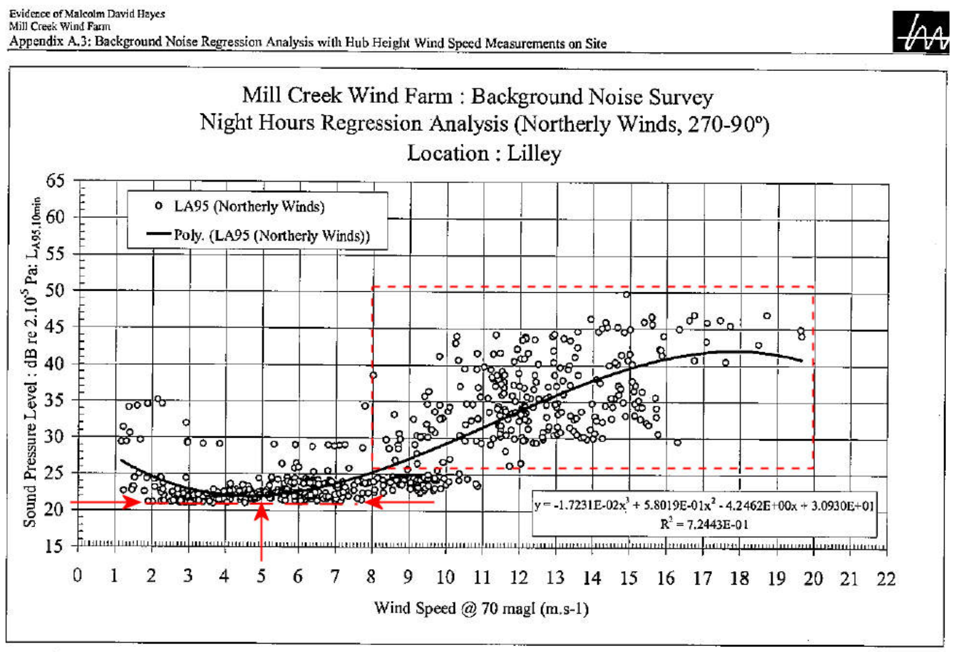
Wind Speed at 10m agl: $m.s^{-1}$	4	5	6	7	8	9	10	11	12
Wind Speed at 70m agl: $m.s^{-1}$	5.5	6.8	8.2	9.6	10.9	12.3	13.7	15.0	16.4

2.4.4 I will repeat my opinion that if one reviews the testimony of Mr. Hayes, one will find no evidence that data collected during conditions that exceed the wind-screen's performance limits was excluded from the measurements when they were collected or later, during post-processing of the test data removed from the final results. Instead, we are provided with charts such as Figures 1 through 20 of Appendix A.3 (From Testimony) that purport to show a regression analysis of the sound levels for the various test locations with wind speeds varying between zero and 15 m per second. But, as I will demonstrate in the next section; they also show us that significant wind artifact was present and included in the reported results.

2.5 What is the Background Sound Level?

2.5.1 Does this mean that all of the data from the studies and testimony is useless? No, careful analysis of the tables and charts provided can provide a very good estimate of the true background sound levels. If we start by looking at each chart, and we draw an imaginary vertical line from 5 m/s (giving the benefit of doubt to the wind speed at the ground being less than at the elevation of the anemometer) then the data to the left of that line can be useful in estimating the long term background sound level at each test site.

2.5.2 I have excerpted a graph from this appendix and added some text and graphics to show the regions that I would consider valid for determining the long term background sound level. In the example inserted below (using Figure 38 of Mr. Hayes' testimony), we see that the slope of the regression line changes at about this point. This is repeated in most of the other graphs except for those like Figure 31 on page 39 of Appendix A.3 which is identified as having 10m wind speeds of less than 1.2 m/s. These conditions do not exceed the windscreen's limits. You may wish to note that the sound levels depicted in this chart are quite low and cluster along the bottom.



Regression Figure 38: Lilley, night hours, northerly wind directions, 70m wind speed

2.5.3 What do we find if we look only at the data to the left of the 5 m/s wind speed lines? We find a cluster of sound levels between 22 and 25 dBA including for most tests. If we look at the test data that is lowest (along the dashed line between the horizontal arrows) we see a cluster of samples that go no lower than 22 dBA. This 'floor' for the test data is showing us the "true" background sound levels. Note that they even occur as wind speeds at the hub increase to about 8 m/s and then the 'floor' begins to move up and finally ends. This shows the increasing impact of the windscreen's limitations on the test data. In this example, the wind screen fails when the winds 10 meters above the ground reach 11 m/s.. The remaining data, especially the data above the regression line, is contaminated by artifact.

2.5.4 If we were to draw a line along the cluster of test data where this 'floor' is steady on each of the charts we will be very close to the true background level at each test site. Why do some of the readings for the low wind speed condition appear to be higher? There is no documentation provided that explains why, but it may be a result of other short term sounds during the test that should also have been excluded. We have no way of knowing what other kinds of short-term sounds may have affected the readings. Vehicles, barking dogs. Wind rustling on leaves of the trees at higher altitudes. All these things could affect the readings and should be removed when conducting a long term background test.

2.5.5 This appendix and its graphs are used by Mr. Hayes to support his assertion that as wind speeds increase so does the ambient sound level, and this increase in the sound level is great enough that it will mask the sounds emitted from the wind turbines during these more intense operational conditions. If we understand the concern about wind artifact contamination of test data and accept that any such data collected when the wind speed at the microphone, exceeds 2 m per second (or even 5m/s) does not meet generally accepted measurement requirements due to limitations of the test equipment then the data for wind speeds above 5 m/s must be excluded. Then, one must accept that these charts contain data that should be discarded because it cannot be demonstrated that the wind speed at the microphone was less than 2 m/s.

2.5.6 Next I would like to turn our attention to Tables 1 and 2 from the testimony of Mr. Hayes (on pages 18 and 19).

2.5.6.1 I will start with Table 1. I have inserted an excerpt from this table for purpose of this discussion. Table 1 from the testimony summarizes the test results from the background sound study categorized by the wind's speed at 10 and 70 meters above ground. We can assume that the wind's speed at the ground surface (microphone location) will be less than the wind speed at the elevated anemometers. Thus, we can also assume that the results shown in the columns for 4 and 5 m/s are likely to be valid tests. The excerpt from Table 1 shows these columns enclosed in a dashed box. If we limit our attention to the data in those two columns we can exclude the data that may be contaminated by wind artifacts. That data, inside the dashed box, shows the night LA95 test levels ranging from 19.3 to 21.9 dBA for North Winds and 22.7 to 24.1 dBA for South Winds. Including the data for the entire day increases this range from 19.3 to 27 dBA. This should be expected since short term events that occur during daytime hours were not excluded as is standard practice and activities at a distance, such as vehicle traffic, which commonly raise the daytime background sound levels.

Evidence of Malcolm David Hayes BSc MIOA
Mill Creek Wind Farm
Noise

Table 1 detailing prevailing background noise levels at representative noise measurement locations

Wind Speed at 10m agl: $m.s^{-1}$	4	5	6	7	8	9	10	11	12
Wind Speed at 70m agl: $m.s^{-1}$	5.5	6.8	8.2	9.6	10.9	12.3	13.7	15	16.4
Bruce All: dB L_{A95}	25.0	25.7	26.9	28.3	29.9	31.9	34.0	36.1	38.5
Bruce Night: dB L_{A95}	21.0	21.9	23.3	25.1	26.9	29.1	31.3	33.3	35.3
Bruce All (North Winds, 270-90°): dB L_{A95}	24.7	25.0	25.6	26.6	27.9	29.7	32.0	34.7	38.2
Bruce Night (North Winds, 270-90°): dB L_{A95}	19.3	20.3	21.8	23.8	25.7	27.9	29.9	31.5	32.8
Bruce All (South Winds, 90-270°): dB L_{A95}	25.5	27.0	29.2	31.7	34.3	37.0	39.6	41.6	43.3
Bruce Night (South Winds, 90-270°): dB L_{A95}	22.7	24.1	26.2	28.7	31.3	34.3	37.3	40.0	42.8
Third All: dB L_{A95}	26.0	27.1	28.7	30.7	32.7	35.0	37.3	39.4	41.4

2.5.6.2 Table 2 shows this more clearly. In Table 2 (From Testimony) Mr. Hayes has presented the study data filtered to show only the low noise condition test results. This table, in my opinion, is the test data that is not potentially contaminated by wind artifacts. It is the data in this table that should be applied when determining the long term (LA95) background sound levels for use in setting the wind turbine project's operating limit. The majority of these readings are between 19 and 22 dBA which, depending on the electrical noise floor of the sound level meter used, may be influenced as much by the instrument's noise floor as it is by sounds from the community's soundscape. It is possible that, if the data was corrected for the instrument's internal noise, the LA95 for some of the test sites could be as low as 16 to 18 dBA.

Table 2 detailing prevailing background noise levels during low noise conditions

Wind Speed at 10m agl: $m.s^{-1}$	4	5	6	7	8	9	10	11	12
Wind Speed at 70m agl: $m.s^{-1}$	5.5	6.8	8.2	9.6	10.9	12.3	13.7	15	16.4
Bruce All (L_{A95} < 25dB & 10m wind speed < 1.5m/s): dB L_{A95}	20.1	19.8	19.7	20.0	20.9				
Bruce Night (L_{A95} < 25dB & 10m wind speed < 1.5m/s): dB L_{A95}	19.7	19.6	19.6	20.0	20.8				
Third All (L_{A95} < 25dB & 10m wind speed < 1.5m/s): dB L_{A95}	19.0	19.4	19.8	20.0	19.7				
Third Night (L_{A95} < 25dB & 10m wind speed < 1.5m/s): dB L_{A95}	18.8	19.2	19.7	20.0	19.9				
Phillips All (L_{A95} < 25dB & 10m wind speed < 1.5m/s): dB L_{A95}	20.7	20.9	21.4	22.2	23.2				
Phillips Night (L_{A95} < 25dB & 10m wind speed < 1.5m/s): dB L_{A95}	20.1	20.6	21.3	22.1	22.8				
Lilley All (L_{A95} < 25dB & 10m wind speed < 1.5m/s): dB L_{A95}	23.0	23.4	23.8	24.0	23.9				
Lilley Night (L_{A95} < 25dB & 10m wind speed < 1.5m/s): dB L_{A95}	22.9	23.3	23.7	24.0	24.0				
Best* All (L_{A95} < 25dB & 10m wind speed < 1.5m/s): dB L_{A95}									
Best* Night (L_{A95} < 25dB & 10m wind speed < 1.5m/s): dB L_{A95}									

Note: * Measurements taken at the Best property represent the proposed Bowen dwelling at 1000 Makara Road

2.5.7 In conclusion, I offer the opinion that the proper values for background sound and for the assessment of compatibility of the community with the predicted wind turbine sounds are in the range of 19 to 25 dBA (and possibly lower), not 38 to 42 dBA as asserted by Mr. Hayes.

2.5.8 The NZ standard's method for assessing background sound levels results in sound levels that are inflated due to artifacts. This is a significant flaw because it permits data contaminated with artifacts to be used for siting decisions. The results, as I have shown, do not meet standards for outdoor acoustical tests and are higher than the true background sound level. They should be replaced with the 20-25 dBA levels that are shown in Table 2.

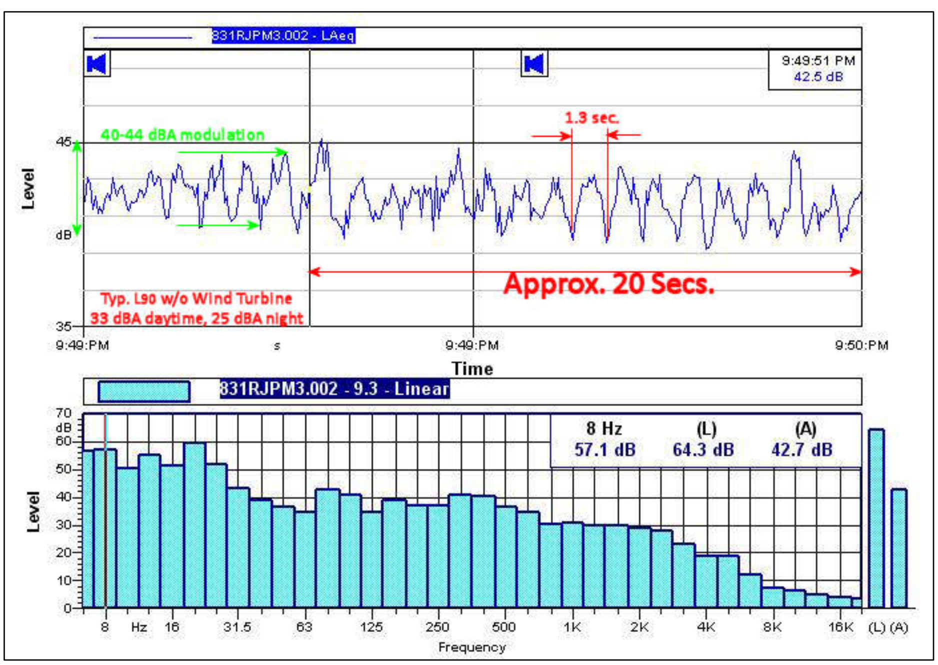
2.6 Low frequency Sound and Amplitude Modulation From Wind Turbines.

2.6.1 I would next like to explain why wind turbine sound can result sleep disturbance even when sound levels outside one's home are 40 to 45 dBA. Low frequency problems resulting from wind turbines are more likely to be noticed inside homes and other structures near wind turbines than they are to be noticed outdoors, where the higher frequency swooshing sounds from the turbines typically are dominant.

2.6.1.1 Amplitude Modulation (Aerodynamic Modulation)

2.6.1.1.1 Some have claimed that amplitude modulation (AM) is not a common problem with wind turbines. The assertion is usually followed with a statement that older turbine designs had this characteristic but modern ones do not. This response is only partly of the whole story. There are more than one cause of amplitude modulation and modern turbines do exhibit one of them. When I see the claim that this "problem" has been "fixed" I have to wonder if the person making it is trying to divert attention away from the other causes of amplitude modulation for which there are no current solutions. To demonstrate the amplitude modulation that is a characteristic of modern wind turbines I have inserted a graphic showing sound levels measured at 1300 feet (about 400 meters) upwind of a wind turbine in the back yard of a farmer's home in the Blue Sky, Green Fields Wind Project in Wisconsin. USA. The weather conditions were such that there was no wind at the ground (microphone). There was no measurable wind at the microphone. Yet, the wind speeds at higher altitudes were sufficient to power the turbines which were operating throughout the wind project. The farmer whose property was used for the test stated that the turbine noise was about 'average' that night and that on other nights it was much worse.

2.6.1.1.2 The top half of this graphic shows the sound level (in dBA) rising and falling in synchronization with the rotation of the wind turbine's blades. This amplitude modulation is characteristic of wind turbine sound immissions at all wind project sites I have studied. The lower part of the chart shows the sound levels at each frequency band for the point in time shown by the



vertical line in the middle of the upper chart near the 9:49 pm label. It is clear that the low frequency content of the wind turbine's immissions is very significant and presents a potential for sleep interference inside the farmer's home. On the nights when the noise is louder the problem will be greater.

2.6.1.2 Low Frequency Sound Inside Homes

2.6.1.2.1 To address this question, I would like to use a portion of "The 'How To' Guide to Siting Wind Turbines….." in Appendix C. Please direct your attention to page 6, beginning with the second paragraph, and continue through to the end of the second paragraph on page 11. That paragraph concludes Section II of the manuscript. In this section Mr. Kamperman and I give a detailed example of how the low frequency content of wind turbine immissions can affect a home's interior.

2.6.1.3 Appropriate limits for sounds outside homes

2.6.1.3.1 There are several references in the reports and studies from Mill Creek's noise and health experts that reference the World Health Organization (WHO) as a source of support for their opinions. Many of these reference a specific statement about the need to keep outside sounds from penetrating into bedrooms and raising sound levels above 30dBA. These references typically imply that wind turbine sound levels of 45 dBA outside a home will be protective of the person sleeping inside because homes will reduce exterior sound levels by 15 dBA. Dr. Trevathan also addresses this issue in a manner with which I am in agreement.

2.6.1.3.2 As discussed above and in the manuscript of Appendix C this use of WHO is specious, argument. It relies on the listener not knowing that the second part of the WHO statement cautions that this 'rule of thumb' only applies when the noise source's immissions are predominantly in the mid-to-high frequency range. It also relies on the listener not knowing that the sounds from turbines that do penetrate the home's walls and roof are the ones in the low frequency range.

2.6.1.3.3 The question of what WHO recommends for wind turbines was asked by one of the people in the US living near a wind project who had heard this claim from the local wind project operator. The response from WHO is provided in Appendix D. In this email, the caution about lower levels being required if there is low frequency content to the sounds outside the home. This is characteristic of wind turbine noise.

2.6.1.3.4 It is my opinion that there is a need for sound levels outside the home to be limited to 35 dBA in order to account for the low frequency sound penetrating the home's exterior.

2.6.1.3.5 The claim made that WHO supports higher exterior sound levels is a misinterpretation of the WHO guidelines that masks the true nature of the sleep disturbance potential of wind turbine sound immissions while providing a false sense of comfort that the wind turbines will not interfere with sleep 'according to WHO.'

2.6.1.4 WHO may have no policy on wind turbines, but they do have a policy on noise sources outside homes when there is significant low frequency content. And, that is to use C-Weighting to determine whether the outdoor noise is adequately shielded by the home's walls and roof. Yet, these qualifiers are seldom mentioned in noise studies and health statements for wind project developers.

2.7 Computer Model Accuracy

2.7.1 As one may conclude from my biographical information and the Business Week article on my early experiences with using computer models, I am personally aware of the issues related to using computer model predictions for assessing whether a new industrial noise source will meet or exceed a community's noise limits. I have faced this situation myself. One of my deepest held opinions, based on over 35 years of being an advocate for this approach, is that they are not accurate enough to directly apply the results without qualifications when determining compliance with criteria.

2.7.2 This is not to say that there are not computer models that are very accurate. But, those models, such as the ones used for traffic noise and airport noise predictions, have been tested for accuracy and adjusted as needed to demonstrate their validity for the specific types of sound sources. They have been independently validated.

2.7.2.1 This validation process is not the same as when the company that constructs the model does its own follow-up studies or when another company working for the same industry does so. I can assure you from my own experience, given the opportunity to validate one's own work the results will most likely "prove" that the model was accurate. I remember this was one of the challenges made to my own work by others interviewed for the Business Week article. Validation requires independent confirmation of the model's accuracy in an open and peer reviewed process.

2.7.2.2 Models of wind turbines have not been subjected to such external validation. For a model's results to be accepted as precise enough to use for determining compliance or for land-use compatibility analysis requires extensive independent, open, peer reviewed research. This has not been performed for wind turbine models. There is an effort underway in the EU to construct and validate such a model but it is not the one used for Mill Creek.

2.7.3 The results of computer models used to predict sound propagation from wind turbines should be not be used as though they were replacements for precision sound measurement equipment testing a 'real world' wind project. It is worth noting that when a measurement is taken with even the most precise sound measurement instruments the tolerances of the instrument are disclosed and applied to the measurement results. A Type I instrument, for example, will have a tolerance of +/- 1dB across its measurement frequency range. Results are reported as 40 dB +/- 1 dB.

2.7.3.1 The results from the computer's model also require corrections for tolerances introduced by the algorithms used, the data that is input, and the conditions that cannot be considered in the model. Without such full disclosure of the assumptions that went into creating the model, the assumptions that could not be modeled, and allowances for the accuracy tolerances of the formulas used in the prediction process the results reported should be considered as indicative of the impact of the wind farm, but nothing more.

2.7.4 I will not repeat the testimony of Dr. Trevathan on the Mill Creek models, but I will state that I fully support his analysis. I have often provided similar testimony at hearings where I am asked to review a wind project developer's application and noise study. As Dr. Trevathan's testimony shows the accuracy of the information used as input into the model (the sound power data, L_w, derived under IEC 61400–11) is not precise and requires that tolerances be considered to account for limits to measurement accuracy from procedures and instrument-ation. It should also include the tolerances for uncertainties disclosed in the ISO 9613-2 standard for modeling sound propagation. And finally, it should include tolerances for the reasonable uncertainty in the sound level due to weather conditions and meteorological conditions that deviate from the very simple mild conditions that are assumed in the formulas used in the iso-9613 standard.

2.7.5 In my opinion, these tolerances should be added to the predicted sound levels increasing the predicted values by ten (10) to eleven (11) dBA.

3 My Recommendations

3.0 As I suggested at the beginning of my testimony, I recommend that criteria of the type developed by myself and Mr. Kamperman be applied to the Mill Creek wind project. See Page 10 of Noise-Con 2008 paper in Appendix B, and Sections V. through VII of the manuscript in Appendix C for details of the criteria and how to use them in a noise standard. It is important to include the dBC limits in the criteria to protect public health.

3.1 If this is not possible, I would recommend that the turbines identified in Dr. Trevathan's testimony for removal be eliminated, as he recommends. In addition, I would recommend that the remaining wind turbines that are within 2km of a home be restricted from operating during nighttime hours.

3.2 I also recommend that the values that I have provided for background sound levels (19-25 dBA) and the adjustments for modeling uncertainties and other tolerances be applied to the Mill Creek model's predicted levels, increasing them by 10-11 dBA.

3.3 Thank you for the opportunity to present my understanding of the issues I have addressed, my opinions and recommendations.

Appendices

Appendix A

- Narrative of Career
- Detailed Bio
- Business Week article

E-Coustic Solutions

Noise Control • Sound Measurement • Consultation
Community • Industrial • Residential • Office • Classroom • HIPPA Oral Privacy
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Principal
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Mr. Richard James is the Principal Consultant for E-Coustic Solutions, of Okemos, Michigan. Mr. James is an acoustical engineer with over 35 years of experience addressing community noise for new and existing industrial and commercial facilities. He is a Full Member of the Institute of Noise Control Engineers. He first joined the Institute in 1973.

Mr. James is the former President of James, Anderson & Associates, Inc., an acoustical consulting firm whose clients included Fortune 100 companies for 23 years. The company grew from the original two partners to a staff of over 40 acoustical engineers, industrial hygienists and technicians. As President, and Principal Consultant, he and his staff developed partnerships with companies such as: General Motors, Ford, Chrysler, Goodyear Rubber Company, Anheuser Busch and Deer and Company, as well as many smaller firms. Services included consulting on community noise issues for existing plants where neighbor's complaints have led to governmental actions against the firms or site selection and planning for new facilities to determine compatibility of the proposed facility and the existing neighborhood.

Mr. James has personally conducted studies throughout the U.S. and Europe for his firm's clients. One of these jobs involved working on behalf of GM over a ten year period to change the Illinois EPA Noise Standard to require a one (1) hour L_{eq} measurement to assess a possible violation of the IEPA Noise Section 901 standards (see Section 900.103(b)). In 2006, Mr. James and his partner, Robert Anderson, closed James, Anderson and Associates, Inc. Mr. James now provides his consulting services through his new firm: E-Coustic Solutions.

In addition to his consulting interests, Mr. James has served as Adjunct to Michigan State University's Department of Communicative and Disorders for 20 years. Until 2006, Mr. James was a voting member of the American National Standards Institute's S12 Committee with oversight responsibilities for acoustical test methods and procedures used to standardize the work of acousticians and noise control engineers for measuring sound and assessing Land-Use-Compatibility.

Since 2006, when the first major wind turbine projects were announced in Michigan, Mr. James has become more involved with this relatively new industrial noise source. His work includes developing siting criteria for county and township governments, conducting acoustical tests of operating wind turbines and pre-construction background sound studies, providing testimony at zoning hearings and public presentations concentrating mainly on Michigan, Ohio, Wisconsin, Illinois , West Virginia, and Pennsylvania. He also has clients in other states, plus the U.K. and New Zealand.

BIOGRAPHICAL SKETCH

NAME	POSITION TITLE	BIRTHDATE
Richard R. James	Principal Consultant, E-Coustic Solutions	3/3/48
	Adjunct Instructor, Michigan State University	

EDUCATION

INSTITUTION	DEGREE	YEAR	FIELD OF STUDY
General Motors Institute, Flint, MI	B. Mech. Eng.	1971	Noise Control Engineering

RESEARCH AND PROFESSIONAL EXPERIENCE:

Richard R. James has been actively involved in the field of noise control since 1969, participating in and supervising research and engineering projects related to control of occupational and community noise in industry. In addition to his technical responsibilities as principal consultant, he has developed noise control engineering and management programs for the automotive, tire manufacturing, and appliance industries. Has performed extensive acoustical testing and development work in a variety of complex environmental noise problems utilizing both classical and computer simulation techniques. In 1975 he co-directed (with Robert R. Anderson) the development of SOUND™, an interactive acoustical modeling computer software package based on the methods that would be later codified in ISO 9613-2 for pre and post-build noise control design and engineering studies of in-plant and community noise. The software was used on projects with General Motors, Ford Motor Company, The Goodyear Tire & Rubber Co., and a number of other companies for noise control engineering decision making during pre-build design of new facilities and complaint resolution at existing facilities. The SOUND™ computer model was used by Mr. James in numerous community noise projects involving new and existing manufacturing facilities to address questions of land-use compatibility and the effect of noise controls on industrial facility noise emissions. He is also the developer of ONE*dB(tm) software. He was also a co-developer (along with James H. Pyne, Staff Engineer GM AES) of the Organization Structured Sampling method and the Job Function Sound Exposure Profiling Procedure which in combination form the basis for a comprehensive employee risk assessment and sound exposure monitoring process suitable for use by employers affected by OSHA and other governmental standards for occupational sound exposure. Principal in charge of JAA's partnership with UAW, NIOSH, Ford, and Hawkwa on the HearSaf 2000tm software development CRADA partnership for world-class hearing loss prevention tools.

1966-1970	Co-operative student: General Motors Institute and Chevrolet Flint Metal Fabricating Plant.
1970-1971	GMI thesis titled: "Sound Power Level Analysis, Procedure and Applications". This thesis presented a method for modeling the effects of noise controls in a stamping plant. This method was the basis for SOUND™.
1970-1972	Noise Control Engineer-Chevrolet Flint Metal Fabricating Plant. Responsible for developing and implementing a Noise Control and Hearing Conservation Program for the Flint Metal Fabricating Plant. Member of the GM Flint Noise Control Committee which drafted the first standards for community noise, GM's Uniform Sound Survey Procedure, "Buy Quiet" purchasing specification, and guidelines for implement-ing a Hearing Conservation Program.
1972-1983	Principal Consultant, Total Environmental Systems, Inc.; Lansing, MI. Together with Robert R. Anderson formed a consulting firm specializing in community and industrial noise control.
1973-1974	Consultant to the American Metal Stamping Association and member firms for in-plant and community noise.
1973	Published: "Computer Analysis and Graphic Display of Sound Pressure Level Data For Large Scale Industrial Noise Studies", Proceedings of Noise-Con '73, Washington D.C.. This was the first paper on use of sound level contour 'maps' to represent sound levels from computer predictions and noise studies.
Nov. 1973	Published: "Isograms Show Sound Level Distribution In Industrial Noise Studies", Sound&Vibration Magazine
1975	Published: "Computer Assisted Acoustical Engineering Techniques", Noise-Expo 1975, Atlanta, GA which advanced the use of computer models and other computer-based tools for acoustical engineers.
1976	Expert Witness for GMC at OSHA Hearings in Washington D.C. regarding changes to the "feasible control" and cost-benefit elements of the OSHA Noise Standard. Feasibility of controls and cost-benefit were studied for the GMC, Fisher Body Stamping Plant, Kalamazoo MI.
1977-1980	Principal Consultant to GMC for the use of SOUND(tm) computer simulation techniques for analysis of design, layout, and acoustical treatment options for interior and exterior noise from a new generation of assembly plants. This study started with the GMAD Oklahoma City Assembly Plant. Results of the study were used to refine noise control design options for the Shreveport, Lake Orion, Bowling Green plants and many others.
1979-1983	Conducted an audit and follow-up for all Goodyear Tire & Rubber Company's European and U.K. facilities for community and in-plant noise.

1981-1985	Section Coordinator/Speaker, Michigan Department Of Public Health, "Health in the WorkPlace" Conference.
1981	Published: "A Practical Method For Cost-Benefit Analysis of Power Press Noise Control Options", Noise-Expo 1981, Chicago, Illinois
1981	Principal Investigator: Phase III of Organization Resources Counselors (ORC), Washington D.C., Power Press Task Force Study of Mechanical Press Working Operations. Resulted in publishing: "User's Guide for Noise Emission Event Analysis and Control", August 1981
1981-1991	Consultant to General Motors Corporation and Central Foundry Division, Danville Illinois in community noise citation initiated by Illinois EPA for cupola noise emissions. Resulted in a petition to the IEPA to change state-wide community noise standards to account for community response to noise by determining compliance using a one hour L_{eq} instead of a single not-to-exceed limit.
1983	Published: "Noise Emission Event Analysis-An Overview", Noise-Con 1983, Cambridge, MA
1983-2006	Principal Consultant, James, Anderson & Associates, Inc.; Lansing, MI. (JAA), Together with Robert R. Anderson formed a consulting firm specializing in Hearing Conservation, Noise Control Engineering, and Program Management.
1983-2006	Retained by GM Advanced Engineering Staff to assist in the design and management of GM's on-going community noise and in-plant noise programs.
1984-1985	Co-developed the 1985 GM Uniform Plant Sound Survey Procedure and Guidelines with James H. Pyne, Staff Engineer, GM AES.
1985-Present	**Adjunct Instructor, Michigan State University, Department of Communicative Sciences and Disorders**
1986-1987	Principal Consultant to Chrysler Motors Corporation, Plant Engineering and Environmental Planning Staff. Conducted Noise Control Engineering Audits of all manufacturing and research facilities to identify feasible engineering controls and development of a formal Noise Control Program.
1988-2006	Co-Instructor, General Motors Corporation Sound Survey Procedure (Course 0369)
1990	Developed One*dB(tm), JAA's Occupational Noise Exposure Database manager to support Organizational structured sampling strategy and Job Function Profile (work-task) approach for sound exposure assessment.
1990-1991	Co-developed the 1991 GM Uniform Plant Sound Survey Procedure and Guidelines with James H. Pyne, Staff Engineer, GM AES. Customized One*dB(tm) software to support GM's program.
1990-2006	Principal Consultant to Ford Motor Company to investigate and design documentation and computer data management systems for Hearing Conservation and Noise Control Engineering Programs. This included bi-annual audits of all facilities.
1993-2006	GM and Ford retain James and JAA as First-Tier Partners for all non-product related noise control services.
1993	Invited paper: "An Organization Structured Sound Exposure Risk Assessment Sampling Strategy" at the 1993 AIHCE
1993	Invited paper: "An Organization Structured Sound Exposure Risk Assessment Database" at the Conference on Occupational Exposure Databases, McLean, VA sponsored by ACGIH
1994-2001	Instructor for AIHA Professional Development Course, "Occupational Noise Exposure Assessment"
1996	Task Based Survey Procedure (used in One*dB(tm)) codified as part of ANSI S12.19 Occ. Noise Measurement
1995-2001	Coordinate JAA's role in HearSaf 2000tm CRADA with NIOSH, UAW,Ford, and HAWKWA
1997-Present	Board Member, Applied Physics Advisory Board, Kettering Institute, Flint Michigan
2002-2006	Member American National Standards Accredited Standards (ANSI) Committee S12, Noise
2005-Present	Consultant to local communities and citizens groups on proper siting of Industrial Wind Turbines. This includes presentations to local governmental bodies, assistance in writing noise standards, and formal testimony at zoning board hearings and litigation.
2006	Founded E-Coustic Solutions
2008	Paper on "Simple guidelines for siting wind turbines to prevent health risks" for INCE Noise-Con 2008, co-authored with George Kamperman, Kamperman Associates.
2008	Expanded manuscript supporting Noise-Con 2008 paper titled: "The "How To" Guide To Siting Wind Turbines To Prevent Health Risks From Sound"

PROFESSIONAL AFFILIATIONS/MEMBERSHIPS

Research Fellow - Metrosonics, Inc.
National Hearing Conservation Association (past)
American National Standards S12 Working Group (past)
American Industrial Hygiene Association (past)
Institute of Noise Control Engineers (Full Member)

Computers to quiet the factory

Ever since the Occupational Safety & Health Administration (OSHA) adopted industrial noise standards in 1971, plant engineers have been struggling to reduce the ear-piercing din in factories. But it is a tough job. The hundreds of machines inside a factory produce different sounds, each of which interacts differently with nearby equipment and partitions. Even skilled acoustical engineers often misjudge the effort needed to get down to the noise level the government permits. And because noise control is often expensive, mistakes can be costly.

Now, however, many corporations are turning to computer models to make sure their noise-control efforts will be cost-effective. Spurred by the falling cost of computer time and the high price of noise control, companies are using models to ensure that newly built plants will comply with OSHA noise rules. Managers are also using computers to test whether modifications of an existing plant will actually reduce noise. And executives are finding that models enable them to contest ineffective noise-control measures proposed by the government.

The computer's advantage. A noise model is based on equations that state in mathematical form the same laws of physics that consultants have traditionally used to forecast sound levels. These equations predict, for example, the effects of bouncing sound off a wall or absorbing it in acoustical tile. To apply a model to a particular plant, a consultant first measures the several different noises emitted by each machine, then records the size, nature, and placement of noise barriers such as walls and ceilings. When these data are fed into the noise model, engineers can get information about the noise level anywhere in the plant.

Without the computer, a noise consultant must calculate intuitively. The advantage of having a model is in being able to track interactions among a larger number of variables to predict the noise level at each station. A model developed by Total Environmental Systems Inc. in East Lansing, Mich., can cope with 3,500 noise sources and 250 partitions. "There are no more than 10 people in the country who can intuitively evaluate 100 variables," says Richard R. James, TES vice-president.

Many company officials are enthusiastic about the success of these models. Using a computer model developed by TES, General Motors Corp. found that it could slash by 25% its expected use of noise-reducing material in the body-fabricating area of its new Oklahoma City assembly plant. Tests made after the plant was built showed that the model had predicted the actual noise level in the plant to within 2 decibels, a high degree of accuracy. "We can't afford trial and error," notes Woodford L. Van Tifflin, the engineer who oversees GM's noise control system.

Peter Yates

Engineers James and Van Tifflin: Using models to plan noise control.

Costs. The average machine shop could not afford the $50,000 it cost GM to have TES model a 750,000-sq.-ft. portion of its Oklahoma City plant. The TES prices for less complex jobs start at $18,000. But even clients paying the highest fees say that the savings from modeling more than cover the costs. "Modeling prices are not out of line," argues Robert F. Birdsall, a Ford Motor Co. environmental engineer. Ford recently completed noise modeling for its new Batavia (Ohio) transaxle plant, slated to be in production by the 1981 model year.

Most of the modeling of existing plants is aimed at preventing OSHA citations for excessive noise. But modeling also helps a company fight alleged violations of noise standards. Stanadyne Inc. in Windsor, Conn., recently used a model to show that the government overstated—by a factor of 20—the effectiveness and thus the feasibility of noise control measures that it claimed Stanadyne should have used at its Bellwood (Ill.) plant to keep workers from being exposed to more than 90 decibels. The model's results played a key role in a judge's Dec. 28 decision in favor of the company, claims Stanadyne's attorney, Columbus R. Gangemi Jr. Testimony based on a model "is easier for the court to understand and easier to defend" than traditional expert testimony based on engineering analysis alone, he says.

Saving time. In addition to eliminating the cost of unnecessary or ineffective noise-control measures, modeling husbands executive time. The model can generate a noise map of a new plant using colors and contour lines to indicate the sound level at each worker station. Additional maps then can display the impact of various noise-reduction strategies. So, rather than having to wade through statistical tables or try to follow complex oral explanations, managers can see at a glance what areas in the plant have noise problems and the effect of potential solutions. "It puts complex information into a meaningful summary," says Ford's Birdsall.

Although users of noise modeling are enthusiastic, there is still some skepticism in the acoustical consulting community. These doubts persist despite the widespread use of modeling to cope with other forms of industrial pollution (BW—Oct. 29). "It could be a gimmick," says Paul Jensen, manager of the industrial noise division at Bolt Beranek & Newman, an acoustical consulting firm in Cambridge, Mass. Jensen contends that it is more important to consider the worker. "The problem with the model is that it doesn't say a darn thing about the worker—where he is, how he moves in and out of noisy areas."

Many other consultants, though, contend that Jensen overstates the case against modeling. "We use it successfully for companies having 5 to 1,000 employees," counters Thomas D. Miller, vice-president of Donley, Miller & Nowikas Inc. in East Hanover, N. J. But he cautions that modeling, like any mathematical simulation, is only as valid as the data base and operating assumptions on which it is built. ■

Appendix B
Noise-Con 2008 Paper

VIII. Noise-Con 2008 Paper

Dearborn, Michigan

NOISE-CON 2008

2008 July 28-31

Simple guidelines for siting wind turbines to prevent health risks[22]

By:

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Revision: 1.2

Industrial scale wind turbines are a familiar part of the landscape in Europe, U.K. and other parts of the world. In the U.S., however, similar industrial scale wind energy developments are just beginning operation. The presence of industrial wind projects will increase dramatically over the next few years given the push by the Federal and state governments to promote renewable energy sources through tax incentives and other forms of economic and political support. States and local governments in the U.S. are promoting what appear to be lenient rules for how industrial wind farms can be located in communities, which are predominantly rural and often very quiet. Studies already completed and currently in progress describe significant health effects associated with living in the vicinity of industrial grade wind turbines. This paper reviews sound studies conducted by consultants for governments, the wind turbine owner, or the local residents for a number of sites with known health or annoyance problems. The purpose is to determine if a set of simple guidelines using dBA and dBC sound levels can serve as the 'safe' siting guidelines. Findings of the review and recommendations for sound limits will be presented. A discussion of how the proposed limits would have affected the existing sites where people have demonstrated pathologies apparently related to wind turbine sound will also be presented.

Background

A relatively new source of community noise is spreading rapidly across the rural U.S. countryside. Industrial grade wind turbines, a common sight in many European countries, are now being promoted by Federal and state governments as the way to minimize coal powered electrical energy and its effects on global warming. But, the initial developments using the newer 1.5 to 3 MWatt wind turbines here in the U.S. has also led to numerous complaints from residents who find themselves no longer in the quiet rural communities they were living in before the wind turbine developments went on-line. Questions have been raised about whether the current siting guidelines being used in the U.S. are sufficiently protective for the people living closest to the developments. Research being conducted into the health issues using data from established wind turbine developments is beginning to appear that supports the possibility there is a basis for the health concerns. Other research into the computer modeling and other methods used for determining the layout of the industrial wind turbine developments and the distances from residents in the adjacent communities are showing that the output of the models should not be considered accurate enough to be used as the sole basis for making the siting decisions.

The authors have reviewed a number of noise studies conducted in response to community complaints for wind energy systems sited in Europe, Canada, and the U.S. to determine if additional criteria are needed for establishing safe limits for industrial wind turbine sound immissions in rural communities. In several cases, the residents who filed the complaints have been included in studies by medical researchers who are investigating the potential health risks associated with living near industrial grade wind turbines 365 days a year. These studies were also reviewed by the authors to help in identifying what factors need to be considered in setting criteria for 'safe' sound limits at receiving properties. Due to concerns about medical privacy, details of these studies are not discussed in this paper. Current standards used in the U.S. and in most other parts of the world rely on not-to-exceed dBA sound levels, such as 50 dBA, or on not-to-exceed limits based on the pre-construction background sound level plus an adder (e.g. L_{90A} + 5 dBA).

Our review covered the community noise studies performed in response to complaints, research on health issues related to wind turbine noise, critiques of noise studies performed by consultants working for the wind developer, and research/technical papers on wind turbine sound immissions and related topics. The papers are listed in Tables 1-4.

Table 1-List of Studies Related to Complaints

Resource Systems Engineering, Sound Level Study – Ambient & Operations Sound Level Monitoring, Maine Department of Environmental Protection Order No. L-21635-26-A-N, June 2007
ESS Group, Inc., Draft Environmental Impact Statement For The Dutch Hill Wind Power Project – Town of Cohocton, NY, November 2006
David M. Hessler, Environmental Sound Survey and Noise Impact Assessment – Noble Wethersfield Wind park – Towns of Wethersfield and Eagle NY For: Noble Environmental Power, LLC January 2007
George Hessler, "Report Number 101006-1, Noise Assessment Jordanville Wind Power Project," October 2006
HGC Engineering, "Environmental Noise Assessment Pubnico Point Wind Farm, Nova Scotia, Natural Resources Canada Contract NRCAN-06-0046," August 23, 2006
John I. Walker, Sound Quality Monitoring, East Point, Prince Edward Island" by Jacques Whitford, Consultants for Prince Edward Island Energy Corporation, May 28, 2007

Table 2- List of Studies related to Health

Nina Pierpont, "Wind Turbine Syndrome – Abstract" from draft article and personal conversations. www.ninapierpont.com
Nina Pierpont, "Letter from Dr. Pierpont to a resident of Ontario, Canada, re: Wind Turbine Syndrome," Autumn 2007
Amanda Harry, "Wind Turbine Noise and Health" (2007)
Barbara J. Frey and Peter J. Hadden, "Noise Radiation from Wind Turbines Installed Near Homes, Effects on Health" (2007)
Eja Pedersen, "Human response to wind turbine noise – Perception, annoyance and moderating factors, Occupational and Environmental Medicine," The Sahlgrenska Academy, Gotenborg 2007
Robin Phipps, "In the Matter of Moturimu Wind Farm Application, Palmerston North, Australia," March 2007
WHO European Centre for Environment and Health, Bonn Office, "Report on the third meeting on night noise guidelines," April 2005

Table 3-List of Studies that review Siting Impact Statements

Richard H. Bolton, "Evaluation of Environmental Noise Analysis for 'Jordanville Wind Power Project,'" December 14, 2006 Rev 3.
Clifford P. Schneider, "Accuracy of Model Predictions and the Effects of Atmospheric Stability on Wind Turbine Noise at the Maple Ridge Wind Power Facility," Lowville, NY – 2007

Table 4-List of Research and Technical papers included in review process

Anthony L. Rogers, James F. Manwell, Sally Wright, "Wind Turbine Acoustic Noise," Renewable Energy Research Laboratory, Dept. of ME and IE, U of Mass, Amherst, amended June 2006
ISO. 1996. Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation. International Organization of Standardization. ISO 9613-2. p. 18.
G.P. van den Berg, "The Sounds of High Winds – the effect of atmospheric stability on wind turbine sound and microphone noise," Ph.D. thesis, 2006
Fritz van den Berg, "Wind Profiles over Complex Terrain," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
William K. G. Palmer, "Uncloaking the Nature of Wind Turbines-Using the Science of Meteorology," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
Soren Vase Legarth, "Auralization and Assessment of Annoyance from Wind Turbines," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
Julian T. and Jane Davis, "Living with aerodynamic modulation, low frequency vibration

and sleep deprivation - how wind turbines inappropriately placed can act collectively and destroy rural quietitude," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
James D. Barnes, "A Variety of Wind Turbine Noise Regulations in the United States - 2007," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
M. Schwartz and D. Elliott, Wind Shear Characteristics at Central Plains Tall Towers, NREL 2006
IEC 61400 "Wind turbine generator systems, Part 11: Acoustic noise measurement techniques,".rev:2002

Discussion

After reviewing the materials in the tables; we have arrived at our current understanding of wind turbine noise and its impact on the host community and its residents. The review showed that some residents living as far as 3 km (two (2) miles) from a wind farm complain of sleep disturbance from the noise. Many residents living one-tenth this distance (300 m. or 1000 feet) from a wind farm are experiencing major sleep disruption and other serious medical problems from nighttime wind turbine noise. The peculiar acoustic characteristics of wind turbine noise immissions cause the sounds heard at the receiving properties to be more annoying and troublesome than the more familiar noise from traffic and industrial factories. Limits used for these other community noise sources do not appear to be appropriate for siting industrial wind turbines. The residents who are annoyed by wind turbine noise complain of the approximately one (1) second repetitive swoosh-boom-swoosh-boom sound of the turbine blades and "low frequency" noise. It is not apparent to these authors whether the complaints that refer to "low frequency" noise are about the audible low frequency part of the swoosh-boom sound, the one hertz amplitude modulation of the swoosh-boom sound, or some combination of both acoustic phenomena.

To assist in understanding the issues at hand, the authors developed the 'conceptual' graph for industrial wind turbine sound shown in Figure 1. This graph shows the data from one of the complaint sites plotted against the sound immission spectra for a modern 2.5 MWatt wind turbine; Young's threshold of perception for the 10% most sensitive population (ISO 0266); and a spectrum obtained for a rural community during a three hour, 20 minute test from 11:45 pm until 3:05 am on a windless June evening in near Ubly, Michigan a quiet rural community located in central Huron County. (Also called: Michigan's "Thumb.") It is worth noting that this rural community demonstrates how quiet a rural community can be when located at a distance from industry, highways, and airport related noise emitters.

During our review we posed a number of questions to ourselves related to what we were learning. The questions (italics) and our answers are:

Do National or International or local community Noise Standards for siting wind turbines near dwellings address the low frequency portion of the wind turbine's sound immissions?[23] No! State and Local governments are in the process of establishing wind farm noise limits and/or wind turbine

[23] Emissions refer to acoustic energy from the 'viewpoint' of the sound emitter, while immissions refer to acoustic energy from the viewpoint of the receiver.

setbacks from nearby residents, but the standards incorrectly presume that limits based on dBA levels are sufficient to protect the residents.

Do wind farm developers have noise limit criteria and/or wind turbine setback criteria that apply to nearby residents? Yes! But the Wind Industry recommended residential wind turbine noise levels (typically 50-55 dBA) are too high for the quiet nature of the rural communities and may be unsafe for the nearest residents. An additional concern is that some of the methods for implementing pre-construction computer models may predict sound levels that are too low. These two factors combined can lead to post-construction complaints and health risks.

Are all residents living near wind farms equally affected by wind turbine noise? No, children, people with pre-existing medical conditions, especially sleep disorders, and the elderly are generally the most susceptible. Some people are unaffected while some nearby neighbors develop serious health effects caused by exposure to the same wind turbine noise.

How does wind turbine noise impact nearby residents? Initially, the most common problem is chronic sleep deprivation during nighttime. According to the medical research documents, this may develop into far more serious physical and psychological problems

What are the technical options for reducing wind turbine noise immission at residences? There are only two options: 1) increase the distance between source and receiver, and/or 2) reduce the source sound power immission. Either solution is incompatible with the objective of the wind farm developer to maximize the wind power electrical generation within the land available.

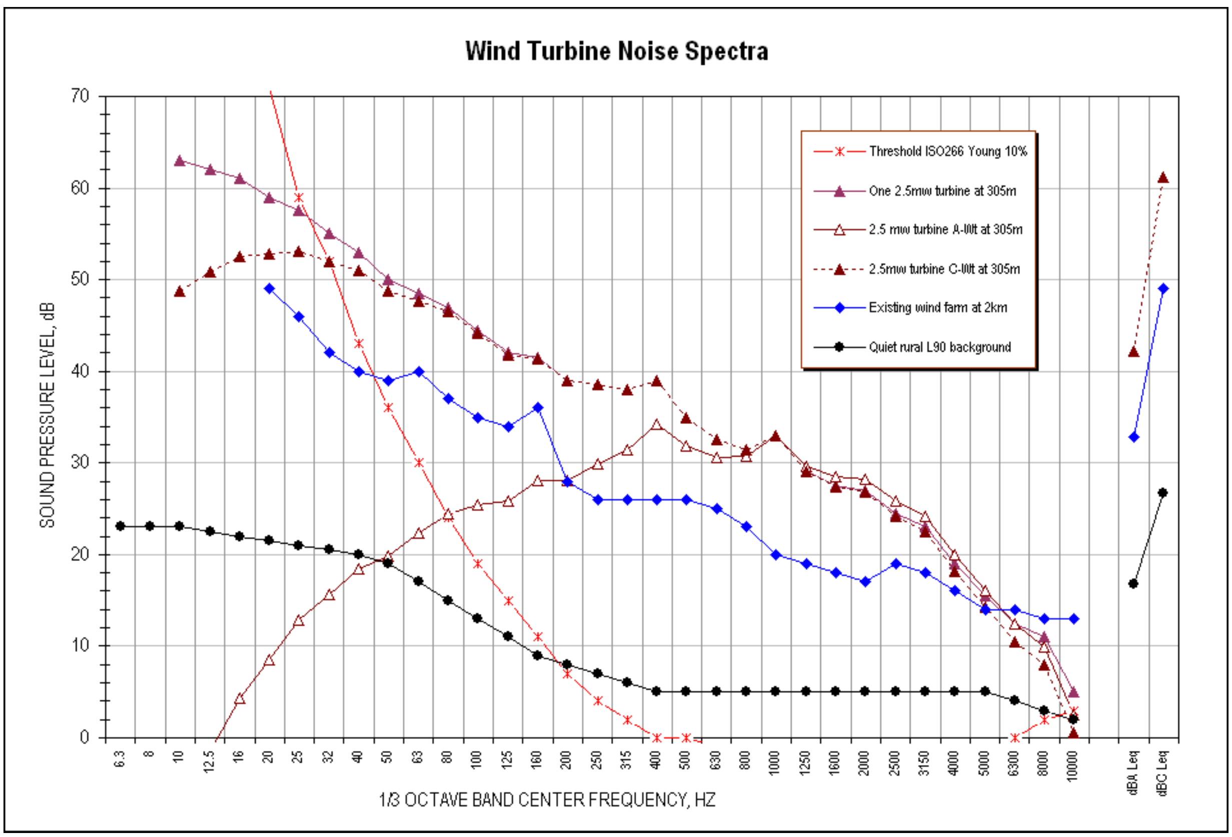

Figure 1-Generalized Sound Spectra vs. perception and rural community L_{90A} background 1/3 octave SPL

Is wind turbine noise at a residence much more annoying than traffic noise? Yes, researchers have found that "Wind turbine noise was perceived by about 85% of the respondents even when the calculated A-weighted SPL were as low as 35.0–37.5 dB. This could be due to the presence of amplitude modulation in the noise, making it easy to detect and difficult to mask by ambient noise." [JASA 116(6), December 2004, pgs 3460-3470, "Perception and annoyance due to wind turbine noise-a dose-relationship" Eja Pedersen and Kerstin Persson Waye, Dept of Environmental Medicine, Goteborg University, Sweden]

Why do wind turbine noise immissions of only 35 dBA disturb sleep at night? This issue is now being studied by the medical profession. The affected residents complain of the middle to high frequency swooshing sounds of the rotating turbine blades at a constant repetitive rate of about 1 hertz plus low frequency noise. The amplitude modulation of the swooshing sound changes continuously. The short time interval between the blade's swooshing sounds described by residents as sometimes having a thump or low frequency banging sound that varies in amplitude up to 10 dBA. This may be a result of phase changes between turbine emissions, turbulence, or an operational mode.. The assumptions about wall and window attenuation being 15 dBA or more may not be sufficiently protective considering the relatively high amplitude of the wind turbine's low frequency immission spectra.

What are the typical wind farm noise immission criteria or standards? Limits are not consistent and may vary even within a particular country. Example criteria include: Australia-the lower of 35 dBA or L_{90} + 5 dBA, Denmark-40 dBA, France L_{90} + 3 (night) and L_{90} + 5 (day), Germany-40 dBA, Holland-40 dBA, United Kingdom-40 dBA (day) and 43 dBA (night) or L_{90} + 5 dBA, Illinois-55 dBA (day) and 51 dBA (night), Wisconsin-50 dBA and Michigan-55 dBA. Note: Illinois statewide limits are expressed only in nine contiguous octave frequency bands and no mention of A-weighting for the hourly l_{eq} limits. Typically, wind turbine noise just meeting the octave band limits would read 5 dB below the energy sum of the nine octave bands after applying A-weighting. So the Illinois limits are approximately 50 dBA (daytime 7 AM to 10 PM) and 46 dBA at night, assuming a wind farm is a Class C Property Line Noise Source.

What is a reasonable wind farm sound immission limit to protect the health of residences? We are proposing an immission limit of 35 dBA or L_{90A} + 5 dBA whichever is lower and also a C-weighted criteria to address the impacted resident's complaints of wind turbine low frequency noise: For the proposed criteria the dBC sound level at a receiving property shall not exceed L_{90A} + 20dB. In other words, the dBC operating immission limit shall not be more than 20 dB above the measured dBA (L_{90A}) pre-construction nighttime background sound level. A maximum not-to-exceed limit of 50 dBC is also proposed.

Why should the dBC immission limit not be permitted to be more than 20 dB above the background measured L_{90A}? The World Health Organization and others have determined a sound emitter's noise that results in a difference between the dBC and dBA value greater than 20 dB will be an annoying low frequency issue.

Is not L_{90A} the minimum dBA background noise level? This is correct, but it is very important to establish the statistical average background noise environment outside a potentially impacted residence during the quietest (10 pm to 4 am) sleeping hours of the night. This nighttime sleep disturbance has generated the majority of the wind farm noise complaints throughout the world. The basis for a community's wind turbine sound immission limits would be the minimum 10 minute nighttime L_{90A} plus 5 dB for the time period of 10 pm to 7 am. This would become the Nighttime Immission Limits for the proposed wind farm. This can be accomplished with one or several 10 minute measurements during any night when the atmosphere is classified stable with a light wind from the area of the proposed wind farm. The Daytime Limits (7 am to 7 pm) could be set 10 dB above the minimum nighttime L_{90A} measured noise, but the nighttime criteria will always be the limiting sound levels.

A nearby wind farm meeting these noise immission criteria will be clearly audible to the residents occasionally during nighttime and daytime. Compliance with this noise standard would be determined by repeating the initial nighttime minimum nighttime L_{90A} tests and adding the dBC (L_{eqC}) noise measurement with the turbines on and off. If the nighttime background noise level (turbines off) was found to be slightly higher than the measured background prior to the wind farm installation, then the results with the turbines on must be corrected to determine compliance with the pre-turbine established sound limits.

The common method used for establishing the background sound level at a proposed wind farm used in many of the studies in Table 1 was to use unattended noise monitors to record hundreds of ten (10) minute measurements to obtain a statistically significant sample over varying wind conditions or a period of weeks. The measured results for daytime and nighttime are combined to determine the statically average wind noise as a function of wind velocity measured at a height of ten (10) meters. This provides an enormous amount of data but the results have little relationship to the wind turbine sound immission or turbine noise impact in nearby residents. The purpose of this exhaustive exercise often only demonstrates how much noise is generated by the wind. In some cases it appears that the data is used to 'prove' that the wind noise masks the turbine's sound immissions.

The most glaring fault with this argument is shown during the frequent nighttime conditions with a stable atmosphere when the wind turbines generate the maximum electricity and noise while the wind at ground level is calm and the background noise level is low. This is the condition of maximum turbine noise impact on nearby residents. It is the condition which most directly causes chronic sleep disruption. Furthermore, this methodology is usually faulty, as much of the wind noise measured by unattended sound monitors is the wind noise generated at the microphone windscreen resulting in totally erroneous results. (See studies in Table 3, esp. Van den Berg)

Are there additional noise data to be recorded for a pre-wind turbine noise survey near selected dwellings? Yes, The measuring sound level meter(s) need to be programmed to include measurement of L_{eqA} , L_{10A}, L_{eq90A} and L_{eqC} plus start time & date for each 10 minute sample. These results will be utilized to help validate the L_{90A} data. For example, on a quiet night one might expect L_{10A} less L_{90A} or L_{eqA} to be less than 10 dB. On a windy night or day the difference may be more than 20 dB. There is a requirement for measurement of the wind velocity near the sound measurement microphone continuously throughout each ten (10) minute recorded noise sample. The ten (10) minute average of the wind speed near the microphone shall not exceed 2 m/s (4.5 mph) and the maximum wind speed for operational tests shall not exceed 4 m/s (9 mph). It is strongly recommended that observed samples be used for these tests.

Is there a need to record weather data during the background noise recording survey? One weather monitor is required at the proposed wind farm on the side nearest the residents. The weather station sensors are at standard ten (10) meter height above ground. It is critical the weather be recorded every ten (10) minutes synchronized with the clocks in the sound level recorders without ambiguity in the start and end time of each ten (10) minute period. The weather station should record wind speed and direction, temperature, humidity and rain.

Why do Canada and some other countries base the permitted wind turbine noise immission limits on the operational wind velocity at the 10m height wind speed instead of a maximum dBA or L_{90} + 5 dBA immission level? First, it appears that the wind turbine industry will take advantage of every opportunity to elevate the maximum permitted noise immission level to reduce the setback distance from the nearby dwellings. Including wind as a masking source in the criteria is one method for elevating the permissible limits. Indeed the background noise level does increase with surface wind speed. When it does occur, it can be argued that the increased wind noise provides some masking of the wind farm turbine noise emission. However, in the middle of the night when the atmosphere is defined as stable (no vertical flow from surface heat radiation) the layers of the lower atmosphere can separate and permit wind velocities at the turbine hubs to be 2 to 2.5 times the wind velocity at the 10m high wind monitor but remain near calm at ground level. The result is the wind turbines can be operating at or close to full capacity while it is very quiet outside the nearby dwellings.

This is the heart of the wind turbine noise problem for residents within 3 km (approx. two miles) of a wind farm. When the turbines are producing the sound from operation it is quietest outside the surrounding homes. The PhD thesis of P.G. van den Berg "The Sounds of High Winds" is very enlightening on this issue. See also the letter by John Harrison in Ontario "On Wind Turbine Guidelines."

What sound monitor measurements would be needed for enforcement of the wind turbine sound ordinance? A similar sound and wind 10 minute series of measurements would be repeated at the pre-wind farm location nearest the resident registering the wind turbine noise complaint, with and without the operation of the wind turbines. An independent acoustics expert should be retained who reports to the County Board or other responsible governing body. This independent acoustics expert shall be responsible for all the acoustic measurements including instrumentation setup, calibration and interpretation of recorded results. An independent acoustical consultant shall also perform all pre-turbine background noise measurements and interpretation of results to establish the Nighttime (and Daytime if applicable) industrial wind turbine sound immission limits. At present the acoustical consultants are retained by, and work directly for, the wind farm developer.

This presents a serious problem with conflict of interest on the part of the consultant. The wind farm developer would like to show the significant amount of wind noise that is present to mask the sounds of the wind turbine immissions. The wind farm impacted community would like to know that wind turbine noise will be only barely perceptible and then only occasionally during the night or daytime.

Is frequency analysis required either during pre-wind farm background survey or for compliance measurements? Normally one-third octave or narrower band analysis would only be required if there is a complaint of tones immission from the wind farm.

Proposed Sound Limits

The simple fact that so many residents complain of low frequency noise from wind turbines is clear evidence that the single A-weighted (dBA) noise descriptor used in most jurisdictions for siting turbines is not adequate. The only other simple audio frequency weighting that is standardized and available on all sound level meters is the C-weighting or dBC. A standard sound level meter set to measure dBA is increasingly less sensitive to low frequency below 500 Hz (one octave above middle-C). The same sound level meter set to measure dBC is equally sensitive to all frequencies above 32 Hz (lowest note on grand piano). It is well known that dBC readings are more predictive of perceptual loudness than dBA readings if low frequency sounds are significant.

We are proposing to use the commonly accepted dBA criteria that is based on the pre-existing background sound levels plus a 5 dB allowance for the wind turbine's immissions (e.g. L_{90A} +5) for the audible sounds from wind turbines. But, to address the lower frequencies that are not considered in A-weighted measurements we are proposing to add limits based on dBC. The Proposed Sound Limits are presented in the text box at the end of this paper.

For the current industrial grade wind turbines in the 1.5 to 3 MWatt range, the addition of the dBC requirement will result in an increased distance between wind turbines and the nearby residents. For the generalized graphs shown in Figure 1, the distances would need to be approximately double the current distance. This will result in setbacks in the range of 1 km or greater for the current generation of wind turbines if they are to be located in rural areas where the L_{90A} background sound levels are 30 dBA or lower. In areas with higher background sound levels, turbines could be located somewhat closer, but still at a distance greater than the 305 m (1000 ft.) or less setbacks commonly seen in U.S. based wind turbine standards set by many states and used for wind turbine developments.

Proposed Wind Turbine Siting Sound Limits

1. Audible Sound Limit

a. No Wind Turbine or group of turbines shall be located so as to cause an exceedance of the pre-construction/operation background sound levels by more than 5 dBA. The background sound levels shall be the L_{90A} sound descriptor measured during a pre-construction noise study during the quietest time of evening or night. All data recording shall be a series of contiguous ten (10) minute measurements. L_{90A} results are valid when L_{10A} results are no more than 15 dBA above L_{90A} for the same time period. Noise sensitive sites are to be selected based on wind development's predicted worst-case sound emissions (in L_{eqA} and L_{eqC}) which are to be provided by the developer.

b. Test sites are to be located along the property line(s) of the receiving non-participating property(s).

c. A 5 dB penalty is applied for tones as defined in IEC 61400-11.

2. Low Frequency Sound Limit

a. The L_{eqC} and L_{90C} sound levels from the wind turbine at the receiving property shall not exceed the lower of either:

1) L_{eqC}-L_{90A} greater than 20 dB outside any occupied structure, or

2) A maximum not-to-exceed sound level of 50 dBC (L_{90C}) from the wind turbines without other ambient sounds for properties located at one mile or more from State Highways or other major roads or 55 dBC (L_{90C}) for properties closer than one mile.

These limits shall be assessed using the same nighttime and wind/weather conditions required in 1.a. Turbine operating sound immissions (L_{eqA} and L_{eqC}) shall represent worst case sound immissions for stable nighttime conditions with low winds at ground level and winds sufficient for full operating capacity at the hub.

3. General Clause

a. Not to exceed 35 dBA within 30 m. (approx. 100 feet) of any occupied structure.

4. Requirements

a. All instruments must meet ANSI or IEC Precision integrating sound level meter performance specifications.

b. Procedures must meet ANSI S12.9 and other applicable ANSI standards.

c. Measurements must be made when ground level winds are 2m/s (4.5 mph) or less. Wind shear in the evening and night often results in low ground level wind speed and nominal operating wind speeds at wind turbine hub heights.

d. IEC 61400-11 procedures are not suitable for enforcement of these requirements except for the presence of tones.

Disclaimer: Use by any party of these recommendations is strictly voluntary and the user assumes all risks.

Appendix C
"The 'How to' Guide…" Manuscript

Date: 9/2/2008

THE "HOW TO" GUIDE
TO
SITING WIND TURBINES
TO PREVENT HEALTH RISKS FROM SOUND

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"A subset of society should not be forced to bear the cost of a benefit for the larger society."[1]

I. Introduction

A new source of community noise is spreading rapidly across the rural U.S. countryside. Industrial-scale wind turbines (WTi), a common sight in many European countries, are now actively promoted by federal and state governments in the U.S. as a way to reduce coal-powered electrical generation and global warming. The presence of industrial wind projects is expected to increase dramatically over the next few years, given the tax incentives and other economic and political support currently available for renewable energy projects in the U.S.

As a part of the widespread enthusiasm for renewable energy, state and local governments are promoting what appear to be lenient rules for how industrial wind farms can be located in communities, which are predominantly rural and often very quiet. Complaints from residents near existing wind turbine installations are common, however, raising questions about whether current U.S. siting guidelines are sufficiently protective for people living close to the wind turbine developments. Research is emerging that suggests significant health effects are associated with living too close to modern industrial wind turbines. Research into the computer modeling and other methods used to determine the layout of wind turbine developments, including the distance from nearby residences, is at the same time showing that the output of the models may not be accurate enough to be used as the sole basis for siting decisions.

Our formal presentation and paper on this topic (*Simple guidelines for siting wind turbines to prevent health risks*) is an abbreviated version of this essay. The formal paper was presented to the Institute of Noise Control Engineers (INCE) at its July Noise-Con 2008 conference in Detroit, MI, A copy of the paper is included at the end of this document. The formal paper covered the community noise studies performed in response to complaints, research on health issues related to wind turbine noise, critiques of noise studies performed by consultants working for the wind developer, and research/technical papers on wind turbine sound immissions and related topics. The formal paper also reviewed sound studies conducted by consultants for governments, the wind turbine owner, or the local residents for a number of sites with known health or annoyance

[1] George S. Hawkins, Esq., "*One Page Takings Summary: U.S Constitution and Local Land Use*," Stony Brook-Millstone Watershed Association; *"…nor shall private property be taken for public use, without just compensation."* Fifth Amendment, US Constitution.

problems. The purpose was to determine if a set of simple guidelines using dBA and dBC sound levels can serve as the 'safe' siting guidelines for noise and its effects on communities and people.. The papers considered in our review included, but were not limited to, those listed in Tables 1-4 on pages 2 through 4 of the Noise-Con document.

This essay expands upon the Noise –Con paper and includes information to support the findings and recommended criteria. We are proposing very specific, yet reasonably simple to implement and assess criteria for audible and non-audible sound on adjacent properties and also present a sample noise ordinance and the procedures needed for pre-construction sound test, computer model requirements and follow-up tests (including those for assessing compliance).

The purpose of this expanded paper is to outline a rational, evidence-based set of criteria for industrial wind turbine siting in rural communities, using 1) a review of the European and other wind turbine siting criteria and existing studies of the prevalence of noise problems after construction; 2) primary review of sound studies done in a variety of locations in response to wind turbine noise complaints (Table 1); 3) review of publications to date on health issues in proximity to wind turbines (Table 2); 4) review of critiques of pre-construction developer noise impact statements (Table 3); and 5) review of technical papers on noise propagation and qualities from wind turbines (Table 4). (Tables are on pages 2-4 of the formal paper.) We also cite standard international criteria for community noise levels and allowances for low-frequency noise.

The specific sections are:

1. Introduction (This section)
2. Results of Literature Review and Sound Studies
3. Development of Siting Criteria
4. Proposed Sound Limits
5. How to Include the Recommended Criteria in Local or State Noise Ordinances
6. Elements of a Wind Energy System Licensing Ordinance
7. Measurement Procedures (Appendix to Ordinance)
8. The Noise-Con 2008 paper "Simple guidelines for siting wind turbines to prevent health risks" with revisions not in the paper included in the conference's Proceedings.

The construction of large WTi projects in the U.S. is a relatively recent phenomenon, with most projects built after 2002. Other countries, especially in Europe, have been using wind energy systems (WES) since the early 1990's or earlier. These earlier installations generally used turbines of less than 1 MW capacity with hub heights under 61 m (200 feet), but now many of these earlier turbines, reaching the end of their useful life, are being replaced with the larger 1.5 to 3 MW units. Thus the concepts and recommendations in this article, developed for the 1.5 MW and larger turbines being build in the U.S, may also be applicable abroad.

II. Results of Literature Review and Sound Studies

In the U.K. there are currently about 133 operating WTi developments. Many of these have been in operation for over 10 years. The Acoustic Ecology Institute (AEI), in a Special Report for the

British government titled "Wind Energy Noise Impacts," [2] found that about 20% of the wind farms in the U.K. generated most of the noise complaints. Another study commissioned by British government, from the consulting firm Hayes, McKensie, reported that only five of 126 wind farms in the U.K. reported problems with the noise phenomenon known as aerodynamic modulation.[3] Thus, experience in the U. K. shows that not all WTi projects lead to community complaints. AEI posed an important question: "**What are the factors in *those* wind farms that may be problematic, and how can we avoid replicating these situations elsewhere?"**

As experienced industrial noise consultants ourselves, we would have expected the wind industry, given the U.K. experience, to have attempted to answer this question, conducting extensive research -- using independent research institutions if necessary -- before embarking on wind power development in the U.S. The wind industry was aware, or should have been aware, that 20% of British wind energy projects provoked complaints about noise and/or vibration, even in a country with more stringent noise limits than in the U.S.

The wind industry complies with stricter noise limits in the U.K. and other countries than it does in the U.S., for example[4]:

- Australia: higher of 35 dBA or L_{90} + 5 dBA
- Denmark: 40 dBA
- France: L_{90} + 3 (night) and L_{90} + 5 (day)
- Germany: 40 dBA
- Holland: 40 dBA
- United Kingdom: 40 dBA (day) and 43 dBA or L_{90} + 5 dBA (night)
- Illinois: Octave frequency band limits of about 50 dBA (day) and about 46 dBA (night)
- Wisconsin: 50 dBA
- Michigan: 55 dBA

Industry representatives on state governmental committees have worked to establish sound limits and setbacks that are lenient and favor the industry. In Michigan, for example, the Governor's State Task Force recommended in its "Siting Guidelines for Wind Energy Systems" that the limits be set at 55 dBA or L_{90} + 5 dBA, whichever is higher. In Wisconsin, the State Task Force has recommended 50 dBA.

When Wisconsin's Town of Union wind turbine committee made an open records request to find out the scientific basis for the sound levels and setbacks in the state's draft model ordinance, it found that no scientific or medical data was used at all. Review of the meeting minutes provided under the request showed that the limits had been set by Task Force members representing the wind industry.[5] This may explain why state level committees or task forces have drafted ordinances with upper limits of 50 dBA or higher instead of the much lower limits

[2] AEI is a 501(c)3 non-profit organization based in Santa Fe, New Mexico, USA. The article is available at http://www.acousticecology.org/srwind.html

[3] Study review available at: http://www.berr.gov.uk/files/file35592.pdf

[4] Ramakrishnan, Ph. D., P. Eng., Ramani, "Wind Turbine Facilities Noise Issues" Dec. 2007 Prepared for the Ontario Ministry of Environment.

[5] Lawton, Catharine M., Letter to Wisconsin's "Guidelines and Model Ordinances Ad Hoc Subcommittee of the Wisconsin Wind Power Siting Collaborative" in Response to Paul Helgeson's 9/20/00 "Wisconsin Wind Ordinance Egroups E-Mail Message," Sept. 20, 2000, a Public Record obtained through Open Meetings Act request by the Town of Union, Wisconsin, Large Wind Turbine Citizens Committee.

applied to similar projects in other countries. There is, in fact, no independent scientific or medical support for claims that locating 400 foot tall wind turbines as close as 1000 feet (or less) to non-participating properties will not create noise disturbances or other risks.[6] But, there is considerable independent research supporting that this will result in public health risks and other negative impacts on people and property.

A typical WTi developer's response to a question raised by a community committee about noise and health is the following:

> **Q: 19. What sound standards will EcoEnergy ensure that the turbines will be within, based on the setbacks EcoEnergy plans to implement, and what scientific and peer reviewed data do you have to ensure and support there will be no health and safety issues to persons within your setbacks?**
>
> **Answer**: As mentioned, turbines are sited to have maximum sound level of 45dBA. These sound levels are well below levels causing physical harm. Medical books on sound indicate sound levels above 80-90dBA cause physical (health) effects. The possible effects to a person's health due to "annoyance" are impossible to study in a scientific way, as these are often mostly psychosomatic, and are not caused by wind turbines as much as the individuals' obsession with a new item in their environment.
>
> **From EcoEnergy's "Response to the Town of Union Health & Safety Research Questionnaire"**
> By Curt Bjurlin, M.S., Wes Slaymaker, P.E., Rick Gungel, P.E., EcoEnergy, L.L.C., submitted to Town of Union, Wisconsin and Mr. Kendall Schneider, on behalf of the Town of Union

A serious question was asked and it deserves a responsible answer. The committee, charged with fact-finding, sought answers based on independent, peer-reviewed studies. The industry response was spurious and misleading, and did not address the question. It stated that the turbines will be located so as to produce maximum sound levels of 45 dBA, the tone and context implying that 45 dBA is fully compatible with the quiet rural community setting. No acknowledgement is made of the dramatic change this will be for the noise environment of nearby families. No mention is made of how the WTi, once in operation, will raise evening and nighttime background sound levels from the existing background levels of 20 to 30 dBA to 45 dBA. There is no disclosure of the considerable low frequency content of the WTi sound; in fact, there are often claims to the contrary, though the home construction techniques used for most wood frame homes result in walls and roofs that cannot block out WTi low frequencies.

There is no mention of the nighttime sound level recommendations set by the World Health Organization (WHO) in its reports, *Guidelines for Community Noise* [7] and "Report on the third meeting on night noise guidelines.[8]" In these documents WHO recommends that **sound levels during nighttime and late evening hours should be less than 30 dBA during sleeping periods to protect children's health**. They noted that a child's autonomic nervous system is 10 to 15 dB more sensitive to noise than adults. Even for adults, health effects are first noted in some studies

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6 It is worth noting that the 2007-06-29 version of the Vestas Mechanical Operating and Maintenance Manual for the model V90 – 3.0 MW VCRS 60 Hz turbine includes this warning for technicians and operators:

> **"2. Stay and Traffic by the Turbine**
>
> Do not stay within a radius of 400m (1300ft) from the turbine unless it is necessary. If you have to inspect an operating turbine from the ground, do not stay under the rotor plane but observe the rotor from the front. Make sure that children do not stay by or play nearby the turbine. ...."

7 Available at http://www.who.int/docstore/peh/noise/guidelines2.html.

8 Available at: http://www.euro.who.int/Noise/activities/20040721_1 References found in Report on third meeting at pages 13 and others

when the sound levels exceed 32 dBA L_{max}. These levels are 10-20 dBA lower than the sound levels needed to cause awakening.

For sounds that contain a strong low frequency component, which is typical of wind turbines, WHO says that the limits may need to be even lower than 30 dBA to avoid health risks. Further, they recommend that the criteria use dBC frequency weighting instead of dBA for sources with low frequency content. When WTi sound levels are 45 dBA outside a home, we expect that the interior sound levels will not drop to the 30 dBA level needed in sleeping areas. because the low frequency content of the noise can penetrate the home's walls and roof with little power reduction. An example demonstrating how WTi sound is affected by walls and windows is provided later in this document.

The wind turbine developers in the excerpt above do not disclose that the International Standards Organization (ISO) in ISO 1996-1971 recommends 25 dBA as the maximum night-time limit for rural communities. As can be seen in the table below, sound levels of 40 dBA and above are only appropriate in suburban communities during the day and urban communities during day and night. There are no communities where 45 dBA is considered acceptable at night.

ISO 1996-1971 Recommendations for Community Noise Limits			
District Type	Daytime Limit	Evening Limit 7-11pm	Night Limit 11pm-7am
Rural	35dB	**30dB**	**25dB**
Suburban	40dB	35dB	**30dB**
Urban residential	45dB	40dB	35dB
Urban mixed	50dB	45db	40dB

Further, the wind industry claims, "*These sound levels are well below levels causing physical harm. Medical books on sound indicate sound levels above 80-90dBA cause physical (health) effects.*" Concern about sound levels in the 80-90 dBA range is for hearing health (your ears) and not the health-related issues of sleep disturbance and other symptoms associated with prolonged exposure to low levels of noise with low frequency and amplitude modulation such as the sound emitted by modern wind turbines. This type of response is a non-answer. It is a conscious attempt to mislead while giving the appearance of providing a legitimate response.

Furthermore, the statement, "*The possible effects to a person's health due to 'annoyance' are impossible to study in a scientific way, as these are often mostly psychosomatic, and are not caused by wind turbines as much as the individuals' obsession with a new item in their environment,*" is both inaccurate and misleading. It ignores the work of researchers such as Pedersen, Harry, Phipps, and Pierpont on wind turbine effects specifically, and the numerous medical research studies reviewed by Frey and Hadden. These studies belie the claims of the wind industry. This "oversight" of published studies is so blatant as to make some interpret the claim of "no medical research" as a conscious decision to not look for it.

Making statements outside their area of competence, wind industry advocates without medical qualifications, label complaints of health effects as "psychosomatic" in a pejorative manner that implies the complaints can be discounted because they are not really "medical" conditions. Such a response cannot be considered to be based in fact. It ignores the work of many researchers, including the World Health Organizations, on the effect of sounds during nighttime hours that result in sleep disturbance and other disorders with physical, not just psychological, pathologies.[9,10] Many people find it difficult to articulate what has changed. They know something is different from before the wind turbines were operating and they may express it as feeling uncomfortable, uneasy, sleepless, or some other symptom, without being able to explain why it is happening.

Our review of the studies listed in Tables 1-4 of our Noise-Con paper show that some residents living as far as 3 km (1.86 mi) from a wind farm complain of sleep disturbance from the noise. Many residents living 1/10 of this distance (300 m or 984 ft) from wind farms experience major sleep disruption and other serious medical problems from nighttime wind turbine noise. The peculiar acoustic characteristics of wind turbine noise immissions[11] cause the sounds at the receiving properties to be more annoying and troublesome than the more familiar noise from traffic and industrial factories. Limits used for these other community noise sources are not appropriate for siting modern industrial wind turbines. The residents who are annoyed by wind turbine noise complain of the repetitive, approximately once-per-second (1 Hz) "swoosh-boom-swoosh-boom" sound of the turbine blades and of "low frequency" noise. It is not clear to us whether the complaints about "low frequency" noise are about the audible low frequency part of the "swoosh-boom" sound, the once-per-second amplitude modulation (amplitude modulation means that the sound varies in loudness and other characteristics in a rhythmic pattern) of the "swoosh-boom" sound, or some combination of the two.

Figure 1 of our Noise Con paper, reproduced as Figure 1, below, shows the data from one of the complaint sites plotted against the sound immission spectra for a modern 2.5 MWatt wind turbine; A home in the United States at 2km distance, Young's <u>threshold of perception</u> for the 10% most sensitive population (ISO 0266); and a spectrum obtained for a rural community during a three hour, 20 minute test from 11:45 pm until 3:05 am on a windless June evening in near Ubly, Michigan a quiet rural community located in central Huron County (also called Michigan's Thumb). It is worth noting that this sound measurement sample demonstrates how quiet a rural community can be when located at a distance from industry, highways, and airport related noise emitters.

The line representing the threshold of perception is the focus of this graph. The remaining graphs show sound pressure levels (dB) at each of the frequency ranges from the lowest inaudible sounds at the left, to sounds that "rumble" (20Hz to about 200 Hz) and then those in the range of communication (200Hz through about 4000Hz) through high pitched sounds (up to 16,00 Hz). At each frequency where the graphs of sound pressures are above (exceed) the graph showing perception the wind turbine sounds would be perceptible or audible. The more the wind turbine sound exceeds the perception curve the more pronounced it will be. When it exceeds the quiet rural background sound level (L_{90}) it will not be masked or obscured by the rural soundscape.

The over-all sounds from each of the frequency bands are summed and presented on the right hand side of the graph. These are presented with corrections for A-weighting (dBA), C-weighting (dBC) and without corrections (dBZ). These show that if only dBA criteria are used in

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9 WHO European Centre for Environment and Health, Bonn Office, "Report on the third meeting on night noise guidelines," April 2005.

10 According to Online Etymology Dictionary, *psychosomatic* means "pertaining to the relation between mind and body, … applied from 1938 to physical disorders with psychological causes."

11 *Emissions* refer to acoustic energy from the viewpoint of the sound emitter, while *immissions* refer to acoustic energy from the viewpoint of the receiver.

assessing and limiting wind turbine sound the low frequency content of the wind turbines emissions are not revealed. Note that in many cases the values for dBC are almost 20 dB higher than the dBA values. This is the basis for the WHO warning that when low frequency sound content is present outside a home that dBA is not an appropriate method of describing predicted noise impacts or sound limits and criteria.

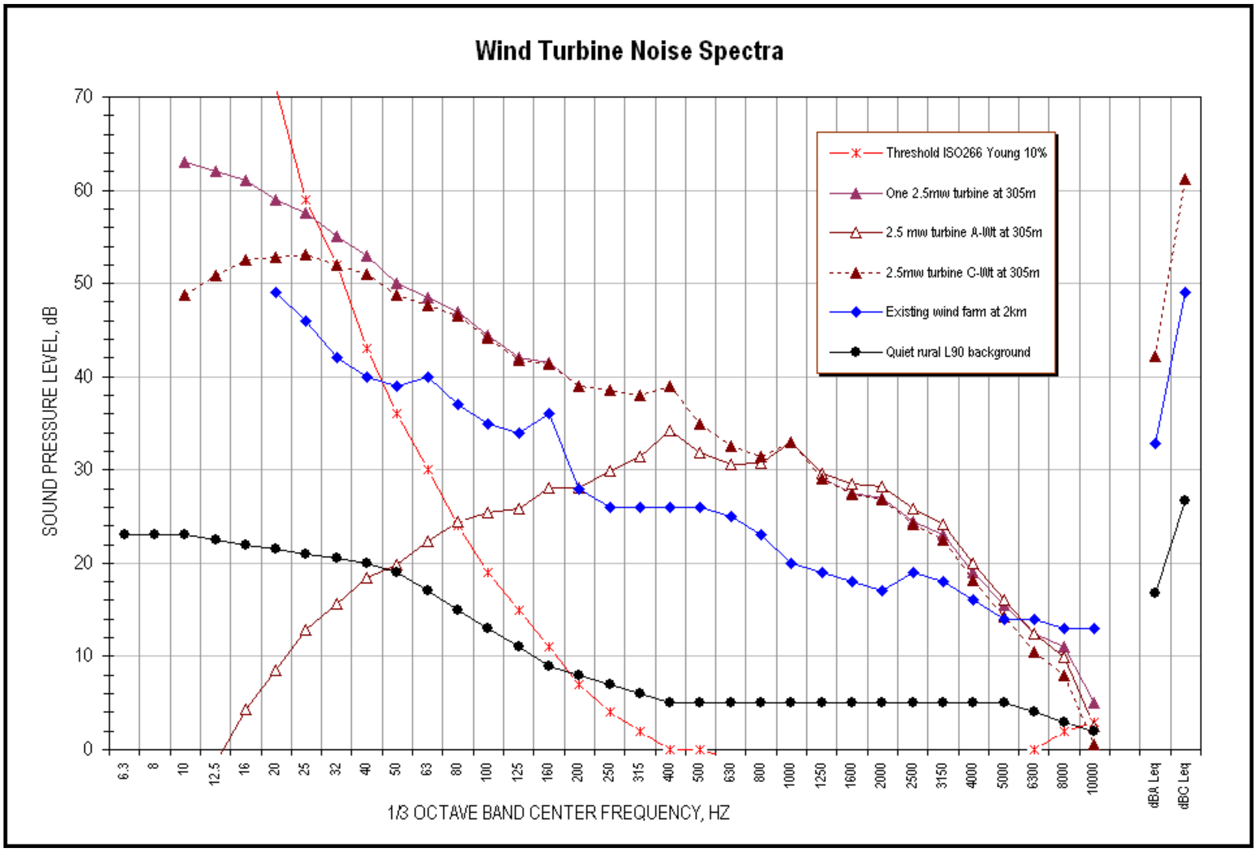

Figure 1-Graph Of Wind Turbine Sounds Vs. Rural Background And Threshold Of Perception

Our review of the studies listed in Tables 1-4 in the Noise-Con paper at the end of this document, provided answers to a number of significant questions we had, as acoustical engineers, regarding the development of siting guidelines for industrial-scale wind turbines. They are provided below for easy of reading and continuity:

Do international, national, or local community noise standards for siting wind turbines near dwellings address the low frequency portion of the wind turbines' sound immissions? No. State and local governments are in the process of establishing wind farm noise limits and/or wind turbine setbacks from nearby residents, but the standards incorrectly assume that limits based on dBA levels are sufficient to protect the residents.

Do wind farm developers have noise limit criteria and/or wind turbine setback criteria that apply to nearby dwellings? Yes. But the industry-recommended wind turbine noise levels (typically 50-55 dBA) are too high for the quiet nature of the rural communities and may be unsafe for the nearest residents. An additional concern is that some of the methods for pre-construction computer modeling may predict sound levels that are too low. These two factors combined can lead to post-construction complaints and health risks.

Are all residents living near wind farms equally likely to be affected by wind turbine noise? No. Children, people with certain pre-existing medical conditions, and the elderly are likely to be the most susceptible. Some people are unaffected while nearby neighbors develop serious health problems caused by exposure to the same wind turbine noise.

How does wind turbine noise impact nearby residents? Wind turbine-associated symptoms include sleep disturbance, headache, ringing in the ears, dizziness, nausea, irritability, and problems with memory, concentration, and problem solving, as described in the first paper in this volume.

What are the technical options for reducing wind turbine noise immission at residences? There are only two options: 1) increase the distance between the source and receiver, or 2) reduce the source sound power emission. Either solution is incompatible with the objective of the wind farm developer, which is to maximize the wind power electrical generation within the land available.

Is wind turbine noise at a residence much more annoying than traffic noise? Yes. Researchers have found that, "Wind turbine noise was … found to cause annoyance at sound pressure levels lower than those known to be annoying for other community noise sources, such as road traffic. …Living in a clearly rural area in comparison with a suburban area increases the risk of annoyance with wind turbine noise.[12]" In other papers by Pedersen wind turbine noise was perceived by about 85% of respondents to the study at sound levels as low as 35.0–37.5 dBA.[13] Currently, this increased sensitivity is believed to be due to the presence of amplitude modulation in the wind turbine's sound emissions which limits the masking effect of other ambient sounds and the low frequency content which is associated with the sounds inside homes and other buildings.

Low frequency noise is a problem inside buildings

When low frequency sound is present outside homes and other occupied structures, it is often more an indoor problem than an outdoor one. This is very true for wind turbine sounds.

Why do wind turbine noise immissions of only 35 dBA disturb sleep at night? Affected residents complain of the middle- to high-frequency, repetitive swooshing sounds of the rotating turbine blades at a constant rate of about 1 Hz, plus low frequency noise. The amplitude modulation of the "swooshing" sound changes continuously. Residents also describe a thump or low frequency banging sound that varies in amplitude up to 10 dBA in the short interval between the swooshing sounds. This may be a result of sounds from multiple wind turbines with similar spectral content combining to increase and decrease the sound over and above the effects of modulation. [Note: These effects (e.g. phasing and coherence effects) are not normally considered in predictive models.] It may also be a result of turbulence of the air and wind on wind turbine operations when the blades are not at an optimum angle for noise emissions and/or power generation. It is also a result of sounds penetrating homes and other buildings at night and at other times where quiet is needed. When low frequency sound is present outside homes and other occupied structures; it is often more likely to be an indoor problem than an outdoor one. This is very true for wind turbine sounds.

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[12] Pedersen E, Bouma J, Bakker R and Van den Berg F, "Wind Farm perception- A study on acoustic and visual impact of wind turbines on residents in the Netherlands;" 2nd International Meeting on Wind Turbine Noise, Lyon France; Sept. 20-21, 2007 (Pages 2 and 3)

[13] Pedersen E and Persson Waye K. 2004. Perceptions and annoyance due to wind turbine noise -- a dose-response relationship. J Acoust Soc Am 116(6): 3460-3470

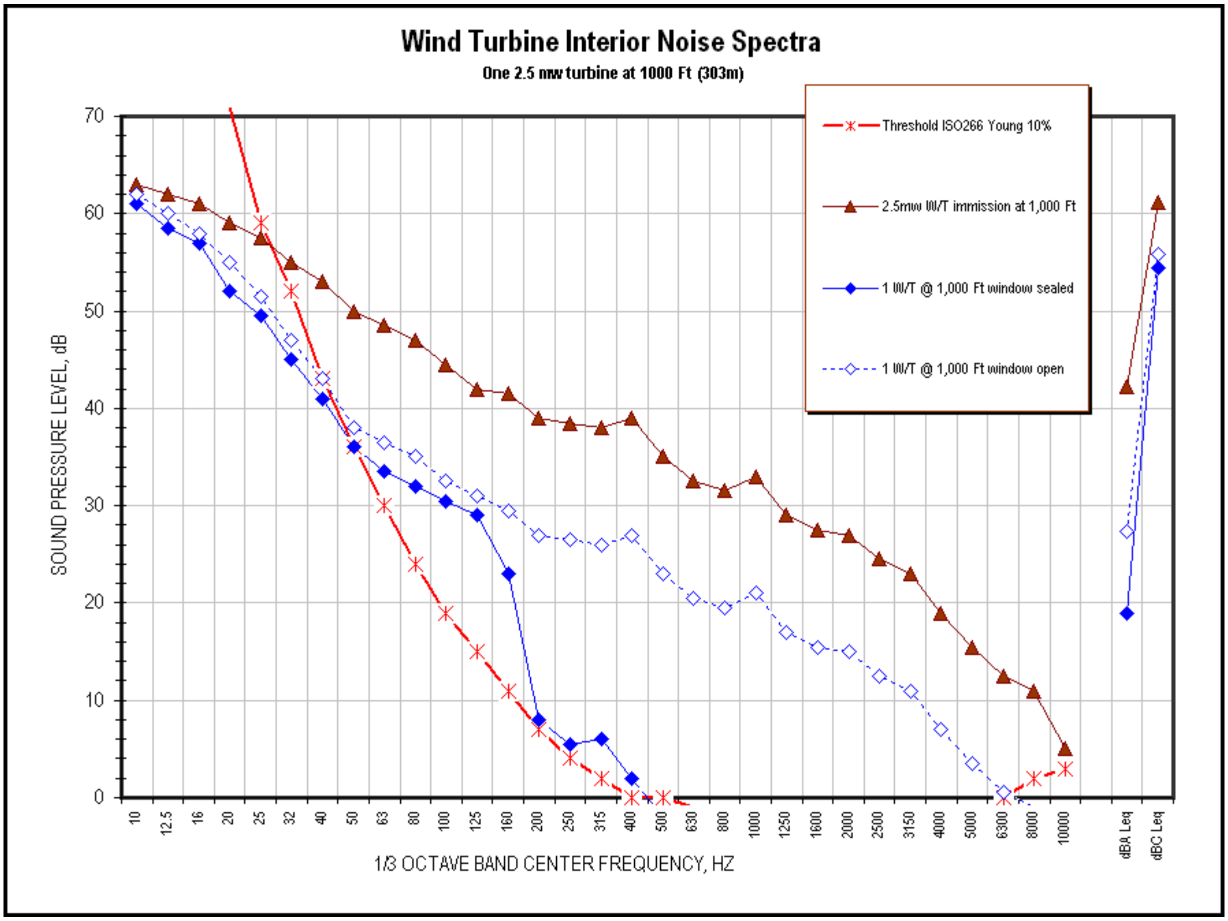

Figure 2-One (1) Wind Turbine Sound Inside Home @ 1000 Feet

The usual assumption about wall and window attenuation being 15 dBA or more, which is valid for most sources of community noise, may not be sufficiently protective given the relatively high amplitude of the wind turbines' low frequency immission spectra. Figures 2 and 3 demonstrate the basis for this concern.

To demonstrate the effects of outdoor low frequency content from wind turbines we prepared two figures showing the effect of a single turbine (propagation model based on sound power level test data) at 1000 feet and then projected ten (10) similar turbines at one (1) mile. We applied the façade sound isolation data from the Canada Research Council to the wind turbine example used in our Noise-Con 2008 paper and shown in Figure 1 above. The graphs each show the outdoor sound pressure levels predicted for the distance of 1000 feet or one mile as the upper graph line. The curve showing the threshold of human perception for sounds at each 1/3 octave band center is also plotted. When the graphs representing wind turbine sound have data points above this curve the sounds will be perceptible to at least 10% of the population.

In addition to the top graph line representing the sounds outside the home there are two other graph lines for the sounds inside the home[14]. One curve represents the condition of no open windows and the other represents one open window.

[14] The typical wood stud exterior used in modern home construction is vinyl siding over 1/2 inch OSB or rigid fiberglass board applied to 2 X 4 studs with the stud space filled with thermal and 1/2 inch gypsum board applied on the exposed interior side. This has a mass of about 3-4 lbs/sq ft and low 26 STC.

With just one turbine at 1,000 feet there is a significant amount of low frequency noise above hearing threshold inside a home near an exterior wall without windows or very well sealed windows. Even with the windows closed the sound pressure levels in the 63 Hz to 200 Hz octave bands still exceed the perception curve, in many cases by more than 10 dB. Note the perceptible sound between 50 and 200 Hz with a wall resonance frequency at 125 Hz (2 X 4 studs on 16 inch centers) for the "windows closed" condition. This would be perceived as a constant low rumble which would be present throughout the homes whenever the turbines are operating.

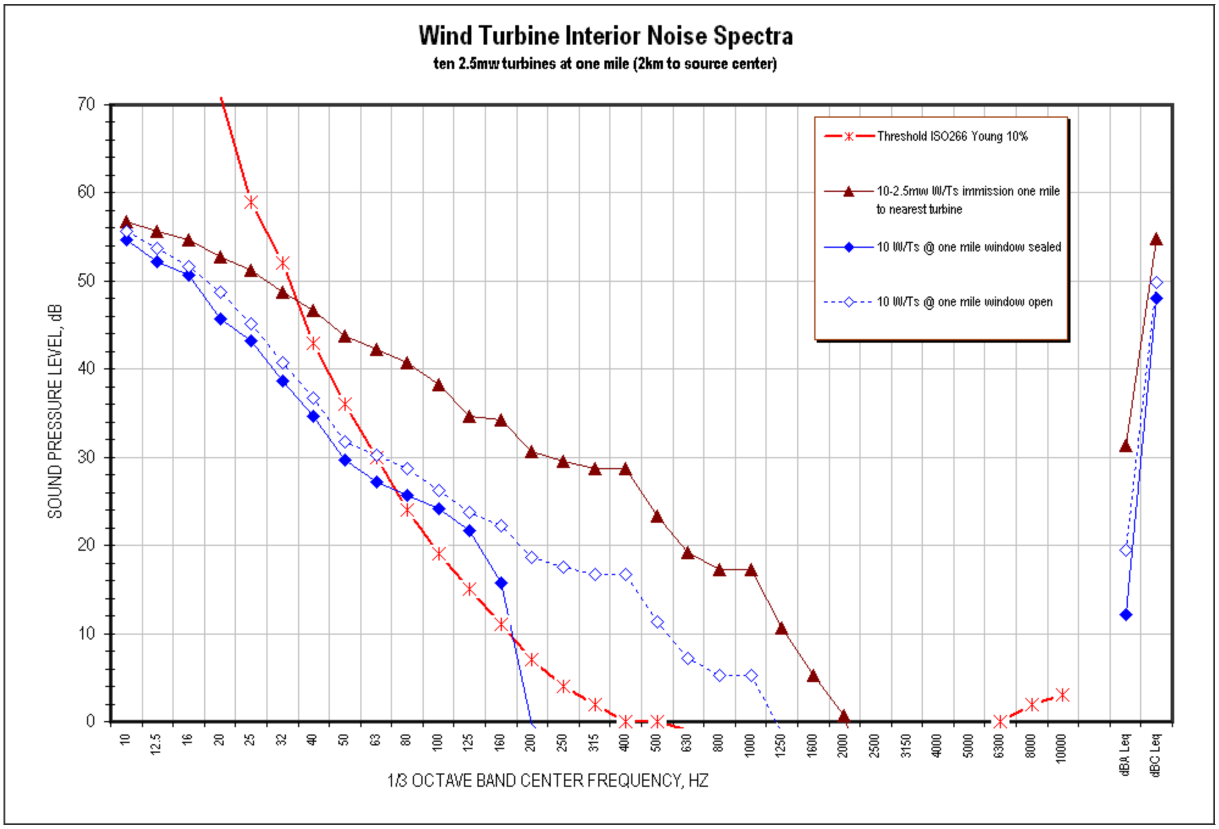

Figure 3-Sound from Ten (10) Wind Turbines inside home at One Mile

When comparing the dBC values the difference between inside sounds and outside is much less. The maximum difference in this example is only 7 dBC and that is for the situation with windows closed. With windows open the sound inside the home would be 56 dBC while it is 61 dBC outside; a difference of only 5 dBC[15],[16],[17]. If we looked only at dBA it would appear that the home's walls and roof provide a reduction of 15 dBA or more. But, that that would be misleading because it ignores the effects of low frequency sound.

We next increased the number of 2.5 Mw turbines from one to ten and moved the receiver one mile from the closest turbine. We assumed the acoustic center for the ten turbines to be 2km (1-

[15] The basis for these predictions includes reports on aircraft sound insulation for dwellings and façade sound isolation data from the Canada Research Council.

[16] "On the sound insulation of wood stud exterior walls" by J. S. Bradley and J. S. Birta, institute for Research in Construction, National Research Council, Montreal Road, Ottawa K1A 0R6, Canada, published: J.Acoust. Soc. Am. 110 (6), December 2001

[17] Dan Hoffmeyer, Birger Plovsing: "Low Frequency Noise from Large Wind Turbines, Measurements of Sound Insulation of Facades." Journal no. AV 1097/08, Client: Danish Energy Authority, Amaliegade 44, 1256 Copenhagen

1/4 miles) from the receiver. These results are in the figure 3. We were surprised to find that the one mile low frequency results are only 6.3 dB below the 1,000 foot one turbine example.

This may explain why some residents as far as two (2) miles from a wind farm find the wind turbines sounds highly annoying. It also demonstrates the primary reason why relying on dBA alone will not work for community noise criteria. It is the low frequency phenomena associated with wind turbine emissions that makes the dBC test criteria an important part of the proposed criteria.

III. Development of Siting Criteria

Basis For Using L_{90A} To Determine Pre-Construction Long-Term Background Sound

We began our research into guidelines for proper siting by reviewing guidelines used in other countries to limit WTi sound emissions. A recent compendium of these standards was presented in the report "Wind Turbine Facilities Noise Issues."[18] We found common ground in many of them. Some set explicit not-to-exceed sound level limits, for example, in Germany, 40 dBA nighttime in residential areas and 35 dBA nighttime in rural and other noise-sensitive areas. Other countries use the existing background sound levels for each community as the basis for establishing the sound level limits for the WES project. This second method has the advantage of adjusting the allowable limits for various background soundscapes. It makes use of a standard method for assessing background sound levels by measuring over a specified period of observation to determine the sound level exceeded 90% of the time (L_{90}) during the night. The night is important because it is the most likely time for sleep disturbance. Then, using the background sound level as the base, the WES project is allowed to increase it by 5 dBA. It is this second method (L_{90} + 5 dBA) that we adopted for the criteria in this document. It has the advantage of adjusting the criteria for each community without the need for tables of allowable limits for different community types. We also focused only on the nighttime criteria. This is because the WES will operate 24 hours a day and the nighttime limits will be the controlling limits whether or not there are other limits for daytime.

Wind turbine noise is more annoying than other noises and needs lower limits

Since many rural communities are very quiet, it is possible that some will have L_{90} values of 25 dBA or lower. This may seem extreme when compared to limits usually imposed on other sources of community noise. However, wind turbine sounds are not comparable to the more common noise sources of vehicles, aircraft, rail, and industry. Several studies have shown that annoyance to wind turbine sounds begins at levels as low as 30 dBA.[19] This is especially true in quiet rural communities that have not had previous experience with industrial noise sources. This increased sensitivity may be due to the periodic 'swoosh' from the blades in the quiet rural

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[18] Ramani Ramakrishnan, Ph.D., P. Eng., "Wind Turbine Facilities Noise Issues," December 2007. Prepared for the Ontario Ministry of Environment.

[19] Eja Pedersen, "Human response to wind turbine noise: perception, annoyance and moderating factors." Dissertation, Occupational and Environmental Medicine, Department of Public Health and Community Medicine, Goteborg University, Goteborg, Sweden, 2007, and

Van den Berg F, Pedersen E, Bouma J, and Bakker R, Wind Farm Perception, Final Repoty Project no. 044628, University of Gothenburg and Medical Center Groningen, Netherlands June 3, 2008 soundscape, or it may be more complex. In either case, it is a legitimate response to wind turbine sound documented in peer-reviewed research.

Noise criteria need to take into account low frequency noise

In the table to the right are a series of observations and recommendations by the World Health Organization (WHO) supporting the need for stricter limits when there is substantial low frequency content in outdoor sound. Our review of other studies, and our own measurements, has demonstrated that wind turbine sound includes considerable low frequency content. We include a dBC limit in our guidelines to address the WHO recommendation that when low frequency sound may be present, criteria based on measurements using a C-weighting filter on the sound level meter (dBC) are needed in addition to dBA criteria.

> The World Health Organization recognizes the special place of low frequency noise as an environmental problem. Its publication “Community Noise” (Berglund et al., 2000) makes a number of references to low frequency noise, some of which are as follows:
>
> - “It should be noted that low frequency noise… can disturb rest and sleep even at low sound levels.
> - For noise with a large proportion of low frequency sounds a still lower guideline (than 30dBA) is recommended.
> - When prominent low frequency components are present, noise measures based on A-weighting are inappropriate.
> - Since A-weighting underestimates the sound pressure level of noise with low frequency components, a better assessment of health effects would be to use C-weighting.
> - It should be noted that a large proportion of low frequency components in a noise may increase considerably the adverse effects on health.”
>
> WHO also states: "The evidence on low frequency noise is sufficiently strong to warrant immediate concern.”
>
> Available at http://www.who.int/docstore/peh/noise/guidelines2.html, References found at pages ix, xii through xv and others.

IV. Proposed Sound Limits

The simple fact that so many residents complain of low frequency noise from wind turbines is clear evidence that the single A-weighted (dBA) noise descriptor used in most jurisdictions for siting turbines is not adequate. The only other simple audio frequency weighting that is standardized and available on sound level meters is the C-weighting or dBC. A standard sound level meter set to measure dBA is increasingly less sensitive to low frequency below 500 Hz (one octave above middle-C). The same sound level meter set to measure dBC is equally sensitive to all frequencies above 32 Hz (lowest note on grand piano). It is well known that dBC readings are more predictive of perceptual loudness than dBA readings if low frequency sounds are significant.

We are proposing to use the commonly accepted dBA criteria that is based on the pre-existing background sound levels plus a 5 dB allowance for the wind turbine’s immissions (e.g. L_{90A} +5) for the audible sounds from wind turbines. But, to address the lower frequencies that are not considered in A-weighted measurements we are proposing to add limits based on dBC. The Proposed Sound Limits are presented in the text box at the end of this section.

For the current industrial grade wind turbines in the 1.5 to 3 MWatt (or over) range, the addition of the dBC requirement will result in an increased distance between wind turbines and the nearby residents. For the generalized graphs shown in Figure 1, the distances would need to be increased significantly. This will result in setbacks in the range of 1 km or greater for the current generation of wind turbines if they are to be located in rural areas where the L_{90A} background sound levels are 30 dBA or lower. In areas with higher background sound levels, turbines could be located somewhat closer, but still at a distance greater than the 305 m (1000 ft.) or less which are setbacks commonly seen in U.S. based wind turbine standards set by many states and used for wind turbine developments.

Following are some additional Questions and Answers that summarize the major points of this discussion relevant to criteria.

What are the typical wind farm noise immission criteria or standards? Limits are not consistent and may vary even within a particular country. Examples are listed above in the section on Results of Literature and Sound Studies.

What is a reasonable wind farm sound immission limit to protect the health of residences? We are proposing an immission limit of 35 dBA or L_{90A} + 5 dBA, whichever is lower, and also C-weighted criteria to address complaints of wind turbine low frequency noise. For the proposed criteria, we propose that the dBC sound level at a receiving property line not exceed the L_{90A} background sound level by more than 20dB. In other words, the dBC operating immission limit should not be more than 20 dB above the measured dBA (L_{90A}) pre-construction nighttime background sound level. A maximum not-to-exceed limit of 50 dBC and 55 dBC is also proposed. Use of the multiple metrics and weightings will address the audible and inaudible portions of wind turbine sound emissions.

Why should the dBC immission limit not be permitted to be more than 20 dB above the background measured L_{90A}? The World Health Organization and others have determined that if a noise has a measured difference between dBC and dBA more than 20 dB, the noise is highly likely to create an annoyance because of the low frequency component.

Isn't L_{90A} the <u>minimum</u> background noise level? This is correct. It is very important to establish the long term background noise environment outside a potentially impacted residence (L_{90A}) during the **quietest** sleeping hours of the night, between 10 p.m. and 4 a.m., since nighttime sleep disturbance has generated the majority of wind farm noise complaints throughout the world. ANSI standards define the long term background sound as excluding all short term sounds from the test sample using carefully selected sampling times and conditions and ten (10) minute samples. Establishing L_{90A} can be accomplished with one or several 10-minute measurements during any night when the atmosphere is classified as stable with a light wind from the area of the proposed wind farm. The basis for the immission limits for the proposed wind farm would then be the Nighttime Immission Limits, which we propose to be the minimum 10 minute nighttime L_{90A} plus 5 dB for the time period of 10 p.m. to 7 a.m. The Daytime Limits (7 a.m. to 7 p.m.) could be set at minimum nighttime L_{90A} plus 10 dB, but the nighttime limit would always be the limiting sound level.

A nearby wind farm meeting these noise immission criteria would be clearly audible to the residents occasionally during nighttime and daytime.

The common method used for establishing the background sound level at a proposed wind farm, in many of the studies in Table 1, do not follow the ANSI standards for outdoor measurements and determination of long term background sound levels. Instead they use unattended noise monitors to record hundreds of 10-minute measurements to obtain a statistically significant sample over varying wind conditions during a period of weeks. The results for daytime and nighttime are combined to determine the average wind noise at the microphone as a function of wind velocity measured at a height of 10 meters. This provides an enormous amount of data, but the results have little relationship to wind turbine sound immissions or to turbine noise impacts on nearby residents. They also do not comply with ANSI standards for quality and as such are not suitable for use in measurements that will be used to assess compliance with other standards and guidelines. This exhaustive exercise often only demonstrates how much noise is generated by the wind. In some cases it appears that the data is used to "prove" that the wind noise masks the turbines' sound immissions.

The methodology used to predict the sound propagation from the turbines into the community also fails to represent the conditions of maximum turbine noise impact on nearby residents. One major fault is that the use of the 'contaminated' background sound levels described above and the limitations of models based on ISO 9613-2 do not consider a frequent nighttime condition of a stable atmosphere. In a stable atmosphere, the wind turbines can be producing the maximum or near maximum electricity while the wind at ground level is calm and the background noise level is low as shown for the Michigan rural night test in the earlier figure. This is one common condition which is known to directly cause chronic sleep disruption.

Are there additional noise data to be recorded for a pre-wind turbine noise survey near selected dwellings? Yes. The measuring sound level meter(s) need to be programmed to include measurement of L_{eqA}, L_{10A}, L_{eq90A}, L_{eqC}, L_{10C}, and L_{eq90C}, with starting time and date for each 10-minute sample. These results will be used to help validate the L_{90} data. For example, on a quiet night one might expect L_{10} and L_{90} or L_{eq} to show similar results within 5 to 10 dBA and 10 to 15 dBC. On a windy night or day the difference between L_{10} and L_{90} may be more than 20 dBA and 30 dBC. There is also a need to obtain a 10- minute, time-averaged, one-third octave band analysis over the frequency range from 6.3 Hz to 10 kHz. The frequency analysis is very helpful for identifying and correcting for extraneous sounds such as interfering insect noise. A standard averaging sound level meter has the capability to perform all of the above acoustic measurements simultaneously and store the results internally. There is a requirement for measurement of the wind velocity near the sound measurement microphone continuously throughout each 10-minute recorded noise sample. The 10-minute maximum wind speed near the microphone should not exceed 2 m/s (4.5 mph) during measurements of background noise (L_{90A}), and the maximum wind speed for noise measurements during turbine operation should not exceed 4 m/s (9 mph). It is strongly recommended that observed measurements, rather than unattended, be used for these tests.

Is there a need to record weather data during the background noise recording survey? One weather monitor is required at the proposed wind farm on the side nearest the residents. The weather station sensors are at the standard 10 meter height above ground. It is critical that the weather be recorded every 10 minutes, synchronized with the clocks in the sound level recorders without ambiguity, at the start and end time of each 10 minute period. The weather station should record wind speed and direction, temperature, humidity and rain.

Why do Canada and some other countries base the permitted wind turbine noise immission limits on the operational wind velocity at the 10m height wind speed instead of a maximum dBA or L_{90} + 5 dBA immission level? First, it appears that the wind turbine industry will take advantage of every opportunity to elevate the maximum permitted noise immission level to reduce the setback distance from the nearby dwellings. Including wind as a masking source in the criteria is one method for elevating the permissible limits. The background noise level does indeed increase with surface wind speed. When this happens, it can be argued that the increased wind noise provides some masking of the wind farm turbine noise emission. However, in the middle of the night when the atmosphere is stable (with no vertical flow from surface heat radiation), the layers of the lower atmosphere can separate and permit wind velocities at the turbine hubs to be 2 to 4 times the wind velocity at the 10 m-high wind monitor but remain near calm at ground level. The result is the wind turbines can be operating at or close to full capacity when it is very quiet outside the nearby dwellings.

This is the heart of the wind turbine noise problem for residents within 3 km (1.86 miles) of a wind farm. When the turbines are producing the sound from operation it is quietest outside the surrounding homes. The PhD thesis of G.P. van den Berg, *The Sounds of High Winds*, is very enlightening on this issue (Table 3). See also the letter by John Harrison in Ontario "On Wind Turbine Guidelines.[20]"

What sound monitor measurements would be needed for enforcement of the wind turbine sound ordinance? A similar set of sound tests using the ten (10) minute series of measurements would be repeated, with and without the operation of the wind turbines, at the location where noise was measured before construction which is closest to the resident registering the wind turbine noise complaint. If the nighttime background noise level (turbines off) was found to be slightly higher than the measured background prior to the wind farm installation, then the results with the turbines on must be corrected using the standard acoustical engineering methods to determine compliance with the pre-turbine established sound limits.

Who should conduct the sound measurements*?* An independent acoustics expert should be retained who reports to the County Board or other responsible governing body. This independent acoustics expert should be responsible for all the acoustic measurements including setup and calibration of instruments and interpretation of recorded results. He or she should perform all pre-turbine background noise measurements and interpretation of results to establish the nighttime (and daytime, if applicable) industrial wind turbine sound immission limits, and to monitor compliance.

At present the acoustical consultants are retained by, and work directly for, the wind farm developers. This presents a serious problem with conflict of interest on the part of the consultants. The wind farm developer would like to show that a significant amount of wind noise is present to mask the sounds of the wind turbine immissions. The community is looking for authentic results showing that the wind turbine noise will be only barely perceptible, and then only occasionally, during the night or daytime.

Is frequency analysis required either during the pre-construction background noise survey or for compliance measurements*?* Normally one-third octave or narrower band analysis would only be required if there is a complaint of tones immission from the wind farm. Although only standardized dBA and dBC measurements are required to meet the proposed criteria, the addition of one-third octave band analysis is often useful to validate the dBA and dBC results.

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[20] Harrison, J., *Wind Turbine Guidelines,* available at http://amherstislandwindinfo.com/

The following outline summarizes the criteria as we have formulated them for use in siting wind turbines to minimize the risk of adverse impacts from noise on the adjacent community[21].

Proposed Wind Turbine Siting Sound Limits

1. Audible Sound Limit

a. No Wind Turbine or group of turbines shall be located so as to cause an exceedance of the pre-construction/operation background sound levels by more than 5 dBA. The background sound levels shall be the dBA L_{90A} sound descriptor measured during a pre-construction noise study during the quietest time of evening or night. All data recording shall be a series of contiguous ten (10) minute measurements. L_{90A} results are valid when L_{10A} results are no more than 10 dBA above L_{90A} for the same time period. Noise sensitive sites are to be selected based on wind development's predicted worst-case sound emissions (in dBA and dBC) which are to be provided by the developer.

b. Test sites are to be located along the property line(s) of the receiving non-participating property(s).

c. Not to exceed 35 dBA within 30 m. (approx. 100 feet) of any occupied structure.

d. A 5 dB penalty is applied for tones as defined in IEC 61400-11.

2. Low Frequency Sound Limit

a. The dBC sound levels from the wind turbine at the receiving property shall not exceed the lower of either:

1) dBC less dBA L_{90A} greater than 20 dB outside any occupied structure, or

2) A maximum not-to-exceed sound level of 50 dBC (outside any occupied structure) from the wind turbines without other ambient sounds for properties located at one mile or more from State Highways or other major roads or 55 dBC for properties with occupied structures closer than one mile.

These limits shall be assessed using the same nighttime and wind/weather conditions required in 1.a. Turbine operating sound immissions (dBA and dBC) shall represent worst case sound immissions for stable nighttime conditions with low winds at ground level and winds sufficient for full operating capacity at the hub.

3. Requirements

a. All instruments must meet ANSI or IEC Precision integrating sound level meter performance specifications.

b. Procedures must meet ANSI S12.9 and other applicable ANSI standards.

c. Measurements must be made when ground level winds are 2m/s (4.5 mph) or less. Wind shear in the evening and night often results in low ground level wind speed and nominal operating wind speeds at wind turbine hub heights.

d. IEC 61400-11 procedures are not suitable for enforcement of these requirements except for the presence of tones.

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[21] The authors have based these criteria, procedures, and language on their current understanding of wind turbine sound emissions, land-use compatibility, and the effects of sound on health. However, use of the following, in part or total, by any party is strictly voluntary and the user assumes all risks. Please seek professional assistance in applying the recommendations of this document to any specific community or WES development.

V. How to Include the Recommended Criteria in Ordinances and/or Community Noise Limits

The following two sections present the definitions, technical requirements, and complaint resolution processes that support the recommended criteria. Following the formal elements is a section discussing the measurement procedures and requirements for enforcement of these criteria. For the purpose of this article the government authority will be referred to as the Local Government Authority (LGA) as a place marker for State, County, Township or other authorized authority. The abbreviation 'WES' is used for industrial scale wind energy system.

The authors have based these criteria, procedures, and language on their current understanding of wind turbine sound emissions, land-use compatibility, and the effects of sound on health. However, use of the following, in part or total, by any party is strictly voluntary and the user assumes all risks. Please seek professional assistance in applying the recommendations of this document to any specific community or WES development.

VI. ELEMENTS OF A WIND ENERGY SYSTEMS LICENSING ORDINANCE FOR SOUND

I. Purpose and Intent.

Based upon the findings stated above, it is the intended purpose of the LGA to regulate Wind Energy Systems to promote the health, safety, and general welfare of the citizens of the Town and to establish reasonable and uniform regulations for the operation thereof so as to control potentially dangerous effects of these Systems on the community.

II. Definitions.

The following terms have the meanings indicated:

"**Aerodynamic Sound**" means a noise that is caused by the flow of air over and past the blades of a WES.

"**Ambient Sound"** Ambient noise encompasses all sound present in a given environment, being usually a composite of sounds from many sources near and far. It includes intermittent noise events, such as, from aircraft flying over, dogs barking, wind gusts, mobile farm or construction machinery, and the occasional vehicle traveling along a nearby road. The ambient also includes insect and other nearby sounds from birds and animals or people. The near-by and transient events are all part of the ambient sound environment but are not to be considered part of the background sound. If present, a different time or location should be selected for determining the L_{90} background sound levels.

"American National Standards Institute (ANSI)" Standardized acoustical instrumentation and sound measurement protocol shall meet all the requirements of the following ANSI Standards:

ANSI S1.43 Integrating Averaging Sound Level Meters: Type-1 (or IEC 61672-1)

ANSI S1.11 Specification for Octave and One-third Octave-Band Filters (or IEC 61260)

ANSI S1.40 Verification Procedures for Sound Calibrators

ANSI S12.9 Part 3 Procedures for Measurement of Environmental Sound

ANSI S12.18 Measurement of Outdoor Sound Pressure Level

IEC 61400-11 Wind turbine generator systems –Part 11: Acoustic noise measurements

"**Anemometer**" means a device for measuring the speed and direction of the wind.

"**Applicant**" means the individual or business entity that seeks to secure a license under this section of the Town municipal code.

"**A-Weighted Sound Level (dBA)**" A measure of over-all sound pressure level designed to reflect the response of the human ear, which does not respond equally to all frequencies. It is used to describe sound in a manner representative of the human ear's response. It reduces the effects of the low with respect to the frequencies centered around 1000 Hz. The resultant sound level is said to be "A-weighted" and the units are "dBA." Sound level meters have an A-weighting network for measuring A-weighted sound levels (dBA) meeting the characteristics and weighting specified in ANSI Specifications for Integrating Averaging Sound Level Meters, S1.43-1997 for Type 1 instruments and be capable of accurate readings (corrections for internal noise and microphone response permitted) at 20 dBA or lower. In this document dBA means L_{eqA} unless specified otherwise.

"**Background Sound (L_{90})**" refers to the sound level present at least 90% of the time. Background sounds are those heard during lulls in the ambient sound environment. That is, when transient sounds from flora, fauna, and wind are <u>not</u> present. Background sound levels vary during different times of the day and night. Because WES operates 24/7 the background sound levels of interest are those during the quieter periods which are often the evening and night. Sounds from near-by birds and animals or people must be excluded from the background sound test data. Nearby electrical noise from street lights, transformers and cycling AC units and pumps etc must also be excluded from the background sound test data.

Background sound level (dBA and dBC (as L_{90})) is the sound level present for at least 90% of the time during a period of observation that is representative of the quiet time for the soundscape under evaluation and with duration of ten (10) continuous minutes. Several contiguous ten (10) minute tests may be performed in one hour to determine the statistical stability of the sound environment. Measurement periods such as at dusk when bird and insect activity is high or the early morning hours when the 'dawn chorus' is present are not acceptable measurement times. Longer term sound level averaging tests, such as 24 hours or multiple days are not at all appropriate since the purpose is to define the quiet time background sound level. It is defined by the L_{90A} and L_{90C} descriptors. It may be considered to be the quietest one (1) minute during a ten (10) minute test. L_{90A} results are valid only when L_{10A} results are no more than 10 dB above L_{90A} for the same time period. L_{10C} less L_{90C} are not to exceed 15 dBC to be valid.

The background noise environment consists of a multitude of distant sources of sound. When a new nearby source is introduced the new background noise level would be increased. The addition of a new source with a noise level 10 below the existing background would increase the new background 0.4 dB. If the new source has the same noise level as the existing background then the new background is increased 3.0 dB. Lastly, if the new source is 3.3 dB above the existing background then the new background would have increased 5 dB. Therefore, if the existing quiet nighttime background noise level is 26 dBA, for example, then the maximum wind turbine noise immission contribution alone cannot exceed 29.3 dBA at a dwelling to meet the requirement of L_{90A} + 5 dB = 31 dBA (26 dBA + 29.3 dBA = 31 dBA).

Further, background L_{90} sound levels documenting the pre-construction baseline conditions should be determined when the ten minute average wind speed is 2 m/s (4.5 mph) or less at the ground level/microphone location.

"**Blade Passage Frequency**" (BPF) means the frequency at which the blades of a turbine pass a particular point during each revolution (e.g. lowest point or highest point in rotation) in terms of events per second. A three bladed turbine rotating at 28 rpm would have a BPF of 1.4 Hz. [E.g. ((3 blades times 28rpm)/60 seconds per minute = 1.4 Hz BPF)]

"**C-Weighted Sound Level (dBC)**" Similar in concept to the A-Weighted sound Level (dBA) but C-weighting does not de-emphasize the frequencies below 1k Hz as A-weighting does. It is used for measurements that must include the contribution of low frequencies in a single number representing the entire frequency spectrum. Sound level meters have a C-weighting network for measuring C-weighted sound levels (dBC)meeting the characteristics and weighting specified in ANSI S1.43-1997 Specifications for Integrating Averaging Sound Level Meters for Type 1 instruments. In this document dBC means L_{eqC} unless specified otherwise.

"**Decibel (dB)**" A dimensionless unit which denotes the ratio between two quantities that are proportional to power, energy or intensity. One of these quantities is a designated reference by which all other quantities of identical units are divided. The sound pressure level (Lp) in decibels is equal to 10 times the logarithm (to the base 10) of the ratio between the pressure squared divided by the reference pressure squared. The reference pressure used in acoustics is 20 MicroPascals.

"**Emission**" Sound energy that is emitted by a noise source (wind farm) is transmitted to a receiver (dwelling) where it is immitted (see "immission).

"**Frequency**" The number of oscillations or cycles per unit of time. Acoustical frequency is usually expressed in units of Hertz (Hz) where one Hz is equal to one cycle per second.

"**Height**" means the total distance measured from the grade of the property as existed prior to the construction of the wind energy system, facility, tower, turbine, or related facility at the base to its highest point.

"**Hertz (Hz)**" Frequency of sound expressed by cycles per second.

"**Immission**" Noise immitted by a receiver (dwelling) is transmitted from noise source (wind turbine) that emitted sound energy (see "emission").

"**Infra-Sound**" sound with energy in the frequency range of 20 Hz and below is considered to be infrasound and is normally considered to not be audible unless in relatively high amplitude. The most significant exterior noise induced dwelling vibration occurs in the frequency range between 5 Hz and 50 Hz. Moreover, levels below the threshold of audibility can still cause measurable resonances inside dwelling interiors. Conditions that support or magnify resonance may also exist in human body cavities and organs under certain conditions, although no specific test for infrasound is provided in this document, its presence will be accounted for in the comparison of dBA and dBC sound levels for the complaint test provided later in this document. See low-frequency sound (LFN) for more information.

"**Low Frequency Sound (LFN)**" refers to sounds with energy in the lower frequency range of 20 to 200 Hz. LFN is deemed to be excessive when the difference between a C-weighted sound level and an A-weighted sound level is greater than 20 decibels at any measurement point outside a residence or other occupied structure. E.G. C-A>20 dB.

"**Measurement Point (MP)**" means location where sound and measurements are taken such that no significant obstruction blocks sound from the site. The Measurement Point should be located so as to not be near large objects such as buildings and in the line-of-sight to the nearest turbines. Proximity to large buildings or other structures should be twice the largest dimension of the structure, if possible.

"**Measurement Wind Speed**" For measurements conducted to establish the background sound pressure levels (dBA, dBC, $L_{90\ 10\ min}$, and etc.) the 2m wind speed less than 5m from the microphone's Measurement Point shall not exceed 2 m/s (4.5 mph) for valid background measurements. For valid wind farm noises measurements conducted to establish the post-construction sound level the 2m wind speed less than 5m from the microphone's Measurement Point shall not exceed 4m/s (9 mph) and the wind speed at the WES blade height shall be at or above the nominal rated wind speed. For purposes of enforcement, the wind speed and direction at the WES blade height shall be selected to reproduce the conditions leading to the enforcement action while also restricting wind speeds at the microphone to 4 m/s (9 mph).

For purposes of models used to predict the sound levels and sound pressure levels of the WES to be submitted with the Application, the Wind Speed shall be the speed that will result in the worst-case dBA and dBC sound levels in the community adjacent the nearest WES. For the purpose of constructing the model the wind direction shall consider the dominant wind direction for the seasons from the late spring to early fall. If other wind directions may cause levels to exceed those of the predominant wind direction at nearby sensitive receptors, these levels and conditions shall be included in the Application.

"**Mechanical Noise**" means sound produced as a byproduct of the operation of the mechanical components of a WES(s) such as the gearbox, generator and transformers.

"**Noise**" means any unwanted sound. Not all noise needs to be excessively loud to represent an annoyance or interference.

"**Project Boundary**" means the external property boundaries of parcels owned by or leased by the WES developers.

"**Property Line**" means the recognized and mapped property parcel boundary line.

"**Pure Tone**" A sound for which the sound pressure is a simple sinusoidal function of the time, and characterized by its singleness of pitch. Pure tones can be part of a more complex sound wave that has other characteristics.

"**Qualified Independent Acoustical Consultant**" Qualifications for persons conducting baseline and other measurements and reviews related to the application for a WES or for enforcement actions against an operating WES include, at a minimum, demonstration of competence in the specialty of community noise testing. An example is a person with Full Membership in the Institute of Noise Control Engineers (INCE). Certifications such as Professional Engineer (P.E.) do not test for competence in acoustical principles and measurement and are thus not, without further qualification, appropriate for work under this document. The Independent Qualified Acoustical Consultant can have no financial or other connection to a WES developer or related company.

"**Sensitive Receptor**" means places or structures intended for human habitation, whether inhabited or not, public parks, state and federal wildlife areas, the manicured areas of recreational establishments designed for public use, including but not limited to golf courses, camp grounds and other nonagricultural state or federal licensed businesses. These areas are more likely to be sensitive to the exposure of the noise, shadow or flicker, etc. generated by a WES or WESF. These areas include, but are not limited to: schools, daycare centers, elder care facilities, hospitals, places of seated assemblage, non-agricultural businesses and residences.

"**Sound**" A fluctuation of air pressure which is propagated as a wave through air

"**Sound Power**" The total sound energy radiated by a source per unit time. The unit of measurement is the watt. Abbreviated as L_w. This information is determined for the WES manufacturer under laboratory conditions specified by IEC 61400-11 and provided to the local developer for use in computer model construction. It cannot be assumed that these values represent the highest sound output for any operating condition. They reflect the operating conditions required to meet the IEC 61400-11 requirements. The lowest frequency is 50 Hz for acoustic power (L_w) requirement in IEC 61400-11. This Ordinance requires wind turbine certified acoustic power (L_w) levels at rated load for the total frequency range from 6.3 Hz to 10k Hz in one-third octave frequency bands tabulated to the nearest 0.1 dB. The frequency range of 6.3 Hz to 10k Hz shall be used throughout this Ordinance for all sound level modeling, measuring and reporting.

"**Sound Pressure**" The instantaneous difference between the actual pressure produced by a sound wave and the average or barometric pressure at a given point in space.

"**Sound Pressure Level (SPL)**" 20 times the logarithm, to the base 10, of the ratio of the pressure of the sound measured to the reference pressure, which is 20 micronewtons per square meter. In equation form, sound pressure level in units of decibels is expressed as SPL (dB) = 20 log p/pr.

"**Spectrum**" The description of a sound wave's resolution into its components of frequency and amplitude. The WES manufacturer is required to supply a one-third octave band frequency spectrum of the wind turbine sound emission at 90% of rated power. The published sound spectrum is often presented as A-weighted values. This information is used to project the wind farm sound levels at all locations of interest. Confirmation of the projected sound spectrum can be determined with a small portable one-third octave band frequency (spectrum) analyzer. The frequency range of interest for wind turbine noise is approximately 10 Hz to 10k Hz.

"**Statistical Noise Levels**" Sounds that vary in level over time, such as road traffic noise and most community noise, are commonly described in terms of the statistical exceedance levels L_{NA}, where L_{NA} is the A-weighted sound level exceeded for N% of a given measurement period. For example, L_{10} is the noise level exceeded for 10% of the time. Of particular relevance, are: L_{10A} and L_{10C} the noise level exceed for 10% of the ten (10) minute interval. This is commonly referred to as the average maximum noise level. L_{90A} and L_{90C} the noise level exceeded for 90% of the ten (10) minute sample period. The L_{90} noise level is described as the average minimum background sound level (in the absence of the source under consideration), or simply the background level. Leq is the frequency-weighted equivalent noise level (basically the time weighted average noise level). It is defined as the steady sound level that contains the same amount of acoustical energy as the corresponding time-varying sound.

"**Tonal sound (sometimes Pure Tone)**" A sound for which the sound pressure is a simple sinusoidal function of the time, and characterized by its singleness of pitch. Tonal sound can be simple or complex.

"**Wind Energy Systems (WES)**" means equipment that converts and then transfers energy from the wind into usable forms of energy on a large, industrial scale for commercial or utility purposes. Small scale wind systems of less than 170 feet in height with a 60-foot rotor diameter and a nameplate capacity of less than 100 kilowatts or less are exempt from this definition and the provisions of this Ordinance.

"**Wind Turbine" or "Turbine" (WTi)** means a mechanical device which captures the kinetic energy of the wind and converts it into electricity. The primary components of a wind turbine are the blade assembly, electrical generator and tower.

III. APPLICATION PROCEDURE FOR WIND ENERGY SYSTEMS AND TECHNICAL REQUIREMENTS FOR LICENSING

This ordinance is intended to promote the safety and health of the community through criteria limiting sound emissions during operation of Wind Energy Systems. It is recognized that the requirements herein are neither exclusive, nor exhaustive. In instances where a health or safety concern is known to the wind project developer or identified by other means with regard to any application for a Wind Energy System, additional and/or more restrictive conditions may be included in the license to address such concerns. All rights are reserved to impose additional restrictions as circumstances warrant. Such additional or more restrictive conditions may include, without limitation (a) greater setbacks, (b) more restrictive noise limitations, or (c) limits restricting operation during night time periods or for any other conditions deemed reasonable to protect the community.

A. Application

Any Person desiring to secure a Wind Energy Systems license shall file an application form provided by the LGA Clerk, together with two additional copies of the application with the LGA Clerk.

B. Information to be submitted with Application

1. Information regarding the: make and model of the turbines, Sound Power Levels (L_w) for each one-third octave band from 6.3 Hz up through 10,000 Hz, and a projection showing the expected dBA and dBC sound levels computed using the one-third octave band sound power levels (L_w) with appropriate corrections for modeling and measurement accuracy tolerances and directional patterns of the WTi for all areas within and to one (1) mile from the project boundary for the wind speed, direction and operating mode that would result in the worst case WTi nighttime sound emissions.

The prediction model shall assume that the winds at hub height are sufficient for the highest sound emission operating mode even though the enforcement tests will be with ground level winds of 4m/s (9.5 mph) or less. The projection may be by means of computer model but shall include a description of all assumptions made in the model's construction and algorithms. If the model does not consider the effects of wind direction, geography of the terrain, and/or the effects of reinforcement from coherent sounds or tones from the turbines these should be identified and other means used to adjust the model's output to account for these factors. These results may be displayed as a contour map of the predicted levels, but should also include a table showing the predicted levels at noise sensitive receptor sites and residences within the model's boundaries. The predicted values must include dBA and dBC values but shall also include un-weighted octave band sound pressure levels from 8 Hz to 10k Hz in data tables.

C. Preconstruction Background Noise Survey

1. The Town reserves the right to require the preparation of (a) a preconstruction noise survey for each proposed Wind Turbine location conducted per procedures provided here-in and in the Appendix showing background dBA and dBC sound levels ($L_{90\ (10min)}$) over one or more valid ten (10) minute continuous measurement periods prior to approval for the final layout and construction as part of an environmental study evaluating what impact the project may have on sensitive receptors in the vicinity of the proposed WES sites.

a. If any proposed wind farm project locates a WES within one mile of a sensitive receptor these studies are mandatory. The preconstruction baseline studies shall be conducted by an Independent Qualified Acoustical Consultant selected by the LGA.

b. The LGA shall hire an Independent Qualified Acoustical Consultant to conduct the sound study for the LGA as specified in this document. However, the applicant shall be responsible for paying the consultant's fees and costs associated with conducting the study. These fees and cost shall be negotiated with the consultant and determined prior to any work being done on the study. The applicant shall be required to set aside 100% of these fees in an escrow account managed by the LGA, before the study is commenced by the consultant. Payment for this study does not require the WES developer's acceptance of the study's results.

c. If the review shows that the predicted dBA or dBC sound levels exceed the criteria specified in this document then the application cannot be approved.

2. The LGA will refer the application to the LGA engineer (if qualified in acoustics) or an independent qualified acoustical consultant for further review and comparison against the predicted dBA and dBC sound levels supplied with the application. The reasonably necessary costs associated with the review of the sound study shall be the responsibility of the applicant, in accord with the terms of this ordinance.

D. Post Construction Noise Measurement Requirements

1. **Sound Regulations Compliance**: A WES shall be considered in violation of the conditional use permit unless the applicant demonstrates that the project complies with all sound level limits. Sound levels in excess of the limits established in this ordinance shall be grounds for the LGA to order immediate shut down of all non-compliant WTi.

2. **Post-Construction Sound Measurements**: Within twelve months of the date when the project is fully operational, and within four weeks of the anniversary date of the pre-construction background noise measurements, repeat the existing sound environment measurements taken before the project approval. Post-construction sound level measurements shall be taken both with all WES's running and with all WES's off. At the discretion of the Town, the Pre-construction background sound levels (L_{90A}) can be substituted for the "all WES off' tests if a random sampling of 10% of the pre-construction study sites shows that background $L_{90A \text{ and } C}$ conditions have not changed more than +/- 5 dB (dBA and dBC) measured under the pre-construction nighttime meteorological conditions. The post-construction measurements will be reported to the LGA (available for public review) using the same format as used for the preconstruction sound studies. Post-construction noise studies shall be conducted by a firm chosen by the LGA. Costs of these studies are to be reimbursed by the Licensee in a similar manner to that described above. The wind farm developer's own consultant is free to observe the publicly retained consultant at the convenience of the latter. The WES developer/applicant shall provide all technical information and wind farm data required by the independent qualified acoustical consultant before, during, and/or after any acoustical studies required by this document and for local area acoustical measurements.

3. Sound Limits

1. Audible Sound Limit

a. No WTi or WES shall be located so as to cause an exceedance of the pre-construction/operation background sound levels by more than 5 dBA. The background sound levels shall be the L_{90A} sound descriptor measured with a stable atmosphere during a pre-construction noise study during the quietest time of night (10pm until 4am). All data sampling shall be one or more contiguous ten (10) minute measurements. L_{90A} results are valid when L_{10A} results are no more than 10 dBA above L_{90A} for the same time period and L_{10C} less L_{90C} is no more than 15 dBC. Noise sensitive sites are to be selected based on wind development's predicted worst-case sound emissions (in L_{eqA} and L_{eqC}) which are to be provided by developer.

b. Test sites are to be located along the property line(s) of the receiving non-participating property(s).

c. Not to exceed 35 dBA within 30 m. (approx. 100 feet) of any occupied structure.

d. A 5 dB penalty is applied for tones as defined in IEC 61400-11. (the reference preconstruction measured L_{90A} and L_{90C} are lowered 5 dB).

2. Low Frequency Sound Limit

a. The L_{eqC} and L_{90C} sound levels from the wind turbine at the receiving property shall not exceed either:

1) dBC minus L_{90A} greater than 20 dB outside any occupied structure, or

2) A maximum not-to-exceed sound level of 50 dBC from the wind turbines without contribution from other ambient sounds for properties located one mile or more away from state highways or other major roads or 55 dBC for properties closer than one mile.

These limits shall be assessed using the same nighttime and wind/weather conditions required in 1.a. Turbine operating sound immissions shall represent worst case sound immissions for stable atmospheric nighttime conditions with low winds at ground level and winds sufficient for full operating capacity at the hub.

3. Operations Exceeding any of the limits in this section will be considered as proof that the WES/WTi is non-compliant and must be shut down immediately.

4. Requirements

a. All instruments must meet ANSI or IEC Type 1 Precision integrating sound level meter performance specifications.

b. Procedures must meet ANSI S12.9 Part 3 including the addendum in the Appendix to this document. Where there are differences between the procedures and definitions of this document and ANSI standards the procedures and definitions of this document will be applied. Where a standard's requirements may conflict with other standards the most stringent requirement shall be followed.

c. Measurements for background sound levels must be made when ground level winds are 2m/s (4.5 mph) or less with wind speeds at the turbine hub at or above nominal operating requirements and for other tests when ground level winds are less than 4m/s (9 mph). Weather in the night often results in low ground level wind speed and nominal operating wind speeds at wind turbine hub heights when the atmosphere is stable.

d. IEC 61400-11 procedures are not suitable for enforcement of these requirements except for the presence of tones.

4. Complaint Resolution

1. The owner/operator of the WES shall respond within five (5) business days after notified of a noise complaint by any property owner within the project boundary and a one-mile radius beyond the project boundary.
2. The tests shall be performed by a qualified acoustical consultant acceptable to the complainant and the local agency charged with enforcement of this ordinance.
3. Testing shall commence within ten (10) working days of the request. If testing cannot be initiated within ten (10) days, the WES(s) in question shall be shut down until the testing can be started.
4. A copy of the test results shall be sent to the property owner, and the LGA's Planning or Zoning department within thirty (30) days of test completion.
5. If a Complaint is made, the presumption shall be that it is reasonable. The LGA shall undertake an investigation of the alleged operational violation by a qualified individual mutually acceptable to the LGA.
   a) The reasonable cost and fees incurred by the LGA in retaining said qualified individual shall be reimbursed by the owner of the WESF.
   b) Funds for this assessment shall be paid or put into an escrow account prior to the study and payment shall be independent of the study findings.
6. After the investigation, if the LGA reasonably concludes that operational violations are shown to be caused by the WESF, the licensee/operator/owner shall use reasonable efforts to mitigate such problems on a case-by-case basis including such measures as not operating during the night time or other noise sensitive period if such operation was the cause of the complaints.

5. Reimbursement of Fees and Costs.

Licensee/operator/owner agrees to reimburse the LGA 's actual reasonable fees and costs incurred in the preparation, negotiation, administration and enforcement of this Ordinance, including, without limitation, the LGA 's attorneys' fees, engineering and/or consultant fees, LGA meeting and hearing fees and the costs of public notices. If requested by the LGA the funds shall be placed in an escrow account under the management of the LGA. The preceding fees are payable within thirty (30) days of invoice. Unpaid invoices shall bear interest at the rate of 1% per month until paid. The LGA may recover all reasonable costs of collection, including attorneys' fees.

VII. MEASUREMENT PROCEDURES

APPENDIX TO WIND ENERGY SYSTEMS LICENSING ORDINANCE FOR SOUND

I. Introduction

The potential impact of sound and sound induced building vibration associated with the operation of wind powered electric generators is often a primary concern for citizens living near proposed wind energy systems (WES(s)). This is especially true of projects located near homes, residential neighborhoods, businesses, schools, and hospitals in quiet residential and rural communities. Determining the likely sound and vibration impacts is a highly technical undertaking and requires a serious effort in order to collect reliable and meaningful data for both the public and decision makers.

This protocol is based in part on criteria published in American National Standards S12.9 –Part 3 Quantities and Procedures for Description and Measurement of Environmental Sound, and S12.18 and for the measurement of sound pressure level outdoors.

The purpose is to first, establish a consistent and scientifically sound procedure for evaluating existing background levels of audible and low frequency sound in a WES project area, and second to use the information provided by the Applicant in its Application showing the predicted over-all sound levels in terms of dBA and dBC as part of the required information submitted with the application.

These values shall be presented as overlays to the applicant's iso-level plot plan graphics (dBA and dBC) and in tabular form with location information sufficient to permit comparison of the baseline results to the predicted levels. This comparison will use the level limits of the ordinance to determine the likely impact operation of a new wind energy system project will have on the existing community soundscape. If the comparison demonstrates that the WES project will not exceed any of the level limits the project will be considered to be within allowable limits for safety and health. If the Applicant submits only partial information required for this comparison the application cannot be approved. In all cases the burden to establish the operation as meeting safety and health limits will be on the Applicant.

Next it addresses requirements for the sound propagation model to be supplied with the application.

Finally, if the project is approved, this Appendix covers the study needed to compare the post-build sound levels to the predictions and the baseline study. The level limits in the ordinance apply to the post-build study. In addition, if there have been any complaints about WES sound or low frequency noise emissions or wind turbine noise induced dwelling vibration by any resident of an occupied dwelling that property will be included in the post-build study for evaluation against the rules for sound level limits and compliance.

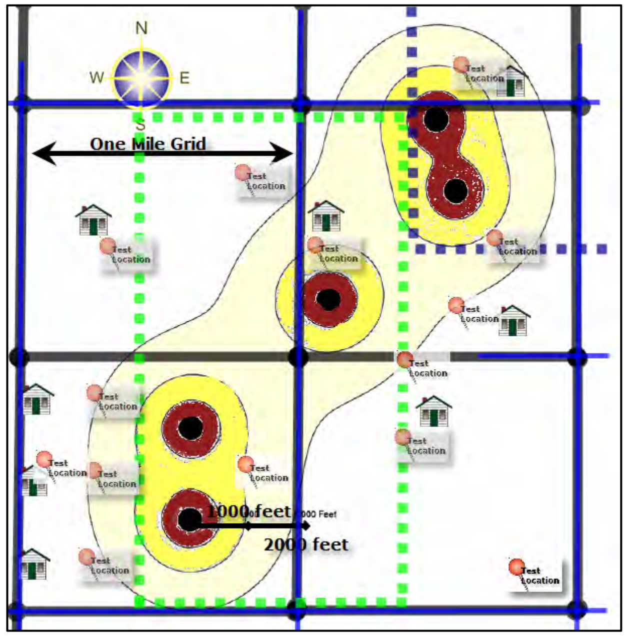
The characteristics of the proposed WES project and the features of the surrounding environment will influence the design of the sound and vibration study. Site layout, types of WES(s) selected and the existence of other significant local audible and low frequency sound sources and sensitive receptors should be taken into consideration when designing a sound study. The work will be performed by an independent qualified acoustical consultant for both the pre-construction background and post-construction sound studies as described in the body of the ordinance.

II. Instrumentation

All instruments and other tools used to measure audible, inaudible and low frequency sound shall meet the requirements for ANSI or IEC Type 1 Integrating Averaging Sound Level Meter Standards The principle standard reference for this document is ANSI 12.9/Part 3 with important additional specific requirements for the measuring instrumentation and measurement protocol.

III. Measurement of Pre-Construction Sound Environment (Base-lines)

An assessment of the proposed WES project areas existing sound environment is necessary in order to predict the likely impact resulting from a proposed project. The following guidelines must be used in developing a reasonable estimate of an area's existing background sound environment. All testing is to be performed by an independent qualified acoustical consultant approved by the LGA as provided in the body of the ordinance. The WES applicant may file objections detailing any concerns it may have with the LGA's selection. These concerns will be addressed in the study. Objections must be filed prior to the start of the noise study. All measurements are to be conducted with ANSI or IEC Type 1 certified and calibrated test equipment per reference specification at the end of this Appendix. Test results will be reported to the LGA or its appointed representative.



Sites with No Existing Wind Energy Systems (Base-line Sound Study)

Sound level measurements shall be taken as follows:

The results of the model showing the predicted worst case dBA and dBC sound emissions of the proposed WES project will be overlaid on a map (or separate dBA and dBC maps) of the project area. An example (right) shows an approximately two (2) mile square section with iso-level contour lines prepared by the applicant, sensitive receptors (homes) and locations selected for the baseline dBA and dBC sound tests whichever are the controlling metric. The test points shall be located at the property line bounding the property of the turbine's host closest to the wind turbine. Additional sites may be added if appropriate. A grid comprised of one (1) mile boundaries (each grid cell is one (1) square mile) should be used to assist in identifying between two (2) to ten (10) measurement points per cell. The grid shall extend to a minimum of one (1) mile beyond the perimeter of the project boundary. This may be extended to more than one mile at the discretion of the LGA. The measurement points shall be selected to represent the noise sensitive receptor sites based on the anticipated sound propagation from the combined WTi in the project. Usually, this will be the closest WTi. If there is more than one WTi near-by then more than one test site may be required.

The intent is to anticipate the locations along the bounding property line that will receive the highest sound immissions. The site that will be most likely negatively affected by the WES project's sound emissions should be given first priority in testing. These sites may include sites adjacent to occupied dwellings or other noise sensitive receptor sites. Sites shall be selected to represent the locations where the background soundscapes reflect the quietest locations of the sensitive receptor sites. Background sound levels (and one-third octave band sound pressure levels for the sound measuring consultants file) shall be obtained according to the definitions and procedures provided in the ordinance and recognized acoustical testing practice and standards.

All properties within the proposed WES project boundaries will be considered for this study.

One test shall be conducted during the period defined by the months of April through November with the preferred time being the months of June through August. These months are normally associated with more contact with the outdoors and when homes may have open windows during the evening and night. Unless directed otherwise by the LGA the season chosen for testing will represent the background soundscape for other seasons. At the discretion of the LGA, tests may be scheduled for other seasons.

All measurement points (MPs) shall be located with assistance from the LGA staff and property owner(s) and positioned such that no significant obstruction (building, trees, etc.) blocks sound and vibration from the nearest proposed WES site.

Duration of measurements shall be a minimum of ten continuous minutes for each criterion at each location. The duration must include at least six (6) minutes that are not affected by transient sounds from near-by and non-nature sources. Multiple ten (10) minute samples over longer periods such as 30 minutes or one (1) hour may be used to improve the reliability of the L_{90} values. The ten minute sample with the lowest valid L_{90} values will be used to define the background sound.

The tests at each site selected for this study shall be taken during the expected 'quietest period of the day or night' as appropriate for the site. For the purpose of determining background sound characteristics the preferred testing time is from 10pm until 4 am. If circumstances indicated that a different time of the day should be sampled the test may be conducted at the alternate time if approved by the Town.

Sound level measurements must be made on a weekday of a non-holiday week. Weekend measurements may be taken at selected sites where there are weekend activities that may be affected by WTi sound.

Measurements must be taken at 1.2 to 1.5 meters above the ground and at least 15 feet from any reflective surface following ANSI 12.9 Part 3 protocol including selected options and other requirements outlined later in this Section.

Reporting

1. For each Measurement Point and for each measurement period, provide each of the following measurements:

    a. L_{Aeq}, L_{10}, and L_{90}, in dBA

    b. L_{Ceq} , L_{10}, and L_{90}, in dBC

2. A narrative description of any intermittent sounds registered during each measurement. This may be augmented with video and audio recordings.

3. A narrative description of the steady sounds that form the background soundscape. This may be augmented with video and audio recordings.

4. Wind speed and direction at the Measurement Point, humidity and temperature at time of measurement will be included in the documentation. Corresponding information from the nearest 10 meter weather reporting station shall also be obtained.

Measurements taken when wind speeds exceed 2m/s (4.5 mph) at the microphone location will not be considered valid for this study. A windscreen of the type recommended by the monitoring instrument's manufacturer must be used for all data collection.

5. Provide a map and/or diagram clearly showing (Using plot plan provided by LGA or Applicant):

- The layout of the project area, including topography, the project boundary lines, and property lines.

- The locations of the Measurement Points.
- The minimum and maximum distance between any Measurement Points.
- The location of significant local non-WES sound and vibration sources.
- The distance between all MPs and significant local sound sources. And,
- The location of all sensitive receptors including but not limited to: schools, day-care centers, hospitals, residences, residential neighborhoods, places of worship, and elderly care facilities.

Sites with Existing Wind Energy Systems

Two complete sets of sound level measurements must be taken as defined below:

1. One set of measurements with the wind generator(s) off unless the LGA elects to substitute the sound data collected for the background sound study.. Wind speeds must be suitable for background testing.

2. One set of measurements with the wind generator(s) running with wind speed at hub height sufficient to meet nominal power output or higher and at 2 m/s or below at the microphone location. Conditions should reflect the worst case sound emissions from the WES project. This will normally involve tests taken during the evening or night when winds are calm (2m/sec or less) at the ground surface yet, at hub height, sufficient to operate the turbines.

Sound level measurements and meteorological conditions at the microphone shall be taken and documented as discussed above.

Sound level Estimate for Proposed Wind Energy Systems (when adding more WTi to existing project)

In order to estimate the sound impact of the proposed WES project on the existing environment an estimate of the sound produced by the proposed WES(s) under worst-case conditions for producing sound emissions must be provided. This study may be conducted by a firm chosen by the WES operator with oversight provided by the LGA.

The qualifications of the firm should be presented along with details of the procedure that will be used, software applications, and any limitations to the software or prediction methods.

Provide the manufacturer's sound power level (L_w) characteristics for the proposed WES(s) operating at full load utilizing the methodology in IEC 61400-11 Wind Turbine Noise Standard. Provide one-third octave band L_w sound power level information from 6.3 Hz to 10k Hz. Furnish the data with and without A-weighting. Provide sound pressure levels predicted for the WES(s) in combination and at full operation and at maximum sound power output for all areas where the predictions indicate dBA levels of 30 dBA and above. The same area shall be used for reporting the predicted dBC levels. Contour lines shall be in increments of 5 dB.

Present tables with the predicted sound levels for the proposed WES(s) in dBA, dBC and at all octave band centers (8 Hz to 10k Hz) for distances of 500, 1000, 1500, 2000, 2500 and 5000 feet from the center of the area with the highest density of WES(s). For projects with multiple WES(s), the combined sound level impact for all WES(s) operating at full load must be estimated.

The above tables must include the impact (increased dBA and dBC above baseline L_{90} Background sound levels) of the WES operations on all residential and other noise sensitive receiving locations within the project boundary. To the extent possible, the tables should include the sites tested in the background study.

Provide a contour map of the expected sound level from the new WES(s), using 5 dBA and 5 dBC increments created by the proposed WES(s) extending out to a distance of one mile from the project boundary, or other distance necessary, to show the 35 dBA and 50 dBC boundary.

Provide a description of the impact of the proposed sound from the WES project on the existing environment. The results should anticipate the receptor sites that will be most negatively impacted by the WES project and to the extent possible provide data for each MP that are likely to be selected in the background sound study (note the sensitive receptor MPs):

1. Report expected changes to existing sound levels for L_{Aeq}, L_{10} and L_{90}, in dBA

2. Report expected changes to existing sound levels for L_{Ceq}, L_{10} and L_{90}, in dBC

3. Report the predicted sound pressure levels for each of the 1/1 octave bands as un-weighted dB in tabular form from 8 Hz to 10k Hz.

4. Report all assumptions made in arriving at the estimate of impact, any limitations that might cause the sound levels to exceed the values of the estimate, and any conclusions reached regarding the potential effects on people living near the project area. If the effects of coherence, worst case weather, or operating conditions are not reflected in the model a discussion of how these factors could increase the predicted values is required.

5. Include an estimate of the number of hours of operation expected from the proposed WES(s) and under what conditions the WES(s) would be expected to run. Any differences from the information filed with the Application should be addressed.

IV. Post-Construction Measurements

Post Construction Measurements should be conducted by a qualified noise consultant selected by and under the direction of the LGA. The requirements of this Appendix for Sites with Existing Wind Energy Systems shall apply

1. Within twelve months of the date when the project is fully operational, and within two weeks of the anniversary date of the Pre-construction ambient noise measurements, repeat the existing sound environment measurements taken before the project approval. Post-construction sound level measurements shall be taken both with all WES(s) running and with all WES(s) off except as provided the ordinance.

2. Report post-construction measurements to the LGA using the same format as used for the background sound study.

3 Project Boundary: A continuous line encompassing all WES(s) and related equipment associated with the WES project.

V. REFERENCES

ANSI/ASA S12.9-1993/Part 3 (R2008) - American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 3: Short-Term Measurements with an Observer Present.

This standard is the second in a series of parts concerning description and measurement of outdoor environmental sound. The standard describes recommended procedures for measurement of short-term, time-average environmental sound outdoors at one or more locations in a community for environmental assessment or planning for compatible land uses and for other purposes such as demonstrating compliance with a regulation. These measurements are distinguished by the requirement to have an observer present. Sound may be produced by one or more separate, distributed sources of sound such as a highway, factory, or airport. Methods are given to correct the measured levels for the influence of background sound.

Wind Turbine Siting Acoustical Measurements
ANSI S12.9 Part 3 Options and other requirements

For the purposes of this ordinance specific options that are provided in ANSI S12.9-Part 3 (2008) shall apply with the additional following requirements to Sections in ANSI S12.9/Part 3:

5.2 background sound: Use definition (1) 'long-term'
5.3 long-term background sound: The L_{90} excludes short term background sounds
5.4 basic measurement period: Ten (10) minutes $L_{90(10\ min)}$
5.6 Sound Measuring Instrument: Type 1 integrating meeting ANSI S1.43 or IEC 61672-1. The sound level meter shall contain one-third octave band analyzer with frequency range from 6.3 Hz to 20k Hz and capability to simultaneously measure dBA L_N and dBC L_N. The instrument must also be capable of accurately measuring low level background sounds down to 20 dBA.
6.5 Windscreen: Required
6.6(a) An anemometer accurate to ± 10% at 2m/s. Ignore reference to full scale accuracy. The anemometer shall be located 2m above the ground and orientated to record maximum wind velocity. The maximum wind velocity, wind direction, temperature and humidity shall be recorded for each 10 minute sound measurement period observed within 5m of the measuring microphone..
7.1 Long-term background sound
7.2 Data collection Methods: Second method Observed samples to avoid contamination by short term sounds (purpose: to avoid loss of statistical data)
8 Source(s) Data Collection: All requirements in ANSI S12.18 Method #2 precision to the extent possible while still permitting testing of the conditions that lead to complaints. The meteorological requirements in ANSI S12.18 may not be applicable. For sound measurements in response to a complaint, the compliance sound measurements should be made under conditions that replicate the conditions that caused the complaint.
8.1(b) Measuring microphone with windscreen shall be located 1.2m to 1.8m above the ground and greater than 8m from large sound reflecting surface.
8.3(a) All meteorological observations required at both (not either) microphone and nearest 10m weather reporting station.
8.3(b) For a 10 minute background sound measurement to be valid the wind velocity shall not exceed 2m/s (4.5 mph) measured less than 5m from the microphone. Compliance sound measurements shall not be taken when winds exceed 4m/s.

8.3(c) In addition to the required acoustic calibration checks, the sound measuring instrument internal noise floor, including microphone, must also be checked at the end of each series of ten minute measurements and no less frequently than once per day. Insert the microphone into the acoustic calibrator with the calibrator signal off. Record the observed dBA and dBC reading on the sound level meter to determine an approximation of the instrument self noise. Perform this test before leaving the background measurement location. This calibrator covered microphone must demonstrate the results of this test are at least 5 dB below the immediately previous ten minute acoustic test results, for the acoustic background data to be valid. This test is necessary to detect undesired increase in the microphone and sound level meter internal self noise. As a precaution sound measuring instrumentation should be removed from any air conditioned space at least an hour before use. Nighttime measurements are often performed very near the meteorological dew point. Minor moisture condensation inside a microphone or sound level meter can increase the instrument self noise and void the measured background data.

8.4 The remaining sections starting at 8.4 in ANSI S12.9 Part 3 Standard do not apply.

ANSI S12.18-1994 (R2004) American National Standard Procedures for Outdoor Measurement of Sound Pressure Level

This American National Standard describes procedures for the measurement of sound pressure levels in the outdoor environment, considering the effects of the ground, the effects of refraction due to wind and temperature gradients, and the effects due to turbulence. This standard is focused on measurement of sound pressure levels produced by specific sources outdoors. The measured sound pressure levels can be used to calculate sound pressure levels at other distances from the source or to extrapolate to other environmental conditions or to assess compliance with regulation. This standard describes two methods to measure sound pressure levels outdoors. METHOD No. 1: general method; outlines conditions for routine measurements. METHOD No. 2: precision method; describes strict conditions for more accurate measurements. This standard assumes the measurement of A-weighted sound pressure level or time-averaged sound pressure level or octave, 1/3-octave or narrow-band sound pressure level, but does not preclude determination of other sound descriptors.

ANSI S1.43-1997(R2007) American National Standard Specifications for Integrating Averaging Sound Level Meters

This Standard describes instruments for the measurement of frequency-weighted and time-average sound pressure levels. Optionally, sound exposure levels may be measured. This standard is consistent with the relevant requirements of ANSI S1.4-1983(R 1997) American National Standard Specification for Sound Level Meters, but specifies additional characteristics that are necessary to measure the time-average sound pressure level of steady, intermittent, fluctuating, and impulsive sounds.

ANSI S1.11-2004 American National Standard 'Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters'

This standard provides performance requirements for analog, sampled-data, and digital implementations of band-pass filters that comprise a filter set or spectrum analyzer for acoustical measurements. It supersedes ANSI S1.11-1986 (R1998) American National Standard Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters, and is a counterpart to International Standard IEC 61260:1995 Electroacoustics - Octave-Band and Fractional-Octave-Band Filters. Significant changes from ANSI S1.11-1986 have been adopted in order to conform to most of the specifications of IEC 61260:1995. This standard differs from IEC 61260:1995 in three ways: (1) the test methods of IEC 61260 clauses 5 is moved to an informative annex, (2) the term 'band number,' not present in IEC 61260, is used as in ANSI S1.11-1986, (3) references to American National Standards are incorporated, and (4) minor editorial and style differences are incorporated.

ANSI S1.40-2006 American National Standard Specifications and Verification Procedures for Sound Calibrators

IEC 61400-11

Second edition 2002-12, Amendment 1 2006-05

IEC 61400-11

Second edition 2002-12, Amendment 1 2006-0

Wind turbine generator systems –Part 11: Acoustic noise measurement techniques

The purpose of this part of IEC 61400 is to provide a uniform methodology that will ensure consistency and accuracy in the measurement and analysis of acoustical emissions by wind turbine generator systems. The standard has been prepared with the anticipation that it would be applied by:

- the wind turbine manufacturer striving to meet well defined acoustic emission performance requirements and/or a possible declaration system;
- the wind turbine purchaser in specifying such performance requirements;
- the wind turbine operator who may be required to verify that stated, or required, acoustic performance specifications are met for new or refurbished units;
- the wind turbine planner or regulator who must be able to accurately and fairly define acoustical emission characteristics of a wind turbine in response to environmental regulations or permit requirements for new or modified installations.

This standard provides guidance in the measurement, analysis and reporting of complex acoustic emissions from wind turbine generator systems. The standard will benefit those parties involved in the manufacture, installation, planning and permitting, operation, utilization, and regulation of wind turbines. The measurement and analysis techniques recommended in this document should be applied by all parties to insure that continuing development and operation of wind turbines is carried out in an atmosphere of consistent and accurate communication relative to environmental concerns. This standard presents measurement and reporting procedures expected to provide accurate results that can be replicated by others.

End of Measurement Procedure

The Noise-Con 2008 paper has been moved to a separate Appendix

Appendix D
Abstract of Dr. Pierpont's Study
"Wind Turbine Syndrome"

Wind Turbine Syndrome: A Report on a Natural Experiment

Nina Pierpont, MD, PhD

ABSTRACT

August 9, 2008

This report documents a consistent, often debilitating complex of symptoms experienced by adults and children while living near large (1.5-3 MW) industrial wind turbines, examines patterns of individual susceptibility, and proposes pathophysiologic mechanisms. Symptoms include sleep disturbance, headache, tinnitus, ear pressure, dizziness, vertigo, nausea, visual blurring, tachycardia, irritability, problems with concentration and memory, and panic episodes associated with sensations of internal pulsation or quivering which arise while awake or asleep.

The study is a case series of 10 affected families, with 38 members age 0-75, living 305 m to 1.5 km (1000 to 4900 ft) from wind turbines erected since 2004. All competent and available adults and older teens completed a detailed clinical interview about their own and their children's symptoms, sensations, and medical conditions before turbines were erected near their homes, while living near operating turbines, and after leaving their homes or spending a prolonged period away.

Risk factors for symptoms during exposure include pre-existing migraine disorder, motion sensitivity, and inner ear damage. Symptoms are not statistically associated with pre-existing anxiety or other mental health disorders. The symptom complex resembles syndromes caused by vestibular dysfunction.

The proposed pathophysiology posits disturbance to balance and position sense due to low frequency noise or vibration stimulating receptors for the balance system (vestibular, somatosensory, or visceral sensory, as well as visual stimulation from moving shadows) in a discordant fashion. Vestibular neural signals are known to affect a variety of brain areas and functions, including memory, spatial processing, complex problem-solving, fear, autonomic effects, and aversive learning, providing a robust neural framework for the symptom associations in Wind Turbine Syndrome. Further research is needed to establish prevalence and to explore effects in special populations, including children. A minimum setback of 2 km (1¼ mi) is proposed to offer interim protection while research is ongoing.

Appendix E
Email from World Health Organization (WHO)

From: Rokho Kim [mailto:rki@ecehbonn.euro.who.int]
Sent: Tuesday, July 31, 2007 4:37 PM
To: nypainter@hughes.net
Cc: kortume@who.int; Bravard, Marie-Françoise
Subject: RE: Noise relation to wind turbines

Dear Francis Andre,

WHO does not have a guideline on noise exposure specific to wind turbines. However, WHO Guidelines on Community Noise of 2000 would be a useful reference regarding health impacts of noise generated by wind turbines. Noise from wind turbines can be considered "continuous noise" mentioned in the above document. In the chapter 4 Guideline Values, the following recommendation is made:

" Where noise is continuous, the equivalent sound pressure level should not exceed 30 dBA indoors, if negative effects on sleep are to be avoided. When the noise is composed of a large proportion of low-frequency sounds a still lower guideline value is recommended, because low frequency noise (e.g. from ventilation systems) can disturb rest and sleep even at low sound pressure levels."

You may download the full document as pdf files at WHO website,
http://www.who.int/docstore/peh/noise/guidelines2.html

For the updated information on health impacts of noise, please check the materials available at http://www.euro.who.int/Noise. WHO European office has recently finished a project on Night Noise Guidelines for Europe. The final document will be available as WHO publication by October 2007.

I hope this helps, and if you have further inquries, feel free to contact me again.

Best regads,
Rokho

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Appendix F
Email from H. Metzen, DataKustic, GmhB

Email communications from H. Metzen, DataKustik, Nov. 2006

“Rick,
Long range propagation including atmospheric refraction is not part of the standards used for (normal, "standard") noise calculations. It is known that atmospheric refraction may cause sound to be refracted downwards again and contributing strongly to the level at long distances. **The atmosphere in the standards existing is just homogeneous above height.**

However, there is also in Europe and in Germany some discussion going on about "atmospheric noise". Recently a study group has been set up here to look for possible solutions. This could end in new standards or in amendments of existing ones. The problem is that nobody knows the layer structure and the properties of the atmosphere vs. height. That's the situation right now.

With kind regards

H. Metzen

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