THE STATE OF NEW HAMPSHIRE
BEFORE THE
SITE EVALUATION COMMITTEE

DOCKET NO. 2010-01

APPLICATION OF GROTON WIND, LLC
FOR A CERTIFICATE OF SITE AND FACILITY

SUPPLEMENTAL PREFILED TESTIMONY OF ROBERT D. O'NEAL ON BEHALF OF GROTON WIND, LLC

October 12, 2010

Qualifications

Q. Please state your name, position and business address.

A. My name is Robert D. O'Neal, INCE, CCM. I am a Principal at Epsilon Associates, Inc. ("Epsilon"). My business address is 3 Clock Tower Place, Maynard, Massachusetts. My qualifications have not changed since the filing of my prefiled direct testimony.

Q. On whose behalf are you testifying?

A. I am testifying on behalf of Groton Wind, LLC ("Groton Wind" or "the Applicant").

Purpose of Testimony

Q. What is the purpose of your supplemental prefiled testimony?

A. The purpose of this testimony is to update information contained in my prefiled direct testimony concerning the Groton Wind Project's potential noise impacts. In addition, it responds to several items contained in the prefiled direct testimony of

Gregory Tocci which was submitted by Counsel for the Public. It also responds to claims asserted by intervenors regarding the issue of low frequency sound.

Q. Please summarize additional activities with which you have been involved on behalf of the Groton Wind Project since the time your prefiled direct testimony was submitted in March 2010.

A. I have participated in the following activities on behalf of Groton wind since March 2010:

- June 28, 2010 – attended NH SEC Public Information Hearing, Plymouth, NH
- July 2010 – answered data requests from Counsel for Public and intervenors
- August 10, 2010 – attended NH SEC Technical Session #1, Concord, NH
- August 11, 2010 – responded to Record Requests from 8/10/10 Technical Session
- September 2010 – reviewed prefiled testimony of intervenors and Counsel for the Public
- September 27, 2010 – attended NH SEC Technical Session #2, Concord, NH
- October 4, 2010 – attended NH Counsel for the Public site visit to deploy sound monitoring stations, Groton/Rumney/Plymouth, NH

Q. Please comment on the prefiled direct testimony of Gregory Tocci.

A. In paragraph 11 of Mr. Tocci's prefiled testimony, he states that modern "upwind" style wind turbines (with turbine blades upstream of supporting towers) avoid the propensity to generate the significant levels of low frequency sound common in older turbine arrangements. This supports our conclusion that modern upwind turbines like those proposed for the Groton Wind Project are not a significant source of low-frequency sound. In fact, Mr. Tocci's own review of the Clayton (NY) wind farm project on behalf of the Town of Clayton Planning Board notes that "[d]esigning wind turbines so that the blades are upstream of the tower support has mostly eliminated low frequency excitation in newer wind turbines." Letter from Cavanaugh Tocci Associates, Inc. to Town of Clayton Planning Board, p. 6 (February 15, 2008) (attached hereto as Attachment 1.)

Paragraph 12 of Mr. Tocci's prefiled testimony discusses the blade passage frequency ("BPF") of wind turbines of the size proposed for the Groton Project and concludes that few sound level meters are designed to measure sound at this low frequency. However, he acknowledges that even if this sound is properly measured, there are no guidelines or criteria that can be used to evaluate or compare these data. In fact, in his review of a paper on infrasound from wind turbines provided by Intervenor Lewis,[1] Mr. Tocci notes that "It is very interesting, but stops short of suggesting a measureable infrasound guideline below which little or not [sic] affect on humans can be expected. Without this scientific backing, it is hard to implement engineering analysis to evaluate impact."[2]

Mr. Tocci concludes, in paragraph 13, that because there are no guidelines for evaluating or comparing low frequency sound data, the meaning of it "would be questionable." Nonetheless, even without these guidelines, Mr. Tocci proposes that the Applicant should undertake evaluating sound at low frequencies including at blade passage. In light of the fact that Mr. Tocci himself acknowledges that without evaluative criteria, the meaning of low frequency sound measurements would be questionable, no

[1] "Response to the Ear to Infrasound and Wind Turbines", Cochlear Fluids Research Laboratory, Washington University in St. Louis, Alec Salt, PhD, revised August 30, 2010. http://oto2.wustl.edu/cochlea/windmill.html

[2] Email from Mr. Tocci dated October 6, 2010 (attached hereto as Attachment 2).

useful purpose would be served by requiring the Applicant to undertake the studies suggested by Mr. Tocci.

The topic of infrasound was discussed further during the technical session on September 27, 2010. One paper provided by Counsel for the Public "Wind Turbines and Infrasound"[3] discussed possible criteria for infrasound. This paper mentions the "G-weighting" network which is designed specifically for infrasound (~1 to 20 Hz). While there are several thresholds discussed, they generally range from 85 to 100 dBG as a minimum level before humans perceive infrasound. While sound level data below 20 Hz were not available for the exact wind turbine proposed for the Groton Wind Project, Epsilon Associates has conducted infrasound measurements on other wind turbines at 1,000 feet away which showed G-weighted sound levels well below 80 dBG (see raw one-third octave band data in reference).[4] The closest residence will be approximately 2,700 feet from the nearest wind turbine. Thus, G-weighted levels would be much lower than those measured by Epsilon at 1,000 feet. Another paper[5] provided by Counsel for the Public following the 9/27/10 technical session, also confirms, on page 1, that "[t]here is no evidence to indicate that low-frequency sound or infrasound from current models of Wind Turbine Generators should cause concern." Based on this information, there is no need to study infrasound in connection with this Application.

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[3] "Wind Turbines and Infrasound," submitted to CanWEA, Brian Howe at HGC Engineering, November 29, 2006. (Provided by Counsel for the Public.)
[4] "Low Frequency Sound and Infrasound from Wind Turbines – A Status Update," R.D. O'Neal, R.D. Hellweg, R.L. Lampeter, Epsilon Associates, Inc., presented at NOISE-CON 2010, Baltimore, MD, 2010 (attached hereto as Attachment 3).
[5] G. Bellhouse, "Low Frequency Noise and Infrasound From Wind Turbine Generators: A Literature Review," New Zealand Energy Efficiency and Conservation Authority, 2004. (Provided by Counsel for the Public.)

Paragraph 14 of Mr. Tocci's prefiled testimony discusses potential modulated broadband sound, often described as "swooshing" sound and suggests that this issue be addressed in a sound impact report. It is important to clarify that modulated broadband sound is not low frequency or infrasound. As reported in the December 2009 AWEA/CanWEA study,[6] the fluctuating aerodynamic sound (swish) in the 500 to 1,000 Hz range occurs from the wind turbine blades disturbing the air, modulated as the blades rotate which changes the sound dispersion characteristics in an audible manner. This fluctuating aerodynamic sound is the cause of most sound complaints regarding wind turbines, as it is harder to become accustomed to fluctuating sound than to sound that does not fluctuate. However, this fluctuation does not always occur and a UK study showed that it had been a problem in only four out of 130 UK wind farms, and had been resolved in three of those. Moreover, there are no objective criteria to which these sound levels can be compared and evaluated. This is further supported by the work of acoustical engineer Dr. Geoff Leventhall[7] and by Mr. Tocci at the September 27, 2010 Technical Conference, where he stated that he was not aware of any BPF criteria. Accordingly, because there are no evaluative criteria for modulated broadband sound, Mr.Tocci's suggestion that it should be addressed in the Applicant's sound reports is unfounded.

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[6] Wind Turbine Sound and Health Effects: An Expert Panel Review, Prepared by W. David Colby, M.D. et. al., Prepared for American Wind Energy Association and Canadian Wind Energy Association; December 2009. (Appendix 52)

[7] "Infrasound from Wind Turbines – Fact, Fiction or Deception," Dr. Geoff Leventhall, Canadian Acoustics, Vol. 34, No. 2, 2006. http://www.wind.appstate.edu/reports/06-06Leventhall-Infras-WT-CanAcoustics2.pdf

Q. Please comment on the prefiled direct testimony of the intervenors as that testimony relates to the issue of sound.

A. Cheryl Lewis, Intervenor from Rumney: Ms. Lewis's prefiled testimony asserts that sound from the Groton Wind Farm may potentially affect her business – a campground – because she fears that the Project's sound will interfere with her campers' ability to sleep. She has requested that the Applicant conduct ambient sound studies at her campground. She has also recommended that if the Application is approved, that the Project should be required to adhere to sound limits of no more than 30 dBA at her campground.

I do not share Ms. Lewis's concerns about the Project's anticipated effects on sound levels at her campground. Based on Epsilon's sound studies, it is anticipated that sound levels at Ms. Lewis's campground, under a worst case scenario, will not exceed 32 dBA. Post-construction sound monitoring for the Lempster Wind Farm at Pillsbury State Park, which has camping facilities 4,800 feet from the closest wind turbine, found that worst-case sound levels were approximately 35 dBA. This is below the noise conditions that the SEC imposed on the Lempster Wind Project, and there have not been any complaints from campers at Pillsbury State Park about wind turbine noise.

I believe that a condition limiting sound levels to 30 dBA is unsupported and unreasonable, especially in light of the fact that existing sound levels in the area of Ms. Lewis's campground are generally already above 30 dBA most of the time due to its proximity to Route 25 traffic.

As for Ms. Lewis's requests for sound monitoring at her campground, I note that such studies are currently under way. On October 4, 2010, I met with Mr. Tocci to determine an appropriate location at Ms. Lewis's campground for monitoring ambient sound over the next few weeks. It is expected that Mr. Tocci will provide a report of this study on or before October 22, 2010, and I reserve the right to submit additional supplemental prefiled testimony regarding that study. In addition, it should be noted that during technical sessions in this docket, Ms. Lewis indicated that her campground closes for the season on Columbus Day. Thus, the time period during which the ambient sound measurements will be collected by Mr. Tocci at Ms. Lewis's campground is at the very end of the camping season, and even after the close of Ms. Lewis's campground. Therefore, I believe that those measurements are of limited or no relevance.

Carl Spring, Intervenor from Rumney: Mr. Spring's prefiled testimony states that he has "serious concerns with the noise and health issues surrounding wind farms that have people surrounded with towers on 2-3 sides of their homes." Because the Project's proposal does not "surround" any homes, and as indicated in the Application, the nearest residence to a turbine is 2,700 feet away, I believe that Mr. Spring's concerns about this Project are unfounded.

Richard Wetterer, Intervenor from Rumney: Mr. Wetterer's prefiled testimony consists of an e-mail dated August 31, 2010 in which he states that he considers the Groton Wind Project to be "a grave risk to health and well being of the people of Rumney." In addition, seven documents were submitted by Mr. Wetterer with his prefiled testimony. The paper by van den Berg states that wind turbines produce low frequency sounds. All mechanical devices do – and this fact is not disputed. The relevant question has been whether they produce low frequency sound at levels that cause negative impacts to people. The New Hampshire Site Evaluation Committee has determined that the van den Berg paper did not provide a sufficient basis upon which the Committee could find that the Lempster Wind Project (which consists of the same type of wind turbines as those proposed by the Groton Project) would produce unreasonable noise levels or unreasonable noise effects in Lempster. *See Application of Lempster Wind, LLC,* Docket No. 2006-01, Decision Issuing Certificate of Site and Facility With Conditions (June 28, 2007), p. 44. Thus, Mr. Wetterer's reliance on the van den Berg paper is misplaced. In addition, several of the other documents on wind turbines and low frequency noise and/or health issues which Mr. Wetterer submitted have been directly reviewed in the AWEA/CanWEA December 2009 report. A copy of this report is contained in Appendix 52. The conclusion drawn by the expert panel members consisting of audiologists, doctors, public health officials, and acousticians was that "vibroacoustic disease," "wind turbine syndrome," and "visceral vibratory vestibular disturbance" are unproven hypotheses that have not been confirmed by appropriate research studies.

Lawrence Mazur, Intervenor from Rumney: Dr. Mazur's prefiled testimony consists of an email dated August 11, 2010 which states that he is concerned about health hazard risks of "wind turbine syndrome", "wind turbine syndrome spectrum disorder" and "vibro-acoustic disease." Dr. Mazur also notes that there are diverse opinions about whether these illnesses are of concern as well as a lack of "respectable, laboratory-designed, variable-controlled hypothesis-testing research of the field-data…" Dr. Mazur argues that more research on the above-stated issues is needed before the Project should be allowed to move forward.

For all of the reasons cited in rebuttal to Intervenor Wetterer, above, I disagree with Dr. Mazur's position.

James Buttolph, Intervenor from Rumney: Mr. Buttolph's prefiled testimony presents no information germane to the Project site. He simply states, in summary fashion, that he has concerns about possible health impacts related to the wind turbines and in support thereof attaches documents from Dr. Michael Nissenbaum relating to other projects and proceedings. I understand that the Applicant's attorneys have moved to exclude those documents from the record and to bar Dr. Nissenbaum from testifying at the hearing. Accordingly, I do not believe it is appropriate to address Dr. Nissenbaum's papers here.

Q. Do you have any additional information to present to the Site Evaluation Committee on the issue of the Project's potential impacts on sound?

A. The Groton Project is a well-designed wind farm with a large distance between the wind turbines and residences and other potentially sensitive receptors. Worst-case sound levels from the wind farm are generally less than 40 dBA at all residences assuming each house is always located directly downwind from all turbines simultaneously. Although this is a physical impossibility, the modeling procedure treats it this way because it provides a measure of conservatism in the estimates relating to sound. Low frequency sound and infrasound levels will be well below any scientific criteria. In sum, while it is possible that sound from the wind farm may occasionally be audible under certain conditions, it will be well below established criteria for both broadband (A-weighted) and low frequency impacts on residents.

In addition, I do have one minor correction to my prefiled testimony of March 2010. Table 8-1 on page 9 of 10 lists the "Increase over Background" for Location 4 – Tenney Mtn Ski Area as 5 dBA. There was a simple math error and the increase should have been listed as 2 dBA.

Q. Does this conclude your testimony?

A. Yes, it does.

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February 15, 2008

Mr. Roland Baril, Chairman
Town and Village of Clayton Planning Board
Riverside Drive
Clayton, New York 13624

c/o Augusta Withington
Bernier Carr & Associates, P.C.

Subject: Clayton Wind Farm Project
Clayton, New York

Dear Roland,

We have reviewed the Noise Analysis PPM Clayton Wind Farm memorandum dated January 15, 2007 for the Wind Power Project, in Clayton, New York. In addition, we have reviewed a number of technical papers and documents pertinent to the operation and acoustic effects of wind turbines. These documents include the following:

1. IEC Standard 61400-11 Wind turbine generator systems – Part11: Acoustic noise measurement techniques, Edition 2.1 dated November 2006.

2. Assessing and Mitigating Noise Impacts, New York State Department of Environmental Conservation, dated October 6, 2000 (revised February 2, 2001).

3. van den Berg, Frits G.P., "Wind Turbines at night: Acoustical practice and sound research," Proceedings of Euronoise, Naples 2003, paper ID 160.

4. Bajdek, Christopher J., "Communicating the Noise Effects of Wind Farms to Stakeholders," Proceedings of Noise-Con 2007, Reno, Nevada, October 2007.

Comments on Noise Analysis PPM Clayton Wind Farm Memorandum

Our comments on the Noise Analysis PPM Clayton Wind Farm Memorandum are given below. The comments are organized by the section headings which appear in the Memorandum.

Significance Thresholds

- Establishing background sound level

The New York State DEC document *Assessing and Mitigating Noise Impacts* does not designate which metric shall be used to evaluate the background sound in the vicinity of a potential project. The document describes the Equivalent Sound Level (L_{eq}) as a value that "*provides an indication of the effects of sound on people. It is also useful in establishing the ambient sound levels at a potential noise source.*" The DEC document also states that the 90th Percentile Sound Level (L_{90}) indicates a sound pressure level that is "*exceeded 90% of the time. L_{90} is often used to designate the background noise level.*"

The Town of Clayton *Local Law No. 1 of 2007* defines the ambient sound level as "*the background (exclusive of the development proposed) Sound Level (L_{90}) found to be exceeded 90 percent of the time over which sound is measured...*"

Comments:

1. A preferred measurement of the background sound level at a given location is the L_{90}, as compared to the L_{eq}. The L_{90} is lower by varying amounts than the L_{eq}, which is influenced by short duration transient events. The current sound survey of the proposed wind farm site uses equivalent sound levels (L_{eq}) as the baseline for evaluating the 6 dBA relative threshold defined in the NYDEC guidelines.

2. The impact of a sound source on a receptor is the arithmetic difference between the source sound pressure level plus the background (SPL_{source} + $SPL_{background}$) and the background ($SPL_{background}$) alone. Although transient sounds such as car pass-bys, and animal noise are inherent in the background sound, the perception of the background level is not one of a time average level. Rather it is our opinion that the perception of the background level is the nearly constant low level that exists, exclusive of transients. The statistical sound level that most closely corresponds to this condition is the L_{90}.

- Establishing relative significance thresholds

The *Noise Analysis PPM Clayton Wind Farm* document states, "*as a project participant becomes one willingly and derives benefit from the project, therefore a relative significance threshold for participants is not established.*"

Comments:

1. We understand that the project participants are entering into an agreement with the agency operating the wind farm. While we cannot speak to the nature of this agreement, we question the applicability of the above statement.

   Furthermore, it appears that in essence the Project Owner would purchase noise easements from the participating property owners. Accordingly, the Project Owner would be purchasing the right to noise-impact homes on these properties, as defined by NYSDEC, in perpetuity. This easement and its noise-impact are then presumed to be accepted by future homeowners.

Our understanding of the sense of "easement" is a right of entry, or a right to produce a temporary impact that would be corrected to allow the land to remain substantially unchanged with respect to its intended use. The noise impact of the proposed project would not be temporary and would not be corrected at anytime. This is a legal issue, but the fact that proposed Project would permit a permanent noise impact at participating property owners' homes must be recognized.

Existing Noise Levels

- Noise Level Measurements

The existing background sound levels were measured at five locations, which are indicated in Figure 3. These levels were collected in 10-minute intervals and correspond to wind speed measurements. The background levels collected at a given location were then applied to receptor locations within a given land area to reflect the representative background (shown in Figure 3).

Comments:

1. The specific site conditions, e.g. proximity to wooded/open areas, microphone height above the ground etc., at the five measurement locations are not documented.

2. The project land area is large and necessitates the efficient gathering of data. This has resulted in data collected at a single location to be used to evaluate existing background sound levels at many receptor locations over a very large area. These large areas, and their representative sound measurement locations, are shown in Figure 3. Ambient sound levels can change significantly from receptor to receptor over the project area, so that using data collected at a single measurement location to represent conditions at a large number of receptors spread over a wide area may not be valid. It is our opinion that similarities between environs at measurement and receptor locations must be more carefully considered. This may require more measurement locations to fully represent sound conditions at all receptors.

3. Although the cut-in hub height wind speed and the full output wind speed are defined to be 4 m/s and 12.5 m/s, respectively, the L_{eq} values given in Table 4 are referenced to cut-in speeds of 6 m/s and 13 m/s.

4. The location and height of the wind monitoring equipment is not given, nor is a description of the uniformity of wind patterns over the project site.

5. The regressions of noise levels vs. wind speed presented in Appendix A show the lack of correlation between background sound level and wind speed. The low R^2 value (coefficient of determination) indicates very little dependence of measured sound levels on measured wind speeds.

   Looking at the data, use of the regression fit for evaluating background sound level for a given wind speed would mean that for a significant number of instances the impact of wind turbine noise would be overestimated by a large margin; correspondingly, for a significant number of instances the impact of wind turbine noise would be underestimated.

Statistically, this would be interpreted as an indication that there are one or more other factors that affect background sound level in addition to wind speed, and that these should be measured and included in a multiple regression. What these other factors are and how they are measured to be included in a multiple regression analysis would be very difficult to determine.

If the data listed in Table 4 are derived from the regressions of sound pressure level plotted against wind speed given in Appendix A, we recommend that the noise data be considered irrespective of wind speed. The NYSDEC guide does not provide specific methods for evaluating background sound. However, on the basis of our experience, we suggest that the 90[th] percentile of the L_{90} sound levels be used as the background.

6. The *Thresholds of Potential Significance* established in Table 5 should be clarified. It is our understanding that the Town of Clayton absolute threshold of 50 dBA (L_{10}) applies to both participating landowners and non-participating landowners unless the relative threshold of 6 dBA outlined in the NYSDEC guidelines imposes a more restrictive limit. In this case, the 50 dBA values listed in the "Relative Threshold (L_{eq})" section of Table 5 would not be L_{eq} values, but instead L_{10} values per the Clayton Local Law No. 1.

Facility Sound Levels

- Data presented in Table 6

The *Noise Analysis PPM Clayton Wind Farm* document states, "*under these high wind speeds no locations are anticipated to exceed the existing nighttime levels by more than 6 dBA.*"

Comments:

1. The above statement is not true for all receptors. Five measured background sound levels were applied to approximately 200 receptors over a defined geographic area. These background levels are not the measured background levels at the individual receptor sites. It is therefore possible that some receptor locations have background levels lower than the "representative" level and could experience a turbine noise level that is greater than 6 dBA above the background.

2. The NYSDEC *Assessing and Mitigating Noise Impacts* document discusses both a 6 dBA exceedance and a 6 dBA increase in the background sound level: "*In non-industrial settings the SPL should probably not exceed ambient noise by more than 6 dB(A) at the receptor. An increase of 6 dB(A) may cause complaints.*" For any receptor listed in Table 6 where the Predicted Turbine Noise Level exceeds the Representative Existing Nighttime Noise Level by at least 5 dBA, a 6 dBA increase of the background sound should be reported.

The Predicted Turbine Noise Level values presented in Table 6 do not have a reference as to what measurement metric was used, i.e. L_{eq} or L_{10}.

Comments:

1. The only case in which the Equivalent Sound Level (L_{eq}) would equal the statistical L_{10} level is when the sound source produces a sound pressure level that is constant in time, and no transients are present. To comply with 50 dBA limit defined in the Town of Clayton *Local Law No. 1 of 2007*, the Predicted Turbine Noise Levels need be L_{10}, *and* less than 50 dBA.

- Data presented in Table 7

The *Noise Analysis PPM Clayton Wind Farm* document states, "*The comparison is based on nighttime levels. Daytime levels are louder as shown in Appendix A.*"

Comments:

1. It is true that the data presented in Appendix A seem to indicate a general increase in sound pressure levels from nighttime to daytime. However, the data points are still distributed over a wide range of sound levels for a given wind speed.

2. Although daytime levels are described as "louder," some receptors report an exceedance of the background level of up to 15 dBA at night. This difference in sound level would be perceived as more than a doubling of loudness at receptor positions.

The *Noise Analysis PPM Clayton Wind Farm* document states, "*The existing levels were collected during the winter and were not strongly influenced by wind blowing through fields or foliage.*"

Comments:

1. It is true that the winter survey represents a conservative acoustical assessment of the potential wind farm. As the winter months comprise a considerable portion of the year in this part of New York State, however, the differences between the representative background and the Predicted Turbine Noise Level are not trivial.

- Comparison of Background Sound Levels to Predicted Turbine Levels

General Comments:

It is worthwhile noting that there are two largely separate sources of wind turbine blade noise: boundary layer turbulence and vortex shedding. Boundary layer turbulence is constant broadband sound mostly produced at the trailing edge of the wind turbine blades.

Vortices shed from the tips of the wind turbine blades are blown back behind the rotating blades by the wind. When these vortices cut across the wind turbine support structure, they produce a pressure pulse. The repeating train of these pulses is the mechanism behind the generation of low frequency sound. When modern wind turbines were originally designed, their blades were located downwind of the support structure. As the blades of these original wind turbines pass through the vortex shed behind the tower supports, the blade is excited, i.e. deflected or displaced slightly momentarily while passing through the vortex. The large blade area thus becomes an efficient radiator of low frequency sound. Designing wind turbines so that the blades are upstream of the tower support has mostly eliminated low frequency excitation in newer wind turbines. Because the remaining concern about low frequency sound produced by wind turbines based on problem experiences with the older designs, it is recommended that the authors comment on concerns about low frequency sound and present low frequency sound data for the turbine design to be installed. This should include estimates of low frequency sound at nearest receptors and comparison with applicable low frequency criteria. These low frequency criteria should also address the widely cited risk of vibroacoustic disease.

The *Noise Analysis PPM Clayton Wind Farm* document presents comparisons between the representative background sound levels and the predicted turbine noise levels when similar wind conditions are assumed at both locations (e.g. low winds at both the turbine hub and the receptor location).

Comments:

1. In the paper by van den Berg, the author maintains that at night, as compared with the day, upper elevation wind speeds are skewed higher than wind speeds at lower elevations. The effect on the Clayton Wind Farm Project is that for a given wind condition at the hub, the ground wind speed may be lower than would be determined using IEC 64100-11. The result would be a greater difference between the wind turbine sound and background corresponding to a higher noise impact than estimated.

If we can provide any further information, please do not hesitate to contact us. Thank you.

Yours sincerely,
CAVANAUGH TOCCI ASSOCIATES, INC.

Gregory C. Tocci William J. Elliot

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cta

Attachment 2

Geiger, Susan S.

From: Gregory C. Tocci [GTocci@cavtocci.com]

Sent: Wednesday, October 06, 2010 1:19 PM

To: cheryl lewis; miacopino@bclilaw.com; Patch, Douglas L.; Geiger, Susan S.; JimButtolph@roadrunner.com; laslaw@metrocast.net; bernie.waugh@gardner-fulton.com; Ann.kerrigan@gardner-fulton.com; rwetterer@roadrunner.com; jmcgowan@dtclawyers.com; larrymazur1@gmail.com; sarahmazur@earthlink.net; Cspring31375@roadrunner.com; theomazur@msn.com; PeterRoth

Cc: MichelleThibodeau

Subject: RE: Post-Tech Session Responses

Cheryl,

Thank you for sending the Salt 2010.08.31 paper. It is very interesting, but stops short of suggesting a measureable infrasound guideline below which little or not affect on humans can be expected. Without this scientific backing, it is hard to implement engineering analysis to evaluate impact. Thank you.

Greg.

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From: cheryl lewis [mailto:bakerriver@yahoo.com]
Sent: Monday, October 04, 2010 3:31 PM
To: miacopino@bclilaw.com; Doug Patch (E-mail); Susan S. Geiger (E-mail); JimButtolph@roadrunner.com; laslaw@metrocast.net; bernie.waugh@gardner-fulton.com; Ann.kerrigan@gardner-fulton.com; rwetterer@roadrunner.com; jmcgowan@dtclawyers.com; larrymazur1@gmail.com; sarahmazur@earthlink.net; Cspring31375@roadrunner.com; theomazur@msn.com; PeterRoth
Cc: Gregory C. Tocci; MichelleThibodeau
Subject: Re: Post-Tech Session Responses

Please find the peer-reviewed study at the following link, by Alec Salt, which I mentioned at the tech session.

http://oto2.wustl.edu/cochlea/windmill.html

Thank you,
Cheryl Lewis

--- On **Mon, 10/4/10, Roth, Peter** ***<Peter.Roth@doj.nh.gov>*** wrote:

From: Roth, Peter <Peter.Roth@doj.nh.gov>
Subject: Post-Tech Session Responses
To: miacopino@bclilaw.com, "Doug Patch (E-mail)" <dpatch@orr-reno.com>, "Susan S. Geiger (E-mail)"

Baltimore, Maryland
NOISE-CON 2010
2010 April 19-21

Low frequency sound and infrasound from wind turbines – A status update

Robert D. O'Neal[a)]
Robert D. Hellweg, Jr.[b)]
Richard M. Lampeter[c)]
Epsilon Associates, Inc.
3 Clock Tower Place, Suite 250
Maynard, MA 01754

A common issue raised with wind energy developers and operators of utility-scale wind turbines is whether the operation of their wind turbines may create unacceptable levels of low frequency noise and infrasound. In order to answer this question, one of the major wind energy developers commissioned a scientific study of their wind turbine fleet. The study consisted of three parts: 1) a world-wide literature search to determine unbiased guidelines and standards used to evaluate low frequency sound and infrasound, 2) a field study to measure wind turbine noise outside and within nearby residences, and 3) a comparison of the field results to the guidelines and standards. The guidelines and standards evaluated were: audibility including infrasound; ANSI S12.2 for interior sounds – both acceptability of low frequency sounds in bedrooms, schools, and hospitals and perceptible rattles and vibration; ANSI S12.9 Part 4 for thresholds of annoyance and beginning of rattles; and certain European criteria for low frequency and infrasound. This paper presents the results of the detailed study and concludes that there should be no adverse effects from infrasound or low frequency noise at distances greater than 305 meters from wind farms with the wind turbine types measured.

1 INTRODUCTION

Early down-wind wind turbines in the US created low frequency noise; however current up-wind wind turbines generate considerably less low frequency noise. Epsilon Associates, Inc. ("Epsilon") has been retained by NextEra Energy Resources, LLC ("NextEra"), formerly FPL Energy, to investigate whether the operation of their wind turbines may create unacceptable levels of low frequency noise and infrasound. Epsilon determined all means, methods, and the testing protocol without interference or direction from NextEra. No limitations were placed on Epsilon by NextEra with respect to the testing protocol or upon the analysis methods; the conclusions are those of the authors.

The project was divided into three tasks: 1) literature search, 2) field measurement program, and 3) comparison to criteria. We conducted an extensive literature search of the technical and scientific literature on the effects of low-frequency noise and infrasound and existing criteria in order to evaluate low-frequency noise and infrasound from wind turbines. After completion of

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the literature search and selection of criteria, a field measurement program was developed to measure wind turbine noise to compare to the selected criteria.

2 EFFECTS AND CRITERIA OF LOW FREQUENCY SOUND AND INFRASOUND

We performed an extensive world-wide literature search of over 100 scientific papers, technical reports and summary reports on low frequency sound and infrasound - hearing, effects, measurement, and criteria. Leventhal[1] presents an excellent and comprehensive study on low frequency noise from all sources and its effects. The Leventhal report also presents criteria in place at that time, which does not include some the more recently developed ANSI/ASA standards on outdoor environmental noise and indoor sounds. The United States government does not have specific criteria for low frequency noise. The following sections describe the low frequency and infrasound criteria to which wind turbine sounds are compared in later sections.

2.1 Threshold of Hearing

Moeller and Pedersen (2004) present a summary on human perception of sound at frequencies below 200 Hz. The ear is the primary organ for sensing infrasound. Hearing becomes gradually less sensitive for decreasing frequencies. But, humans with a normal hearing organ can perceive infrasound at least down to a few hertz if the sound level is sufficiently high.

The threshold of hearing is standardized for frequencies down to 20 Hz in ISO 226:2003. Based on extensive research and data, Moeller and Pedersen propose normal hearing thresholds for frequencies below 20 Hz. The hearing thresholds show considerable variability from individual to individual with a standard deviation among subjects of about 5 dB independent of frequency between 3 Hz and 1000 Hz with a slight increase at 20 – 50 Hz. This implies that the audibility threshold for 84% of the population is greater than the average values minus 5 dB. Moeller and Pedersen suggest using the pure-tone thresholds for non-sinusoidal sound; this relationship is what is used in ISO 226 for frequencies down to 20 Hz. ISO 226:2003 gives one-third octave band threshold of hearing down to 20 Hz.

2.2 ANSI/ASA S12.9 Parts 4 and 5 – Environmental Sound

ANSI/ASA S12.9-2007/Part 5 has an informative annex which provides guidance for designation of land uses compatible with existing or predicted annual average adjusted day-night average outdoor sound level. There are adjustments to day-night average sound level to account for the presence of low frequency noise, and the adjustments are described in ANSI S12.9 Part 4, Annex D which use a sum of the sound pressure levels in the 16, 31 and 63 Hz octave bands. Procedures are given for adjustments to L_{Aeq} and L_{dn} value, which are significant for high levels of low frequency sound.

ANSI S12.9 /Part 4 identifies two thresholds: annoyance is minimal when the 16, 31.5 and 63 Hz octave band sound pressure levels are each less than 65 dB and there are no rapidly fluctuations of the low frequency sounds. The second threshold is for increased annoyance which begins when rattles occur, which begins at L_{LF} 70 - 75 dB. L_{LF} is 10 times the logarithm of the ratio of time-mean square sound pressures in the 16, 31.5, and 63-Hz octave bands divided by the square of the reference sound pressure. (Since the determination of L_{LF} involves integrating concurrently the sound pressures in the three octave bands, an energy sum of the levels in each of these separate bands results in an upper bound to L_{LF}.)

2.3 ANSI/ASA S12.2-2008 – Evaluating Room Noise

ANSI/ASA S12.2-2008 discusses criteria for evaluating room noise, and has two separate provisions for evaluating low frequency noise: (1) the potential to cause perceptible vibration and rattles, and (2) meeting low frequency portions of room criteria curves.

Vibrations: ANSI/ASA S12.2 presents limiting levels at low frequencies for assessing (a) the probability of clearly perceptible acoustically induced vibration and rattles in lightweight wall and ceiling constructions, and (b) the probability of moderately perceptible acoustically induced vibration in similar constructions. The limiting values are 16, 31.5 and 63 Hz octave band sound pressure levels.

Room criteria: ANSI/ASA S12.2 has three primary methods for evaluating the suitability of noise within rooms: a survey method - A-weighted sound levels, an engineering method – noise criteria (NC) curves and a method for evaluating low-frequency fluctuating noise using room noise criteria (RNC) curves. "The RNC method should be used to determine noise ratings when the noise from HVAC systems at low frequencies is *loud* and is suspected of containing *sizeable fluctuations or surging*." [emphasis added] The NC curves are appropriate to evaluate low frequency noise from wind turbines in homes since wind turbine noise does not have significant fluctuating low frequency noise sufficient to warrant using RNC curves. Annex C.2 of this standard contains recommendations for bedrooms, which are the most stringent rooms in homes: NC and RNC criteria curve between 25 and 30.

Since the ANSI S12.2 criteria are for indoor sounds, data from Sutherland[2] and Hubbard[3] were used to determine typical noise reductions from outdoor to indoor with windows open to determine equivalent ANSI S12.2 outdoor criteria.

2.4 The UK Department for Environment, Food, and Rural Affairs (DEFRA)

A report prepared by the University of Salford for the UK Department for Environment, Food, and Rural Affairs (DEFRA) on low frequency noise proposed one-third octave band sound pressure level L_{eq} criteria and procedures for assessing low frequency noise[4]. The guidelines are based on complaints of disturbance from low frequency sounds and are intended to be used by Environmental Health Officers. In developing the DEFRA guidelines, existing low frequency noise criteria from several European countries were reviewed and considered.

The DEFRA criteria are based on measurements in an unoccupied room. If the low frequency sound is "steady" then the criteria may be relaxed by 5 dB. A low frequency noise is considered steady if either L_{10}-L_{90} < 5dB or the rate of change of sound pressure level (Fast time weighting) is less than 10 dB per second.

3 FIELD PROGRAM

Two types of utility-scale wind turbines were studied for this field program. These two turbines are among the most commonly used in the NextEra fleet: General Electric (GE) 1.5sle (1.5 MW), and Siemens SWT-2.3-93 (2.3 MW).

Typical hub height for these wind turbines is 80 meters above ground level (AGL). Sound levels for these wind turbine generators (WTGs) vary as a function of wind speed from cut-in wind speed to maximum sound level. Table 1 lists the reference sound power levels of each

WTG as a function of wind speed at 10 meters AGL as provided by the manufacturer. This is in conformance with the sound level standard for wind turbines IEC 61400-11.

Real-world data were collected from operating wind turbines to compare to the low frequency noise guidelines and criteria discussed previously in Sec. 2. These data sets consisted of outdoor measurements at various reference distances, and concurrent indoor/outdoor measurements at residences within the wind farm.

Field measurements were conducted in order to measure sound levels at operating wind turbines, and compare them to the guidelines and criteria discussed in this paper. NextEra provided access to the Horse Hollow Wind Energy Center in Taylor and Nolan Counties, Texas in November 2008 to collect data on the GE 1.5sle and Siemens SWT-2.3-93 wind turbines. The portion of the wind farm used for testing is relatively flat with no significant terrain. The land around the wind turbines is rural and primarily used for agriculture and cattle grazing. The siting of the sound level measurement locations was chosen to minimize local noise sources except the wind turbines and the wind itself.

Epsilon noise consultants collected sound level and wind speed data over the course of one week under a variety of operational conditions. Weather conditions were dry the entire week with ground level winds ranging from calm to 12.5 m/s (28 mph) over a 1-minute average. In order to minimize confounding factors, the data collection tried to focus on periods of maximum sound levels from the wind turbines (moderate to high hub height winds) and light to moderate ground level winds.

A series of simultaneous interior and exterior sound level measurements were made at four houses owned by participating landowners within the wind farm. Two sets were made of the GE WTGs, and two sets were made of the Siemens WTGs. Data were collected with both windows open and windows closed. Due to the necessity of coordinating with the homeowners in advance, and reasonable restrictions of time of day to enter their homes, the interior/exterior measurement data sets do not always represent ideal conditions. However, enough data were collected to compare to the criteria and draw conclusions on low frequency noise.

Sound level measurements were also made simultaneously at two reference distances from a string of wind turbines under a variety of wind conditions. Using the manufacturer's sound level data, calculations of the sound pressure levels as a function of distance in flat terrain were made to aid in deciding where to collect data in the field. Based on this analysis, two distances from the nearest wind turbine were selected – 305 meters (1000 feet) and 457 meters (1500 feet) - and were then used where possible during the field program. Distances much larger than 457 meters were not practical since an adjacent turbine string could be closer and affect the measurements, or would put the measurements beyond the boundaries of the wind farm property owners.

4 RESULTS AND COMPARISON TO CRITERIA

Results from the field program were organized by wind turbine type. Due to space constraints in this paper, only the results from the Siemens SWT-2.3-93 wind turbine will be shown. However, the results and conclusions for the GE 1.5sle wind turbine are very similar.

For the Siemens WTG, results are presented per location type (outdoor or indoor) with respect to applicable criteria. Results are presented for 305 meters (1,000 feet) from the nearest wind turbine. The data collected at 457 meters (1,500 feet) from the nearest wind turbine showed lower sound levels. Therefore, wind turbines that met the criteria at 305 meters also met it at 457 meters. Data were collected under both high turbine output and moderate turbine output conditions (defined as sound power levels 2 or 3 dBA less than the maximum sound power levels), and low ground-level wind speeds. The sound level data under the moderate conditions were equivalent to or lower than the high turbine output scenarios, thus confirming the conclusions from the high output cases. A-weighted sound power levels presented in this section (used to describe turbine operation) were estimated from the actual measured power output (kW) of the wind turbines and the sound power levels in Table 1 as a function of wind speed. All sound power levels in Tables 2 – 3 and Figs. 1 to 9 include an adjustment factor of 2 dBA (correction from reference values to "guaranteed" values) according to IEC/TS 61400-14.

Outdoor measurements are compared to criteria for audibility, for UK DEFRA disturbance using equivalent outdoor levels, for rattle and annoyance as contained in ANSI S12.9 Part 4, and for perceptible vibration using equivalent outdoor levels from ANSI/ASA S12.2. Indoor measurements are compared to criteria for audibility, for UK DEFRA disturbance, and for suitability of bedrooms, hospitals and schools and perceptible vibration from ANSI/ASA S12.2.

4.1 Outdoor Measurements - Siemens SWT-2.3-93

Several periods of high wind turbine output and relatively low ground wind speed (which minimized effects of wind noise) were measured outdoors approximately 305 meters (1,000 feet) from the closest Siemens WTG. This site was actually part of a string of 15 WTGS, four of which were within 610 meters (2,000 feet) of the monitoring location. The sound level data presented herein include contributions from all wind turbines as measured by the recording equipment. The key operational and meteorological parameters during these measurements are listed in Table 2.

4.1.1 Outdoor audibility

Figure 1 plots the one-third octave band sound levels (L_{eq}) for both samples of high output conditions. The results show that infrasound is inaudible to even the most sensitive people 305 meters (1,000 feet) from these wind turbines (more than 20 dB below the median thresholds of hearing). Low frequency sound above 40 Hz may be audible depending on background sound levels.

4.1.2 UK DEFRA disturbance criteria – Outdoor measurements

Figure 2 plots the one-third octave band sound levels (L_{eq}) for both samples of high output conditions. The low frequency sound was "steady" according to DEFRA procedures, and the results show that all outdoor equivalent DEFRA disturbance criteria are met.

4.1.3 Perceptible vibration, rattle and annoyance – Outdoor measurements

Figure 3 plots the 16, 31.5, and 63 Hz octave band sound levels (L_{eq}) for both samples of high output conditions. The results show that all equivalent outdoor ANSI/ASA S12.2 perceptible vibration criteria are met. The 31.5 and 63 Hz sound levels are below the level of 65 dB identified for minimal annoyance in ANSI S12.9 Part 4, and the 16 Hz sound level is within 1.5 dB of this level, which is an insignificant increase since the levels were not rapidly fluctuating. The low frequency sound levels are below the ANSI S12.9 Part 4 thresholds for the beginning of rattles (the combined sound level in the 16, 31.5, 63 Hz bands are less than 70 dB).

4.2 Indoor Measurements - Siemens SWT-2.3-93

Simultaneous outdoor and indoor measurements were made at two residences at different locations within the wind farm to determine indoor audibility of low frequency noise from Siemens WTGs. In each house measurements were made in a room facing the wind turbines, and were made with either window open or closed. These residences are designated Homes "A" and "D" and were approximately 305 meters (1,000 feet) from the closest Siemens WTG. Both homes were near a string of multiple WTGS, four of which were within 610 meters (2,000 feet) of the house. The sound level data presented herein include contributions from all wind turbines as measured by the recording equipment. The key operational and meteorological parameters during these measurements are listed in Table 3.

4.2.1 Indoor audibility

Figure 4 plots the indoor one-third octave band sound levels (L_{eq}) for Home "A", and Fig. 5 plots the indoor one-third octave band sound levels for Home "D". The results show that infrasound is inaudible to even the most sensitive people 305 meters (1,000 feet) from these wind turbines with the windows open or closed (more than 20 dB below the median thresholds of hearing). Low frequency sound at or above 50 Hz may be audible depending on background sound levels.

4.2.2 UK DEFRA disturbance criteria – Indoor measurements

Figure 6 plots the indoor one-third octave band sound levels (L_{eq}) for Home "A". The low frequency sound was "steady" according to DEFRA procedures, and the results show that all indoor DEFRA disturbance criteria are met. Figure 7 plots the indoor one-third octave band sound levels (L_{eq}) for Home "D". According to DEFRA procedures, the low frequency sound was not "steady" and therefore the data were compared to both criteria. The results show the DEFRA disturbance criteria were met for steady low frequency sounds, the DEFRA criteria were met for unsteady low frequency sounds except for the 125 Hz band, which was within 1 dB and which is an insignificant difference.

4.2.3 ANSI/ASA S12.2 low frequency criteria – Indoor measurements

Figure 8 plots the indoor 16 Hz to 125 Hz octave band sound levels (L_{eq}) for Home "A", and Fig. 9 plots the indoor 16 Hz to 125 Hz octave band sound levels (L_{eq}) for Home "D". The results show the ANSI/ASA S12.2 low frequency criteria were easily met for both windows open and closed scenarios. The ANSI/ASA S12.2 low frequency criteria for bedrooms, classrooms and hospitals were met, the spectrum was balanced, and the criteria for moderately perceptible vibrations in light-weight walls and ceilings were also met.

5 CONCLUSIONS

Siemens SWT-2.3-93 and GE 1.5sle wind turbines at maximum noise at a distance more than 305 meters (1,000 feet) from the nearest residence do not pose a low frequency noise or infrasound problem. At this distance the wind farms:

- meet ANSI/ASA S12.2 indoor levels for low frequency sound for bedrooms, classrooms and hospitals;
- meet ANSI/ASA S12.2 indoor levels for moderately perceptible vibrations in light-weight walls and ceilings;
- meet ANSI S12.9 Part 4 thresholds for annoyance and beginning of rattles;
- meet UK DEFRA disturbance based guidelines;
- have no audible infrasound to the most sensitive listeners; and

- might have slightly audible low frequency noise at frequencies at 50 Hz and above depending on other sources of low frequency noises in homes, such as refrigerators or external traffic or airplanes.

6 ACKNOWLEDGEMENTS

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7 REFERENCES

1. Geoff Leventhal, "A Review of Published Research on Low Frequency Noise and Its Effects", A report for DEFRA, (2003).
2. L.C. Sutherland, "Indoor Noise Environments Due to Outdoor Noise Sources", *Noise Control Engr. J.*, **11**(3), 124-137, (1978).
3. H.H. Hubbard and K.P. Shepherd, "Aeroacoustics of large wind turbines", *J. Acoust. Soc. Am,*,**89** (6), (1991).
4. DEFRA, "Proposed criteria for the assessment of low frequency noise disturbance", University of Salford report, UK Department for Environment, Food, and Rural Affairs, DEFRA NANR45 Project Report, (2005).

Table 1 - Wind turbine reference sound power levels as a function of wind speed (dBA).

Wind Speed at 10 meters AGL (m/s)	**GE 1.5sle 80 m hub height; 77 m rotor diameter**	**Siemens SWT-2.3-93 80 m hub height; 92.4 m rotor diameter**
3	<96	ND
4	<96	ND
5	99.1	99
6	103.0	103.4
7	≤104	104.9
8	≤104	105.1
9	≤104	105.0
10	≤104	105.0

NOTE: The reference sound power levels in Table 1 do not include the 2 dBA adjustment per IEC/TS 61400-14.

Table 2 - Summary of Operational Parameters – Siemens SWT-2.3-93 (Outdoor).

Parameter	**Sample #34**	**Sample #39**
Distance to nearest WTG	1,000 feet	1,000 feet
Time of day	22:00-22:10	22:50-23:00
WTG power output	1,847 kW	1,608 kW
Sound power	107 dBA	106.8 dBA
Measured wind speed @ 2 m	3.3 m/s	3.4 m/s
L_{Aeq}	49.4 dBA	49.6 dBA
L_{A90}	48.4 dBA	48.6 dBA
L_{Ceq}	63.5 dBC	63.2 dBC

Table 3 - Summary of Operational Parameters – Siemens SWT-2.3-93 (Indoor).

Parameter	Home "A" (closed / open)	Home "D" (closed / open)
Distance to nearest WTG	1,060 feet	920 feet
Time of day	7:39-7:49 / 7:51-8:01	16:16-16:26 / 16:30 -16:40
WTG power output	1,884 kW / 1564 kW	2,301 kW / 2299 kW
Sound power	107 dBA / 106.7 dBA	107 dBA / 107 dBA
Measured wind speed @ 2 m	3.2 m/s / 3.7 m/s	9.6 m/s / 8.8 m/s
L_{Aeq}	33.8 dBA /38.1 dBA	35.0 dBA / 36.7 dBA
L_{A90}	28.1 dBA / 36.8 dBA	29.6 dBA / 31.2 dBA
L_{Ceq}	54.7 dBC / 57.1 dBC	52.8 dBC / 52.5 dBC

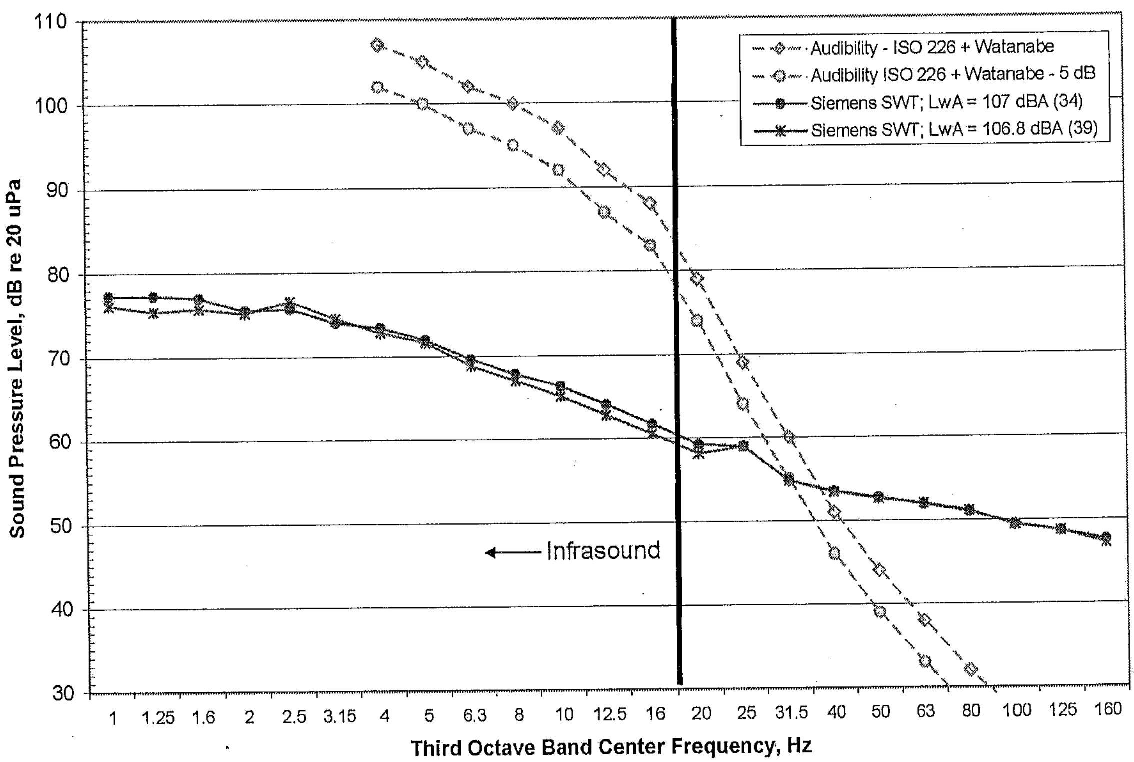

Fig. 1 - Siemens SWT-2.3-93 Wind Turbine Outdoor Sound Levels at 305 meters compared to Audibility Criteria.

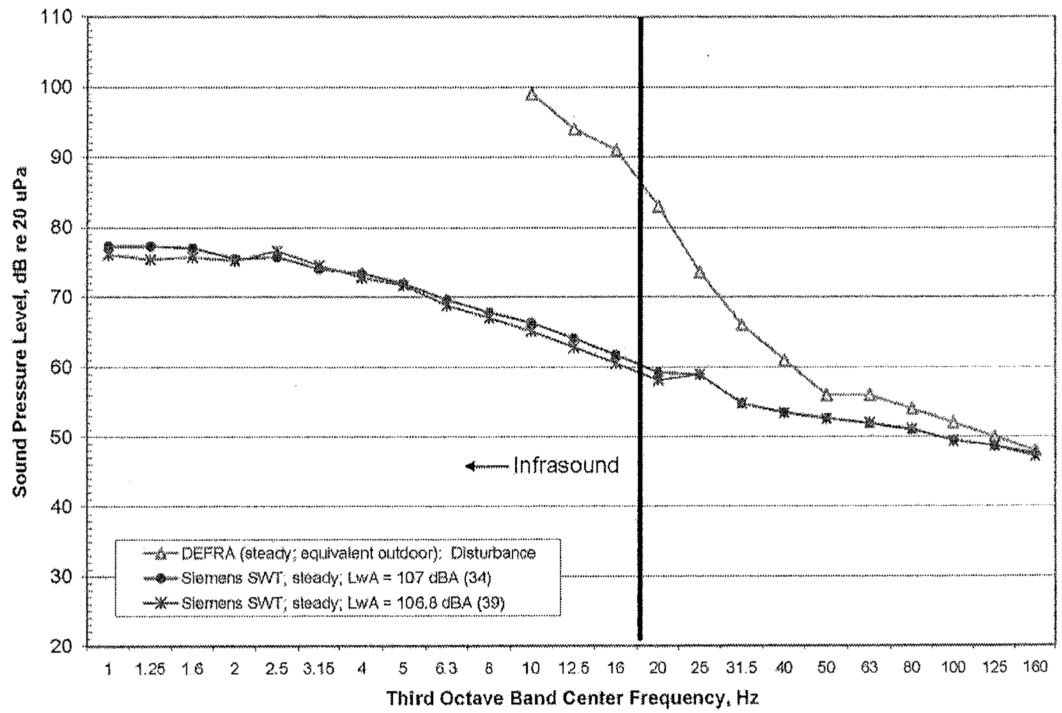

Fig. 2 - Siemens SWT-2.3-93 Wind Turbine Outdoor Sound Levels at 305 meters compared to outdoor equivalent DEFRA Criteria.

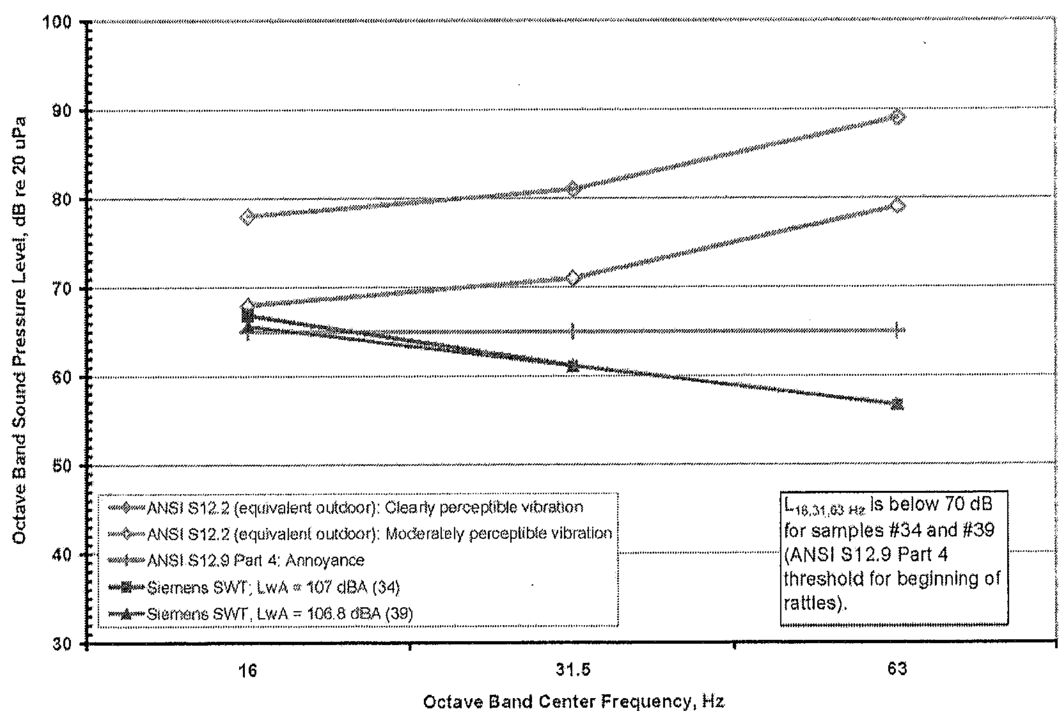

Fig. 3 - Siemens SWT-2.3-93 Wind Turbine Outdoor Sound Levels at 305 meters compared to equivalent outdoor ANSI Criteria.

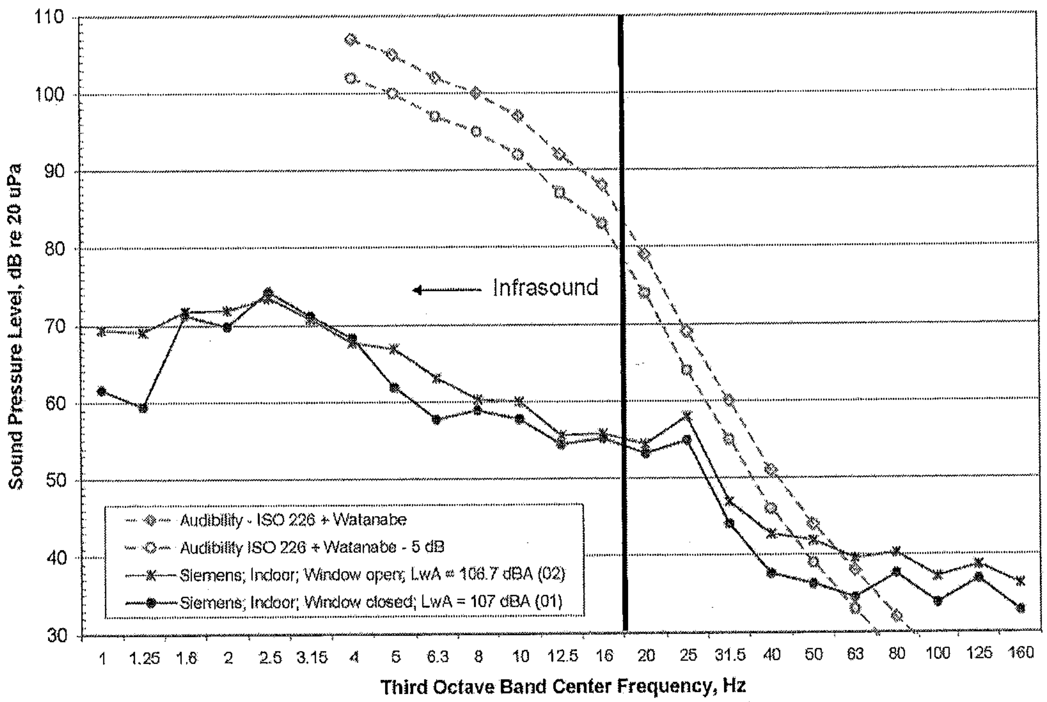

Fig. 4 - Siemens SWT-2.3-93 Wind Turbine Indoor Sound Levels at 323 meters compared to Audibility Criteria (Home "A").

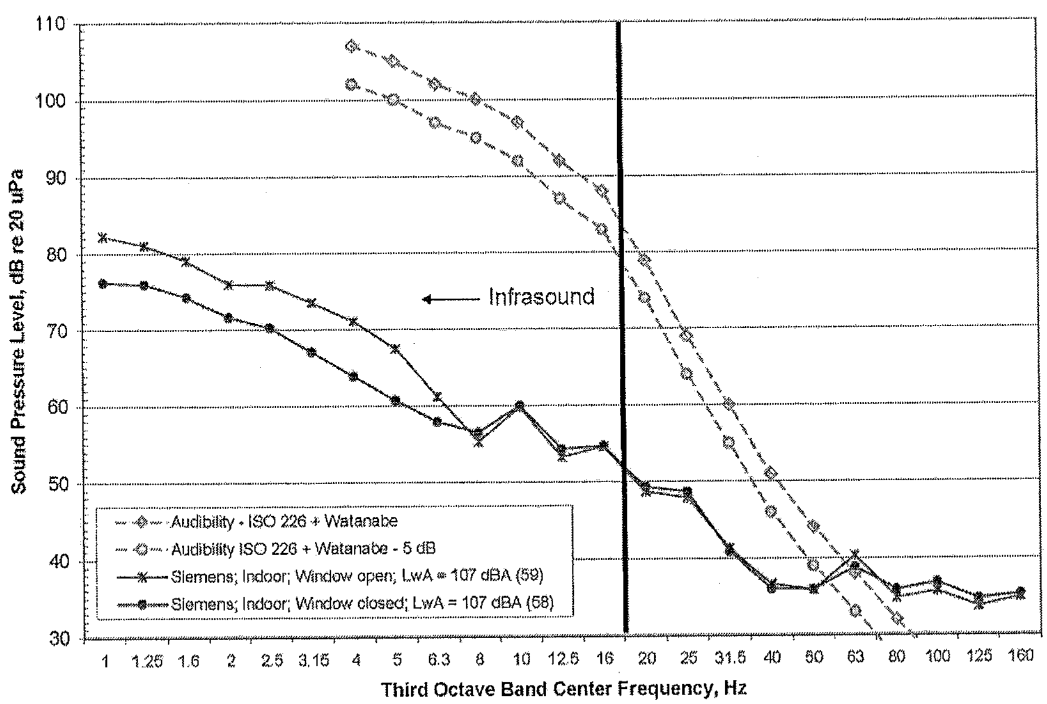

Fig. 5 - Siemens SWT-2.3-93 Wind Turbine Indoor Sound Levels at 280 meters compared to Audibility Criteria (Home "D").

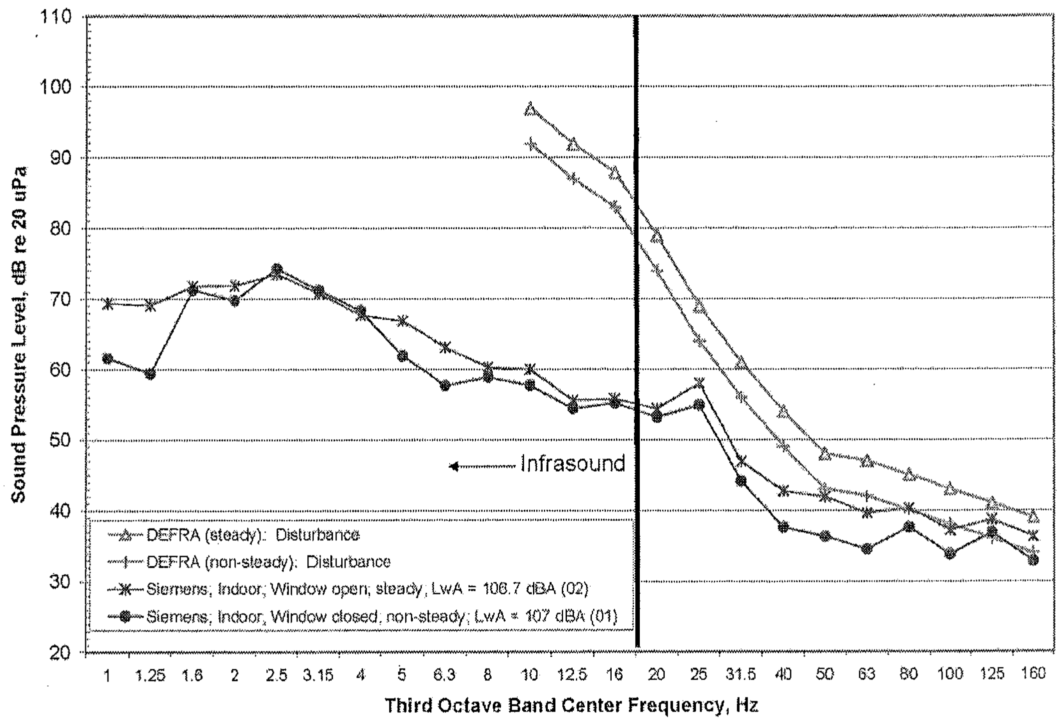

Fig. 6 - Siemens SWT-2.3-93 Wind Turbine Indoor Sound Levels at 323 meters compared to DEFRA Criteria (Home "A").

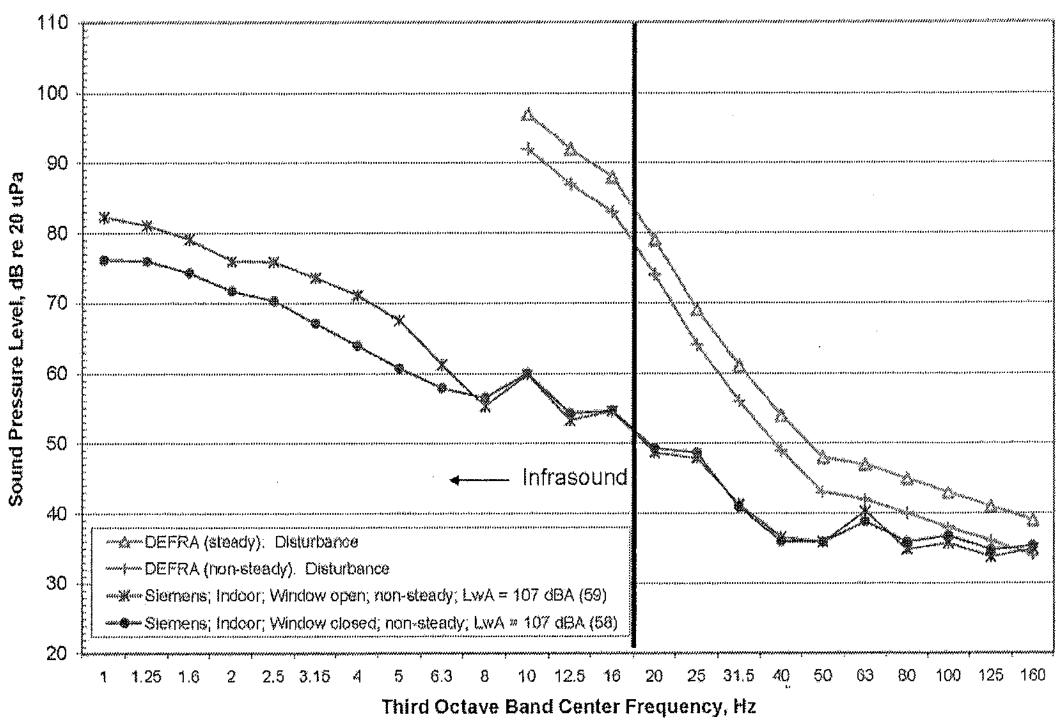

Fig. 7 - Siemens SWT-2.3-93 Wind Turbine Indoor Sound Levels at 280 meters compared to DEFRA Criteria (Home "D").

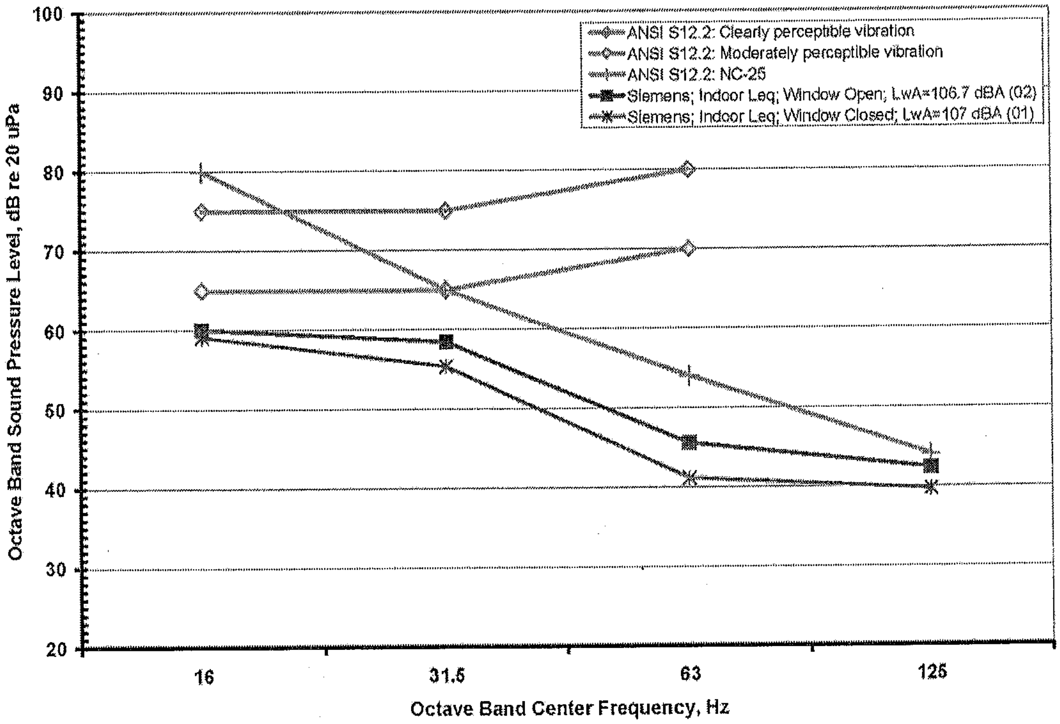

Fig. 8 - Siemens SWT-2.3-93 Wind Turbine Indoor Sound Levels at 323 meters compared to ANSI 12.2 Criteria (Home "A").

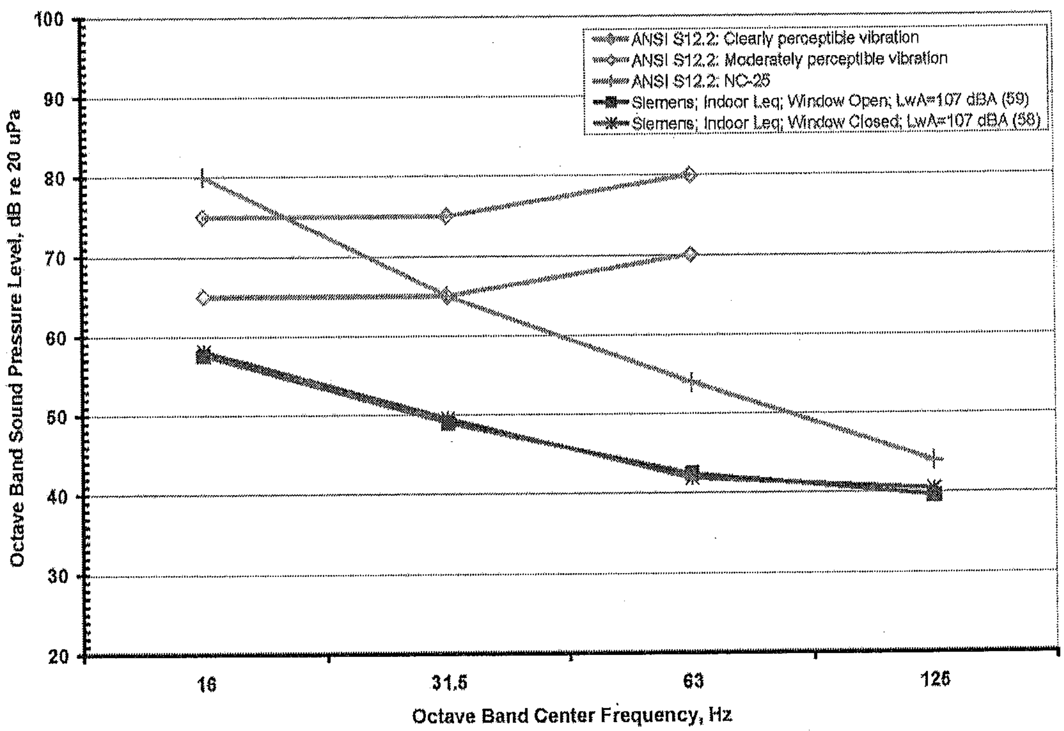

Fig. 9 - Siemens SWT-2.3-93 Wind Turbine Indoor Sound Levels at 280 meters compared to ANSI 12.2 Criteria (Home "D").