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BEFORE THE OHIO POWER SITING BOARD

In the Matter of the Application of Buckeye Wind LLC for a Certificate to Install Numerous Electricity Generating Wind Turbines in Champaign County to be Collected at an Electric Substation in Union Township, Champaign County, Ohio	)	**Case No. 08-666-EL-BGN**

DIRECT TESTIMONY OF RICHARD R. JAMES ON BEHALF OF INTERVENORS UNION NEIGHBORS UNITED, INC., ROBERT AND DIANE McCONNELL, AND JULIA F. JOHNSON

Q.1. Please state your name and business address.

A.1. My name is Richard R. James. My business address is P.O. Box 1129, Okemos, MI 48805.

Q.2. What is your occupation?

A.2. I have been a practicing acoustical engineer for over almost 40 years. A true and accurate copy of my resume is attached as UNU Exhibit 31.

Q.3. What types of work do you perform as an acoustical engineer?

A.3. My particular roles as an acoustical engineer can best be summarized as: 1) noise measurement, 2) noise control, and 3) techniques for predicting sound levels as a tool for guiding the design of new or retrofit facilities.

My work in the first part of my career was directed towards the use and interpretation of engineering procedures and methods so that I could assist my clients, who operated manufacturing facilities. This involved the design and operation of industrial facilities for in-plant communication, and protecting workers against hearing loss as well as designing new facilities so as to maintain compatibility with existing uses. In pursuing this line of consulting, I have been interested since my earliest years in the application of computers to model sound propagation and to display acoustical data, the best example of which are contour maps.

The combination of these two interests, computer modeling and measurement procedures, led to my work applying them to evaluate 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 on a commercial building to the projects involving

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modeling of complete automotive manufacturing sites (inside and outside the buildings) in my work for U.S. automobile and other large manufacturers in the USA, Canada, and Europe.

Q.4. How many years of experience do you have as an acoustical engineer?

A.4. I conducted my first sound study in 1970. Its purpose was to document sound levels inside and outside a large metal stamping facility and was conducted in my role as noise engineer for Chevrolet Division of General Motors. I formed my first company in 1973 and have been an independent consultant since that time. That would make my total experience fairly close to 39 years.

Q.5. Please describe your educational background.

A.5. I obtained my Bachelor's Degree in Mechanical Engineering in 1971 from Kettering Institute (then General Motor's Institute) in the sub-category of applied acoustical engineering. I have since attended numerous seminars and short classes on various aspects of my profession. In addition, I have been a Full Member of the Institute of Noise Control Engineers since 1973, shortly after its formation.

Q.6 What training and experience do you possess concerning the health effects of noise?

A.6. The primary reason why my profession exists is because there is a linkage between noise and health. However, as an engineer, my interests are as a consumer of medical research that establishes the boundaries of what levels and types of noise are safe and which are not. Thus, my training in the late 1960's as an acoustical engineer included courses on the effects of noise on people both as a cause of hearing loss and as a cause of other pathologies such as those attributed to sleep disturbance, annoyance, and other factors. This aspect of my work has allowed me to work with some of the top medical researchers in occupational hearing health and with the occupational medical doctors that managed the medical programs for my clients.

My training continued with the seminars and conferences held annually by the Institute of Noise Control Engineers (INCE) and the American Industrial Hygiene Association. I have also participated in conducting training on the topics of noise and health to members of these associations and to my clients' engineering, medical and safety staffs since the early 1980's.

In the late 1980's and early 1990's I engaged in several collaborations with the National Institute of Occupational Safety and Health (NIOSH) to assess whether the presumptions built into the Occupational Safety and Health Act of 1972 regarding human response to noise were correct. This included a contract with NIOSH to construct a database of worker hearing test results, noise exposures, and hearing protection devices that could be used by their epidemiology staff to re-evaluate these assumptions based on the records of a major automotive company and a major food processing company.

Q.7. Please provide an overview of your occupational experience.

A.7. From 1968 to 1972 I was the noise control engineer for the Chevrolet Division of GM headquartered out of the Flint Metal Fabricating Plant. In this capacity I also participated on GM's Central Noise Committee which was responsible for setting standards for all GM facilities regarding in-plant and community noise.

From 1973 through 1983, I was Principal Consultant, Vice President and co-owner of Total Environmental Systems.

From 1983 through 2006 I was Principal Consultant, President and co-owner of James, Anderson & Associates, Inc. (JAA).

Q.8. What were your duties as a noise control engineer in the Chevrolet Flint Metal Fabricating Plant?

A.8. My duties were to assess sound levels inside and outside Chevrolet facilities, develop noise controls for equipment and processes that caused unacceptable levels of sound either for a worker or the adjacent community, and to represent my host facility on the GM Central Noise Committee for internal standards and guidelines.

Q.9. Who started Total Environmental Systems and what types of work did this company do?

A.9. Total Environmental Systems, Inc. was started by me and Mr. Robert Anderson who was also a noise engineer working for GM. The services we offered were similar to those I describe for my work as a Chevrolet noise engineer plus I was also able to pursue my interests in developing and using computer applications for sound propagation models and contour mapping of the model results.

Q.10. What were your duties in your position as a Principal Consultant with Total Environmental Systems from 1972 to 1983?

A.10. I was responsible for all projects conducted by TES and its staff.

Q.11. Please describe some of the major noise control projects that you performed in your capacity as a Principal Consultant with Total Environmental Systems.

A.11. During the first year or two of TES's history, most of the work was similar to what I described as my role for Chevrolet, except that it was applied to other non-automotive clients involved in metal stamping, forging, foundries, and other businesses. During these years I was also working on the software that would become SOUND6, which is TES's acoustic modeling application. It was in my role as Principal Consultant for TES that I used that software to develop the first large scale acoustical model of an industrial facility for GM. This model was used by the auto industry (through its trade associations and the Chamber of Commerce) in testimony during the 1976 Hearings held by OSHA on its proposal to drop the action level for worker hearing health from 90 dBA to 85 dBA. Subsequent to the 1976 hearings TES used its software to model in-plant and community noise for GM Assembly Division's new series of assembly plants and other types of plants for other divisions of GM, Ford and others. Along with this work I continued my work on noise measurement and noise controls for in-plant and community noise for a variety of clients. This work involved community noise problems faced by my clients at their facilities in the US, Canada, Europe, and Indonesia. Clients included the major automotive manufacturers, Goodyear Tire and Rubber Company, Armstrong Tire, and to a lesser extent companies involved in food processing and other types of industry.

The SOUND6 software permitted modeling of both community noise and noise inside manufacturing facilities. It was early in this period when I also developed the use of contour maps to depict sound measurement data. This concept was presented by me to others in my field at the INCE conference in the early 1970's. The combination of the SOUND6 software and contour maps was used to assess compatibility with host communities for many new facilities for clients in the automotive, tire, and other types of manufacturing operations.

Q.12. Who started the firm of James, Anderson & Associates, Inc.?

A.12. James, Anderson and Associates, Inc (JAA) was started by me and Mr. Robert Anderson.

Q.13. What types of work did this company do?

A13.. We continued the work of TES and its clients and expanded our client base to include many other manufacturing companies including automotive transplants like Toyota, Mazda, and Mitsubishi, and other firms such as John Deere and Co., Navistar, and Anheuser-Busch. In addition to expanding our client base, we developed partnerships with many of our clients that put JAA in the position of handling all noise related problems, in and outside of facilities on a sole-source (e.g. First Tier Partner) status. During this time I also expanded my work with the tire industry to include audits and other work for their European facilities in Italy, France, Germany, Luxembourg, and the U.K. This gave me broad exposure to the community noise standards and the enforcement practices in the European Union to add to my experiences in Canada, Mexico and the U.S.

JAA also focused more on the use of small acoustical models instead of the larger models that TES constructed. This was a result of our experience with the difficulty of accurately portraying the interactions between noise sources and the various real-world situations that often needed to be considered for specific projects. When using spreadsheet software and the manual methods for prediction upon which the larger models were based, it was more effective to construct a model that represented a specific situation than it was to try to use SOUND6, our general purpose model.

Q.14. What were your duties as a Principal Consultant with James, Anderson & Associates, Inc. from 1983 to 2006?

A.14. I was responsible for all projects deemed too complex for other members of my staff (which included acoustical engineers with Master's degrees) as well as the daily operation and management of a company that had between 25 and 45 employees. My work in this capacity built upon the work started in TES and expanded to include a much larger client base and higher levels partnerships with my clients. During this period my work continued, but I also took on more management responsibilities as my company grew. The types of problems my clients faced also became more complicated, because the easier problems had already been solved. It was during this time that my involvement with, audiologists, medical researchers and medical doctors increased and my relationship with NIOSH and other government agencies became more involved.

Q.15. Please describe some of the major noise-related projects that you performed in your capacity as a Principal Consultant with James, Anderson & Associates, Inc.

A15.. During this period JAA took on First Tier Partner responsibility for the noise control programs at its clients. This meant that JAA operated as a replacement for our clients' in-house staffs. Through this out-sourcing arrangement, JAA was responsible for annual or bi-annual auditing all of its client's facilities for upper management reporting, maintaining on-going noise control activities, assessing new problems related to community noise complaints, and all other activities not associated with our clients' facilities. In the early 1990's JAA had over 750 individual manufacturing facilities, primarily located in the U.S., Canada and Mexico for which it was responsible. The exposure that this caused was the basis for the start of our relationship with NIOSH. Our NIOSH related collaborations included the epidemiological database discussed earlier and a separate project under the title of "Safe@Work" formed to assist a software developer who was converting his DOS based software to Windows. NIOSH's interest in this software was that it would form the basis for its internal storage of occupational noise and health data for workers in the U.S.

Q.16. Who started the firm of E-Coustic Solutions?

A16.. I started E-Coustic Solutions as the sole owner in 2006 after my JAA partner Robert Anderson and I decided to close JAA due to the economic uncertainties in our client base.

Q17.. What types of work does your firm do?

A.17. E-Coustic Solutions focuses on much of the same work as I did with JAA but with more emphasis on community noise than in-plant noise. When JAA was closed, the contracts it held were passed forward to the new companies formed by each of its partners with E-Coustic Solutions taking the community noise aspects of the work and Mr. Anderson taking the in-plant portion of the services.

Q18.. What are your duties with E-Coustic Solutions?

A.18. I am its sole full time employee and as such have responsibility for all of its work.

Q.19. Have you been a member of any professional organizations related to noise?

A19.. Yes. These organizations include the American National Standards Institute (ANSI), the Insitute of Noise Control Engineers (INCE), American Industrial Hygiene Assoc (AIHA), and the National Hearing Conservation Assoc (NHCA). Each of these associations are stakeholders in the health effects of sound on people and their members interface with acoustical engineers and medical researchers relevant to each one's focus.

Q.20. Do you have any experience as a member of the faculty for any educational institutions?

A.20. Yes. For 12 years I conducted courses for Masters level audiology students on noise control and hearing conservation for audiologists. More recently this program has been dropped by my department. I now act as an advisor to the staff and professors in the Department on matters related to test equipment and procedures and in that capacity have been a co-author of papers on the effects of personal entertainment devices on listener hearing health and have acted as co-advisor for students required to conduct research projects involving acoustical testing. Most recently, this has involved a student's study of wind turbines in Michigan and preparation of a presentation for an upcoming conference of the America Speech-Language-Hearing Association (ASHA) titled: " What you can't hear can hurt you." with Professor Jerry Punch. This presentation is to alert ASHA professionals to the problems being identified with wind turbine noise.

Q.21. What training and experience do you possess concerning noise from wind turbines?

A.21. I first took interest in wind turbines as a potential source of community noise in late 2002. As a result of a viral infection in my heart causing complete heart failure in late 2001, I had been directed by my medical advisors to take a leave of absence from my duties at JAA and to do nothing that would stress my heart for a recovery period of two years. During this time, I conducted research into the types of problems that were occurring in Europe, the United Kingdom, and elsewhere as the 1.5 MW and larger wind turbines were being installed. It was clear to me that the U.S. would also be considering use of these modern industrial scale upwind turbines in the near future and I wanted to make sure that my company would be in a position to service clients and communities where they may be hosted. As the new projects came online in the U.S., such as Mars Hill, Maine and in Canada, New Zealand, and other countries, I used internet technology to obtain the siting studies and also the follow-up studies that were conducted to validate the siting studies or address post-construction complaints. I also started to collect research papers from consultants to the wind turbine manufacturers, developers and others to give me insight into the mechanisms involved in wind turbine sound generation. I have continued this research until the present. Now, the papers are routinely presented at national and international conferences held on the topic of wind turbine noise. I returned to my regular JAA duties in late 2004 but this sabbatical allowed me to conduct an in depth look at the issues that provided an excellent foundation for my present work on wind turbine siting criteria and noise impact on host communities.

Q.22. On how many occasions have you testified as an expert in administrative hearings concerning noise?

A.22. I have testified in approximately 10 to 15 administrative hearings as an expert in acoustical engineering on behalf of such companies as General Motors, Ford, and Chrysler held by the Occupational Safety and Health Administration. The purpose of my testimony in these cases was directed towards the limits of feasibility of engineering controls and to establish that my clients were taking the necessary administrative and medical/safety precautions to protect their employees from the adverse health effects of occupational noise exposure. I have also testified in approximately 10 to 12 administrative hearings considering applications by wind power companies to install wind powered electrical generating utilities. The subject matter of my testimony in these cases was to review and comment upon the noise studies conducted on behalf of the wind developer by its acoustical consultants, to present my research and recommendations for whether the wind project would result in nighttime sleep disturbance and other adverse health effects from the turbine's noise emissions, and to state my recommendations for criteria that would limit wind turbine noise to a level that would not be likely to cause adverse health effects.

Q23.. Do your responsibilities as an acoustical engineer require you to understand the effects of noise on persons who hear the noise?

A.23. Yes, all acoustical engineers need to understand effects the effects of noise on people. Such effects include effects on our auditory organs that are related to hearing loss and on-the-job safety as well as those that are related to annoyance and sleep disturbance. Acoustical engineers are not medical researchers but often work with such professions as part of a team to solve problems for their clients. This is especially true for work done for large corporations where medical and other health and safety professionals are part of the study team. Acoustical engineers are consumers of medical and health related studies and reports on effects of noise on people. For work related to community response to noise, we have traditionally been required to use this type of information in our work as members of teams who are designing airports, new manufacturing facilities, highways, and other common community sources of noise to maintain compatibility with existing land-uses. In many cases this type of work focuses on issues of night time noise and how to prevent sleep deprivation for people with homes near the new noise sources.

Q.24. Have you reviewed the portions of Buckeye Wind's application in this proceeding related to the noise impacts of its proposed wind turbines?

A.24. Yes.

Q.25. Do you hold an opinion, to a reasonable degree of engineering certainty, as to what sound levels will cause sleep deprivation?

A25.. One of the fundamental "rules of thumb" used by acoustical engineers since the 1970's and early 1980's when portable lab grade measurement instrumentation capable of performing calculations on the incoming data stream made it possible to study sound using statistical descriptors is that when the noise from a new source of sound is less than 5 decibels (dB) it is generally found to be unnoticed to tolerable. When it exceeds the naturally occurring sound levels in the receiving community by more than five dB, it becomes intrusive. When the new noise source will operate during night time hours, this intrusiveness will lead to sleep disturbance. If it occurs on a regular basis, night after night, it leads to sleep deprivation. The number of people affected and the degree to which they are affected increases as the differences between noise level and background noise level become larger. The World Health Organizations (WHO) 2007 "Night Noise Guidelines" lists the following effects for sleep disturbance:

"The review of available evidence leads to the following conclusions.

• Sleep is a biological necessity, and disturbed sleep is associated with a number of adverse impacts on health.

• There is sufficient evidence for biological effects of noise during sleep: increase in heart rate, arousals, sleep stage changes, hormone level changes and awakening.

• There is sufficient evidence that night noise exposure causes self-reported sleep disturbance, increase in medicine use, increase in body movements and (environmental) insomnia.

• While noise-induced sleep disturbance is viewed as a health problem in itself (environmental insomnia) it also leads to further consequences for health and well-being.

• There is limited evidence that disturbed sleep causes fatigue, accidents and reduced performance.

• There is limited evidence that noise at night causes clinical conditions such as cardiovascular illness, depression and other mental illness. It should be stressed that a plausible biological model is available with sufficient evidence for the elements of the causal chain.

Chronic sleep disturbance (sleep deprivation), is frequently associated with night time noise levels that are more than 5 dB above the natural background sound levels of a community. This is especially true when the new noise source emits sounds that are dissimilar to the host community's natural nighttime sounds or when it produces fluctuating sound levels. This effect should not be considered surprising for anyone who has experienced the sleep disturbing effects caused by sounds like a dripping water faucet in a room near a bedroom.

Q.26. What are the bases of your opinion that noise higher than five decibels above background sound levels will cause sleep deprivation?

A.26. This is a basic formula. It is presented as a rule in most modern textbooks that address community noise and is used in community noise standards worldwide. For example, L_{A90} +5 dBA (A-weighted decibels) is used in standards for the United Kingdom., Ireland, Netherlands (rural night 30 dBA), New Zealand, France (night L_{A90} +3 and +5 daytime). Other locations, such as Germany, have set upper limits based on the use of this formula. The German rural night limit is 35 dBA. It should be noted that Germany and the Netherlands are also major users of wind turbines as part of their electric utility system.

It is also incorporated directly into many U.S. state and community standards, such as New York's or in modified forms in other communities.

Q.27. Have you read the written direct testimony of David Hessler in this case?

A. Yes.

Q.28. Does Mr. Hessler's testimony agree with your position that noise from wind turbines should be no higher than five decibels above background sound levels?

A.28. Yes. In question 6 of his testimony, Mr. Hessler states:

"Under critical wind conditions of 5 and 6 m/s - when the turbine sound output is highest relative to the amount of background noise - mean L90 background levels of 29 and 35 dBA were found, for nighttime and daytime conditions, respectively. Consequently, nominal design goals of L90 plus 5 dBA, of 34 dBA night/40 dBA day, were recommended for project-only noise at residences to minimize any potential noise impact. This design approach, which is common for power plants and new industrial noise sources, generally limits the intrusiveness of a new source to a reasonable level but, particularly in the case of wind turbines, does not define the limit of audibility."

and

"…. Relative to the residual (L90) background level; however, there are a moderate number of homes within the 40 dBA daytime threshold (an L90 of 35 dBA plus 5 dBA) and a large number within the 34 dBA nighttime threshold. The practical meaning of this is that project noise is likely to be clearly audible at these residences and possibly at others further away during times when the background is fairly low, such as during lulls in the surface wind at night. …"

Mr. Hessler's assessment of background sound levels for the community in the footprint of Buckeye project is 29 dBA at night which is approximately 2 dBA higher than what I measured during my background sound tests conducted the summer of 2008. My assessment led me to conclude that the wind turbines should be limited to less than 35 dBA at the property lines of the non-participating residents. Mr. Hessler's assessment led him to conclude that the appropriate design goal should be 34 dBA.

Q.29. Do you hold an opinion, to a reasonable degree of engineering certainty, as to the distance that needs to be maintained between Buckeye Wind's turbines and nearby residences to avoid an increase of more than five decibels above background sound levels?

A.29. Yes. Any wind turbine project with randomly located wind turbines should be located at least 1.25 miles from the nearest residential property. If the turbines are arranged in rows such that the noise will drop off with increasing distance at ½ the rate of the randomly located turbines, they should be located at least two miles from the nearest residence.

Q.30. What are point source turbines and line source turbines?

A.30. Sound propagates (decays or is reduced) differently for noise sources that are arranged in rows or arrays than it does from noise sources that are by themselves or arranged in a random pattern that does not form lines or arrays. When discussing these types of arrangements the situation where there is no row or array pattern is called a line-source and sound propagates as an expanding cylinder centered on the line through the row. This propagation is at the rate of 3 dB per doubling of distance. Common examples of line sources are heavily used roads and trains. Wind turbines arranged in rows have the same characteristics. This effect is well known and has been part of every acoustical engineers training since the early 1960's. When there is no pattern to the layout of the noise sources as in the case of randomly located wind turbines on flat farmland the sound propagates in a spherical (or hemispherical) manner. Then, the sound decays are a rate of 6 dB per doubling of distance. Thus, a "point source" turbine refers to those turbines in a project areas that are not in rows. A "line source" of turbines are those located in a row of three, four or more turbines for any residence that is located to the sides of the row (e.g. approximately perpendicular to a residence).

This is basic acoustical modeling theory. Studies of wind turbines conducted for NASA in the 1980's and early 1990's confirmed that wind turbines in rows or arrays must be modeled as line sources. Failure to do so results in serious under prediction of the sound levels at receiving properties. Even for short distances of 1000 feet to several thousand feet, errors caused by modeling rows of wind turbines as point sources instead of line sources results in under predictions of 5 to 7 dB. At greater distances this error becomes even larger.
This error has been observed in all of the US acoustical models of wind farms I have reviewed. It is also a defect in the model's constructed by Mr. Hessler for the Buckeye project.

Q.31. What are the bases for your opinion that point source turbines should be located at least 1.25 miles from a residence?

A.31. My opinion is based on the following:

(1) Application of elementary principles of acoustic engineering involving how much a new noise source can raise nighttime sound levels before it becomes a source of sleep disturbance;

(2) Available literature about the health effects of sleep disturbance for other common nighttime noise sources such as roads, aircraft, trains, and industrial operations;

(3)Studies I have conducted for my clients while with TES and JAA where I was working for the noise producer and studies that I have conducted since 2006 for clients who are concerned about nighttime noise from wind turbines near their homes.

(4) Measurements of the ambient (background) noise levels I have taken for clients with homes in the Buckeye Wind project area; and

(5) My personal experiences during studies of wind turbines that required staying overnight in the homes of people who have reported night time sleep disturbance from wind turbines located near their homes.

Q.32. How do the basic principles of acoustic engineering support your opinion that Buckeye Wind's turbines need to be located at least 1.25 miles from point source turbines?

A.32. This is fully explained as part of the recommendations of Mr. George Kamperman and me, as published in our paper titled: "The 'How To' Guide To Siting Wind Turbines To Prevent Health Risks From Sound." This paper is attached as UNU Exhibit 32. My findings about the need for a 1.25 mile setback from the Buckeye Wind point source turbines are based on sound propagation models we constructed for this paper and on my experiences with other wind farm projects. The studies and results of our models were used to produce the graphs and charts for our report such as Figure 1 on page 7, Figure 3 on page 10, and Figure 4 on page 11. The text associated with those figures explains the rationale for the 1.25 mile setback in some detail. For outdoor noise we found that, given the quiet nature of nights in rural communities where nighttime background sound levels are routinely 20 to 30 dBA, this distance is needed to meet the L_{A90} + 5 rule to avoid sleep disturbance from intrusive noise at night. 1.25 miles is based on my experience with background sound levels in rural communities and in my opinion it is appropriate for all wind farms where nighttime background sound levels are 30 dBA or less.

Q.33. How does the literature on wind turbines from other researchers support your opinion that Buckeye Wind's turbines need to be located at least 1.25 miles from point source turbines?

A.33. A classic study of wind turbine noise was conducted for NASA (Technical Paper 3057) in 1990 by Hubbard and Shepherd titled: "Wind Turbine Acoustics." Their research covered all aspects of wind turbine noise including the modern upwind industrial scale turbine types that are now being installed across the US. This study examined issues of computer modeling as well as the effects of wind turbine noise on people both inside and outside their homes. It should be considered as required reading by any acoustical engineer or other professional involved with wind turbine noise. It confirms that the 6 dB decay rate for theoretical point sources applies to wind turbines in random patterns and that the 3 dB decay rate should be used when they are in rows or arrays. It was this research paper that confirmed my opinion that the models developed by Mr. Kamperman and myself for our paper were correct. A true and accurate copy of the applicable pages of this report are attached as UNU Exhibit 33.

Q.34. What is the goal for using five dB as the standard?

A.34. The goal of the 5 dB over background rule is to prevent community noise complaints as well as to prevent nighttime sleep disturbance. This principle was developed in studies of noise sources, such as highways, rail, air and industrial noise sources which are common to suburban and urban communities where background sound levels at night range from 35 to 45 dBA in the residential areas. The purpose of these studies was to establish the relationship between 'annoyance' and absolute sound level. These studies confirmed that as the background sound levels increased, the tolerance for nighttime noise also increased. The relationship of L90 + 5 applied to these situations, too.

Q.35. Are there any other standards that are commonly used to establish allowable noise levels?

A.35. Yes. For the purpose of establishing community noise limits for common community noise sources, it was deemed to be politically acceptable to set the limits at the point where 10%

of the exposed population would be "annoyed." Similar studies conducted in the European Union for existing wind turbine utilities show that the absolute sound level where 10% of the population reports the noise as "annoying" is approximately 10 dBA lower for wind turbines than it is for the other noise sources. The most recent study of this type is titled: "WindFarm Perception" sponsored by the University of Groningen and Göteborg University. This study involved a review of operating wind utilities where the turbines ranged from smaller under 1MW models to the larger types proposed for the Buckeye Wind project. It reports that the sound level at which 10% of the population is "very annoyed" is 30 to 35 dBA. At these sound levels sleep disturbance was reported by 25% of the population. This increased sensitivity to noise over what would be expected from other common community noise sources has been identified in many other studies.

Q.36. How do the studies you just mentions support your opinion that Buckeye Wind's turbines need to be located at least 1.25 miles from point source turbines?

A.36. They confirm, based on empirical data, what the computer models used for our manuscript show. That is, that when the sound levels of wind turbines at night exceed the range of 30 to 35 dBA there will be complaints and that sleep interference is likely. Under the current design and layout for Buckeye Wind, I would expect that sound levels sound level outside the homes within 1500 feet of turbines will be in the range of 45 to 50 dBA and inside the homes the low frequency sounds will be clearly audible in quiet rooms such as bedrooms. If the windows are open to the outside I expect that on some nights sound levels of 40 dBA or higher will be inside these rooms. This is based on my field studies of other similar wind projects where these sound levels were observed and also on the initial modeling studies conducted for our manuscript.

Q.37. How do measurements of the ambient (background) noise levels in the Buckeye Wind project area support your opinion that Buckeye Wind's turbines need to be located at least 1.25 miles from point source turbines?

A.37. During May and August of 2008 I conducted a study of late evening and night time sound levels for properties located within the footprint of the proposed Buckeye Wind project. My studies established that the only significant nighttime sources of noise for these residences were traffic noise on nearby roads and highways. My findings were that the background sound level during the evening and night when people would be sleeping ranged from 24.4 to 30.3 dBA (L_{A90}). The highest background level observed was for a property near Highway 36 where heavy trucks were audible at night as they went up a grade and also as they used engines and other means to slow down as they went down the grade. This test was conducted near midnight when truck traffic was still frequent at a location not shielded by the home or other structures. Sites at a distance from the highway were quieter with levels of 27 dBA (L_{A90}). One site, located along highway 36, was tested during the later hours of the night with the test site on the side of the home opposite the highway. This combination of less night traffic and shielding of the traffic by the home resulted in a background sound level of 24.4 dBA (L_{A90}). This would indicate that had the other test site near the highway where 30.3 dBA was measured been tested later at night that it would have had a lower background sound level more in line with the 27 dBA readings. If we can presume that 27 dBA L_{A90} is representative of the homes in the project area then applying the L_{A90} + 5 dB rule would set the design goal for the Buckeye project at 32 dBA.

Q.38. Have you measured background noise in rural areas other than the Buckeye Wind project area?

A.38. Yes. I have conducted numerous studies of background sound levels at night in communities in Illinois, Wisconsin, Michigan, West Virginia, Pennsylvania, other parts of Ohio, and New York. A quick count of my background sound studies since 2006 shows approximately 20 communities with multiple test sites in each community.

Q.39. How have your measurements of background sound levels in other rural areas compared to the level you found in the Buckeye Wind project area?

A.39. My findings are consistent. In all cases I found that rural communities have little or no man-made noises at night. If there is a source of man-made sound, it is a highway or other heavily traveled road where traffic continues throughout the night. For those communities that are over five miles from such a road, the sound levels range from 25 dBA and lower (sometimes below the noise floor of my instruments which are less than 18 dBA depending on the instrument).

Q.40. How do your personal experiences in evaluating noise from wind turbines support your opinion that Buckeye Wind's turbines need to be located at least 1.25 miles from point source turbines?

A.40. The most personal experience I have had is when I was asked to sleep overnight at the homes of clients in Ontario where wind turbines were located at distances of about 700 meters or more from the homes. The wind speeds and power production data for the turbines indicated that they were operating at less than 30-40% of capacity which would be line with the moderate wind speeds used in Mr. Hessler's models for 5 m/s and 6 m/s at 10 meters above grade. I spent two nights at one of these homes. The window of the bedroom was partly open and faced a turbine about 700 meters distant. The first night I was awakened by the sound of blade swish from the turbines several times, such that I did not get a good night's sleep. The second night at this home, I decided I needed to get a good nights rest. I have a prescription for a night-time sleep aid that I use when staying in noisy motels/hotels. I took my prescribed dose so that I would sleep through the night. However, I was still awakened twice during the night by blade swish.

Q.41. What are the bases for your opinion that Buckeye Wind's line source turbines should be located at least two miles from neighboring residences?

A.41 This is based on our calculations for wind turbines arranged in a row where the sound decays at 3 dB per doubling of distance and our opinion that the sounds received at the distant properties should meet the 5 dB rule for increases in nighttime background sounds. This methodology is standard acoustic engineering practice and it was confirmed as being applicable to wind turbines by the NASA study. Unless Buckeye Wind's line source turbines are located at least two miles from homes, their noise will disturb the sleep of the residents in those homes.

Q.42. How does the NASA study support your opinion that Buckeye Wind's line source turbines should be located at least two miles from neighboring residences?

A.42. In the section of the NASA study that addresses noise propagation there is a section devoted to explaining the use of point and line source models for estimating noise at a distance from wind turbines. The section entitled 'Distance Effects' beginning on page 18 of the report details the conditions under which line source modeling procedures should be applied to wind turbines.

Q.43. Does Buckeye Wind's application provide a distance of at least 1.25 miles between point source turbines and the homes of neighbors who are not participating in the Buckeye Wind project as landowners?

A.43. No.

Q.44. On what information do you base your statement that Buckeye Wind's application fails to provide a distance of at least 1.25 miles between point source turbines and the homes of non-participating residents?

A.44. I have reviewed both the reports of Mr. Hessler and the contour maps that depict the results of his models using the scale of the maps as a guide. Mr. Hessler's report also confirms that many properties will be affected by wind turbine noise. Had a distance of 1.25 miles between any turbine and the nearest home been part of the project layout the projected sound levels would have been below 35 dBA for all homes.

Q.45. Are the homes of any members of Union Neighbors United, Julie Johnson, or Robert and Diane McConnell located closer than 1.25 miles of any proposed wind turbine site?

A.45. Yes. The maps in UNU Exhibit 8 show the boundary of the properties of the UNU members at a scale of 1inch = 1000 feet. Using a ruler, I measured the distance between each home and property line to determine the distance to the nearest turbine. The properties for all UNU members shown on the maps had turbines within 1800 and 2500 feet of each home and in two cases (Julie Johnson and Robert and Diane McConnell) were within 600 to 800 feet of their property lines.

Q.46. Does Buckeye Wind's application provide a distance of at least two miles between line source turbines and the homes of all non-participating residents?

A.46 No.

Q.47. On what information do you base your statement that Buckeye Wind's application fails to provide a distance of at least two miles between line source turbines and the homes of non-participating residents?

A.47. I used the same process as I did for 1.25 miles.

Q.48. Are the homes of any members of Union Neighbors United located closer than two miles of any proposed wind turbine site?

A.48. Some of the homes are within two miles of turbines arranged in rows.

Q.49. What effects will noise from Buckeye Wind's turbines have on persons residing closer than 1.25 miles for point source turbines, or two miles for turbines in a line?

A.49. They will be awakened frequently, will suffer sleep deprivation, and hear the wind turbines as the dominant noise when outside their homes. The noise will also be audible inside their homes during the winter with windows closed, especially in bedrooms where the sounds interfere with sleep.

Q.50. Are you familiar with the model that Mr. Hessler used in Buckeye Wind's application to predict the level of wind turbine noise that will reach the neighbors' homes?

A.50. Yes.

Q.51. Please explain the model that he used.

A.51. Mr. Hessler states that he used the commercial software package Cadna/A for his models. Cadna/A is a well known model which implements the formulas of ISO 9613-2 "Acoustics-Attenuation Of Sound Outdoors-Part 2 General Method of Calculation.

Cadna/A (Computer Aided Noise Abatement) is described on the developer's website as: "the leading software for calculation, presentation, assessment and prediction of environmental noise. Whether your objective is to study the noise immission of an industrial plant, of a mart including a parking lot, of a new road or railway scheme or even of entire towns and urbanized areas: Cadna/A is designed to handle all these tasks." It should be noted that although the software is commonly used for wind turbine projects, this is not its intended application. There are limitations of the ISO 9613 calculations that make its use for noise sources located high more than 30 meters off the ground questionable.

Q.52. Does any of Mr. Hessler's work for the Buckeye Wind application utilize techniques that you have developed?

A.52. Yes. During the early years of my career I pioneered the use of computer models for new facilities and also the use of contour maps as a means of depicting the large amounts of data generated by these models. I described some of my work using sound models earlier in my testimony. I published the first paper on the use of contour maps for acoustical data in Sound and Vibration in 1973 titled: "Isograms Show Sound Level Distributions In Industrial Noise Studies." A reproduction of one of my first contour maps was depicted on the cover of that issue. My research at the time indicated that this was the first time that this method of depicting acoustical data was presented to this acoustical engineers in the US. In addition, I made a presentation on the use of this method to the members of the Institute of Noise Control Engineers at a conference in Washington, D.C. at about the same time. By the end of the 1970's almost all acoustical engineers had adopted this method of displaying data and many had also created their own software for modeling.

Q.53. Did Mr. Hessler employ the correct methodology in his model designed to accurately predict the level of wind turbine noise that will reach the neighbors' homes?

A.53. No.

Q.54. What if any mistakes did Mr. Hessler make in his model?

A.54. There are several errors in the way Mr. Hessler created his models that preclude his characterization of the results as "worst case." They include:

1. Failure to disclose the stated limitation of the ISO/Cadna/A model to noise sources that are within 30 meters of the ground. The known errors for noise sources that meet all of the assumptions of the ISO model is 3 dB. Use of this model for noise sources at heights higher than 30 meters will have errors greater than 3 dB.

2. Use of a ground absorption coefficient of 0.5 for a noise source that is 80+ meters above the ground such that the sound energy propagating from the source to the nearby homes does not interact with the surface.

3. Use of a ground absorption coefficient of 0.5 for a noise source that will operate during winter and other seasons when the ground will be 'hard' and reflect sound. The appropriate coefficient to use would have been 0.

4. Use of sound power level data from the manufacturer without disclosing normal measurement errors. The test procedures (such as IEC 61400-11) for deriving the sound power data have published errors of 2 dB. This error was not considered in Mr. Hessler's models.

5. Use of sound power data from the manufacturer that is collected under standardized wind and weather conditions that does not include the types of weather and wind conditions that cause the intrusive blade swish that is commonly associated with nighttime sleep disturbance and complaints. The manufacturer's reported power levels should be seen in the same light as the EPA mileage statements on new vehicles. It represents a standardized value for 'typical' conditions and not 'worst-case' conditions as Mr. Hessler claims in his report.

Had Mr. Hessler properly disclosed and used the known errors and tolerance the contour maps and the results he states in his narrative and testimony would have been 5 dBA greater for the L_{Aeq} average sound levels and higher yet during periods when blade swish is present. Blade swish is most often heard during the night where it can lead to sleep disturbance.

Q.55. On page 1 of Exhibit K of the application, Mr. Hessler states that the average sound level (Leq) is the "'typical' sound level most likely to be observed at any given moment." Do you agree with this statement?

A.55. No. It is not correct to assume that the average value is typical of what is happening at any moment. If one is driving one's car through both urban and expressway roads (where one drives 25 mph and also 70 mph respectively) the average speed might be 50 mph. Yet, the car was traveling at 70 mph when on the highway and 25 mph in town. To say that at any time the 'average speed' is typical of the true speed is a serious error in understanding about average values. This error, however, is consistently made in Mr. Hessler's reports and testimony.

Q.56. How do the mistakes in Mr. Hessler's model affect the conclusions he has drawn from the model?

A.56. The combination of not including known errors into his model, of concluding that the manufacturer's test data used as input to the model represents a true "worst case," and his failure to state the true maximum levels that will occur leads to a severe underestimate of the sound levels and the character of the sound levels at the receiving properties and homes.

All of his reported sound levels in his narrative and in the contour maps should be increased by 5 dB to account for known errors and tolerances of the ISO and IEC procedures. Further, the maximum sound levels during blade swish and other weather conditions that cause noises to exceed the manufacturer's test data should have been disclosed.

Q.57. Even if Mr. Hessler's model were accurately performed, how far from neighboring residences would Buckeye Wind's turbines have to be to maintain an increase of no more than a five dBA of noise above background levels?

A.57. Given that both the background sound studies by Mr. Hessler and my own studies show nighttime background sound levels in the range of 25 to 30 dBA (L_{A90}), the distances would need to be 1.25 miles.

Q.58. During what time of the day is it necessary to maintain no more than a five dBA difference between background level sound and wind turbine noise?

A.58. The most critical time to maintain this standard is at night when persons are sleeping. However, it is still important during daytime to prevent annoyance and allow persons to enjoy their homes and yards.

Q.59 In your testimony so far, you have been describing the dBA noise from the turbines. What is dBA noise?

A.59. dBA stands for A-weighted noise, which refers to sound test data.

Q.60. Is your opinion that Buckeye Wind's turbines need to be located at least 1.25 miles from point source turbines and two miles from line source turbines based on the distance necessary to protect neighboring residents from the turbines' A-weighted noise?

A.60. Yes, it is. Even if wind turbines produced no C-weighted (low frequency) noise, it would still be necessary to have at least 1.25 miles between Buckeye Wind's point source turbines and the homes of non-participating neighbors.

Q.61 Some persons say that wind turbines with upwind blades produce little or no low frequency noise. Do you agree with these statements?

A.61. No. Wind turbines produce sound emissions that are predominantly low frequency.

Q.62 Do you have any personal experience in evaluating low frequency noise from wind turbines with upwind blades?

A.62. Yes. I have conducted measurements of operating wind turbines and always find that the dominant energy is low frequency. Also, the manufacturer's test data, when reported in octave bands and corrected to remove A-weighting, show similar spectrum shapes consistent with my measurements of low frequency noise.

Q.63. Is their any literature that documents the fact that upwind turbines produce low frequency noise?

A.63. Yes, numerous papers by pro-wind and neutral acoustical engineers show these effects. So do the manufacturers' test data. However, it is often necessary to remove the A-weighting from the graphs of test results to see that this is the case.

Q.64. What is the significance, if any, of the fact that upwind turbines produce low frequency noise?

A.64. Low frequency sound both travels further with less attenuation over distance than mid and higher frequency sounds and penetrates walls of homes with less reduction in level. As an illustration, consider the rumble of thunder in the distance where the higher frequency sounds are lost. Also, this rumble penetrates into one's homes. A similar effect is noticed when near a 'boom car' where the emphasis on amplifying the lowest frequencies of music can make nearby vehicles shake. This is yet another reason why wind turbines should stay at least 1.25 or 2 miles away from homes in the Buckeye Wind project.

Q.65. Does the noise from wind turbines have a different quality than leaf rustle and other wind noise?

A.65. Yes. The sound characteristics of operating wind turbines, especially during periods of blade swish are distinctive and will not be masked by the sound of wind in leaves or against ground level structures. I have confirmed this during many field trips. I have always been able to hear the wind turbines as distinct sounds even in the presence of high winds and storms.

Q.66. How does that affect the likelihood that a neighbor will hear the wind turbine noise?

A66. This means the noise will be more likely to be both heard and annoying. The sounds of a wind turbine at high wind speeds combines the sounds of aircraft overhead, blade swish, and mechanical sounds from the turbine as blades and other parts are stressed by the wind. It is a sound that is best characterized as "industrial" noise.

Q.67. Some witnesses have testified in this proceeding that they have visited wind turbines and have not heard much noise while standing near them. Is the noise heard near the turbine representative of the noise heard at longer distances?

A.67. No. The noise from the blades projects outward to the front and back. At the base of the turbine, it is often much less noisy than it is at 1000 to 1500 feet from the turbines.

Q.68. Are you aware of any instances where landowners participating in a wind farm project were fooled into thinking that the turbine noise would not be significant?

A.68. Yes. I have two clients that have signed agreements and then after hearing how noisy the turbines were regretted their decisions. One of these clients, Judge Hal Graham of Cohocton, NY, was taken on a tour of a nearby wind project where he was allowed to listen to the turbine at its base. He signed a lease based on this trip and affirmations by the wind developer's agents that he would hear no more than what he heard on the tour from turbines on his property. Once the turbines were operating, he felt that he had been mislead by the developer and has made many public statements to the press and local government agencies about how he was misled.

Q.69. Do you know Dr. Michael Nissenbaum?

A. Yes.

Q.70. What is Dr. Nissenbaum's profession?

A. Medical doctor.

Q.71. Are you familiar with Dr. Nissenbaum's study of noise effects on the neighbors of the Mars Hill Wind Farm?

A.71. Yes.

Q.72. Is Dr. Nissenbaum's study an example of the studies on the effects of noise that an acoustic engineer is expected to know?

A.72. Yes. It represents the type of study that provides an early warning that something is wrong with the policies that led to the Mars Hill situation. This type of information should be incorporated into the designs of future wind projects and used to upgrade the standards used for siting guidelines.

Q.73. Are you personally familiar with the Mars Hill Wind Farm?

A.73. Yes.

Q.74. How did you become familiar with the Mars Hill Wind Farm?

A.74. I first studied the reports on Mars Hill during my recovery period in 2003-2004. I continued to follow it until 2007 when I first made contact with some of the residents at the base of the ridge including the Todd family. Since then I have been hired by the Todds and their neighbors to represent them in meetings and other activities involving Maine's Environmental Protection agency.

Q75.. What do you personally know about the effects that the wind turbines are having on the persons living near the Mars Hill Wind Farm?

A.75. I have listened to people reporting severe sleep disturbance over consecutive nights from heavy blade swish and rumble in their homes. They have described their symptoms to me in a similar manner to what they describe to Dr. Nissenbaum. Most of the people at Mars Hill would sell their homes and leave if they could find a buyer in order to restore their lives to what they were before the project started operation.

Q.76. Have you reviewed the written direct testimony of Kenneth Mundt filed in this proceeding?

A76. Yes.

Q.77. Are you familiar with the articles by Pedersen and Persson Waye (2007), Pedersen, van den, et al. (2009), and waye (2004) that he discusses in his testimony?

A.77. Yes. These studies are the basis for establishing absolute sound levels at which annoyance and sleep disturbance occur. They should be used by all acoustical consultants involved in siting wind turbines to avoid annoyance.

Q.78. Do these articles demonstrate that wind turbine noise does not have any health effects on humans?

A.78. No. The questions on health effects of wind turbine noise were worded in such a way as to elicit inaccurate answers. Further, while they found that sleep disturbance was common at sound levels of 35 dBA and higher, they did not address the sleep deprivation and resulting health effects such as headaches, instead concentrating on other diseases.

Q.79. Kenneth Mundt's testimony states that Dr. Nissenbaum has not used a control group to compare the symptoms experienced by the persons living within 3400 feet of the Mars Hill wind turbines. Do you have any information about this topic?

A.79. Yes. Dr. Nissenbaum has interviewed a control group of individuals living at least two miles from the Mars Hill Wind Farm. In a private communication regarding his study, he informed me that he found that none of the control group reported similar symptoms or sleep disturbance. This is in stark contrast to the headaches, hypertension, and other problems that were being experienced by the persons living within 3400 feet of the turbines. Dr. Nissenbaum found that chronic sleep disturbance brought on by the noise and annoyance of too-close wind turbine installations is responsible for the majority of symptoms and negative health effects at Mars Hill. Chronic sleep disturbance results in stress and increased risk for a host of serious diseases that reduce quality of life and life expectancy. The link between chronic sleep disturbance and stress and these illnesses is proven and unimpeachable.

Q.80. Dr. Mundt uses a report of the National Research Council in support of his testimony that low frequency noise from wind turbines is not a concern. Does this testimony contradict your opinion that the point source wind turbines should be located at least 1.25 mile away from residences and line source turbines should be located at least two miles away?

A.80. No. My opinion is equally supported by just the dBA content of the turbine sounds, so even if there were no low frequency noise it would not change my opinion.

Q.81 Do you know whether it is a common practice for wind farm operators to mount cameras on the turbines?

A.81. Yes. Based on my observations while conducting field tests and the comments of people who are neighbors to wind turbines, it is apparent that there are surveillance cameras on all or most of the wind turbines in my clients' communities. This has been confirmed by my work as turbines have turned on and off based on where I am conducting my tests. I have also seen security trucks for the wind utility operator arrive to watch my work within minutes of my arrival at a test site. This has also been observed by others who have attempted to walk inside the boundaries the utility operator identifies as private property.

Q.82. Do you know whether there are situations in which these cameras are recording or viewing what is in the yards of persons living near the turbines?

A.82 Yes As I just stated I have been standing in the yard of one house trying to measure sound, and the nearest turbines stop. When I move to a new test site the stopped turbines restart and the ones close to my new test stand stop.

Q.83. Please summarize your conclusions about the noise levels from Buckeye Wind's turbines that will reach the homes of neighboring residences.

A. If we assume that Mr. Hessler's models are correct, he states in his conclusions that sound levels (L_{Aeq}) will vary from 43 to 44 dBA during the day and 38 to 40 dBA at night. However, these results are predicated upon his assumption that wind speeds will be lower at night than the day and thus the sound received at homes will be lower during the night than day. There is no basis for this assumption. Indeed, it is quite common for nighttime winds to be higher than day time winds. Thus we must evaluate his conclusions from the point of view that his daytime sound levels could also occur at night. Given that 43 dBA at night is known to result in sleep disturbance and to cause adverse health effects from studies conducted by WHO and reported in 2009, Mr. Hessler's work leads to the conclusion that the current arrangement proposed for the Buckeye Wind Project will cause adverse health effects.

If we assume that Mr. Hessler's model should have included error tolerances to account for known errors in the ISO (3dB) and IEC (2 dB) standard procedures, then we can conclude that the sound levels outside the walls of homes will be 43+5 db=48 dBA to 44+5=49 dBA. This means that the sound levels outside the homes of people in the footprint of the Buckeye Wind project will be subjected to 48 to 49 dBA. Given that sound levels over 40 dBA at night are associated with adverse health effects, these higher levels mean that the risks to the community residents is greater for those nearest the turbines and will extend to homes at somewhat greater distances such that they will now have outdoor sound levels exceeding 40 dBA.

Based on my own field tests at operating wind utilities with turbines that have similar sound emission characteristics, I would expect that the sound levels at night for the nearest homes would be 45 dBA or higher on a regular basis (assuming the turbines are operating) and that under some wind and weather conditions sound levels will exceed 50 dBA.

Thus, I conclude that all of the data that is presented by both Mr. Hessler and my own arguments in this testimony show that the Buckeye Wind Project is not compatible with the current land uses and that the incompatibility will result in adverse health effects since the normal operation of the wind turbines at night will cause sound levels to exceed 40 dBA at the outside wall of neighboring residences.

These levels exceed the 34 dBA set by Mr. Hessler using L_{A90} plus 5 dB at neighboring homes, including UNU members, given both my and Hessler's measurements of background noise, if less than 1.25 miles away, by as much as 15 dB or more.

Q. Does this conclude your direct testimony?

A. Yes.

CERTIFICATE OF SERVICE

I hereby certify that, on November 2, 2009, a copy of the foregoing Direct Testimony was served by regular mail on Gene Park, Piqua Shawnee Tribe, 1803 Longview Drive, Springfield, Ohio 45504, and by electronic mail upon the following counsel of record:

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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. From 1973 through 1983, Mr. James was Vice President and co-owner of Total Environmental Systems. In addition to providing traditional acoustical engineering services, Mr. James directed the development of Sound6. This software permitted modeling of both community noise and noise inside manufacturing facilities. This software was used to assess compatibility with host communities for many new facilities for clients in the automotive, tire and types of manufacturing operations.

Mr. James is the former President of James, Anderson & Associates, Inc., an acoustical consulting firm whose clients included Fortune 100 companies from 1983 until 2006. 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 partner 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 complaints 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 and provided other services for his firm's clients throughout the U.S., Canada, Mexico, and Europe. 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 (E-CS).

In addition to his consulting interests, Mr. James has served as an Adjunct to Michigan State University's Department of Communicative and Disorders for 20 years. Until 2006, Mr. James was a member of the American National Standards Institute's S12 Committee which has 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. Mr. James is currently participating in the Acoustical Society of America's update of community noise sound levels in the US. This is the first re-evaluation of the background sound levels in communities since the early 1970's when it was first conducted under the auspices of the US EPA. Mr. James, and his collaborator, George Kamperman were asked by ASA/ANSI to participate in the formal review and comment process on the current draft revision to the IEC 61400-11 standard for measuring wind turbine sound power levels. This international standard is used worldwide to produce the sound data used as input to sound propagation models by the wind project developers. All suggestions submitted by Mr. James and Kamperman were adopted by the US ANSI/ASA committee charged with review of the IEC standard.

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 for clients in Michigan, Ohio, Wisconsin, Illinois , West Virginia, Pennsylvania, Maine, New York, Oregon, Washington and Colorado and in 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"

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American Industrial Hygiene Association (past)
Institute of Noise Control Engineers (Full Member)

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

By:

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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 (WT), 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 "Model Ordinances" for siting industrial wind farms which establish limits for noise and other potential hazards. These are used to determine where wind projects can be located in communities, which are predominantly rural and often extremely quiet during the evening and night. Yet, complaints about noise from residents near existing industrial wind turbine installations are common. This raises serious questions about whether current state and local government siting guidelines for noise 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 accurately predict sound propagation. The models are used to make decisions about how close a turbine can be to a home or other sensitive property. The errors in the predicted sound levels can easily result in inadequate setback distances thus exposing the property owner to noise pollution and potential health risks. Current information suggests the models should not be used for siting decisions unless known errors and tolerances are applied to the results.

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

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[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.

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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 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 on health issues for those living in close 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).

The 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 WT (industrial wind turbines) projects in the U.S. is a relatively recent phenomenon, with most projects built after 2000. 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). 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 WT developments. Many of these have been in operation for over 10 years. The Acoustic Ecology Institute[2] (AEI) reported that a Special Report for the British government titled "Wind Energy Noise Impacts,"[3] 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.[4] Thus, experience in the U. K. shows that not all WT 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 credible independent research institutions -- 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*[5]:

- Australia: higher of 35 dBA or L_{90} + 5 dBA
- Denmark: 40 dBA
- France: L_{90} + 3 dBA (night) and L_{90} + 5 dBA (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 State Task Force (working under the Department of Labor and Economic Growth) 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

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[2] (http://www.acousticecology.org/srwind.html)

[3] 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

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

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

under the request showed that the limits had been set by Task Force members representing the wind industry.[6] 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 applied to similar projects in other countries. There is 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, economic losses or other risks.[7] But, there is considerable independent research supporting that this will result in public health risks and other negative impacts on people and property.

To illustrate the way a typical WT developer responds to a question raised by a community committee about noise and health the following example is presented and discussed:

> **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 they presumed would be based on independent, peer-reviewed studies. Instead, 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 WT, 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 WT sound; in fact, there are often claims to the contrary. They fail to warn that the home construction techniques used for modern wood frame homes result in walls and roofs that cannot block out WT 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* [8] and "Report on the third

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[6] 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.

[7] 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. ...."

[8] Available at http://www.who.int/docstore/peh/noise/guidelines2.html.

meeting on night noise guidelines.[9]" 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 is an adult. Even for adults, health effects are first noted in some studies when the sound levels exceed 32 dBA L_{max}. These sounds 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 WT sound levels are 45 dBA outside a home, we may find that the interior sound levels will drop to the 30 dBA level recommended for sleeping areas but low frequency noise only decreased 6-7 dBC from outside to inside. That could create a sleep problem because the low frequency content of the noise can penetrate the home's walls and roof with little reduction. An example demonstrating how WT 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 (dBA)			
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 an overt 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. The studies belie the claims of the wind industry. This "failure to locate" published

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

studies that are readily available on the internet as to make some interpret the claim of "no medical research" as a conscious decision to not look for it. Those companies that do acknowledge the existence of medical research take the position that it is not credible for one or another reason and thus can be ignored.

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 is, at best, an opinion. 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.[10,11] 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[12] 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 near Ubly, Michigan. This is 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 10,000 Hz). At

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

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

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

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_{A90}) 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) and C-weighting (dBC). These show that if only dBA criteria are used to assess and limit 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 dBA is not an appropriate method of describing predicted noise impacts, sound limits, or criteria.

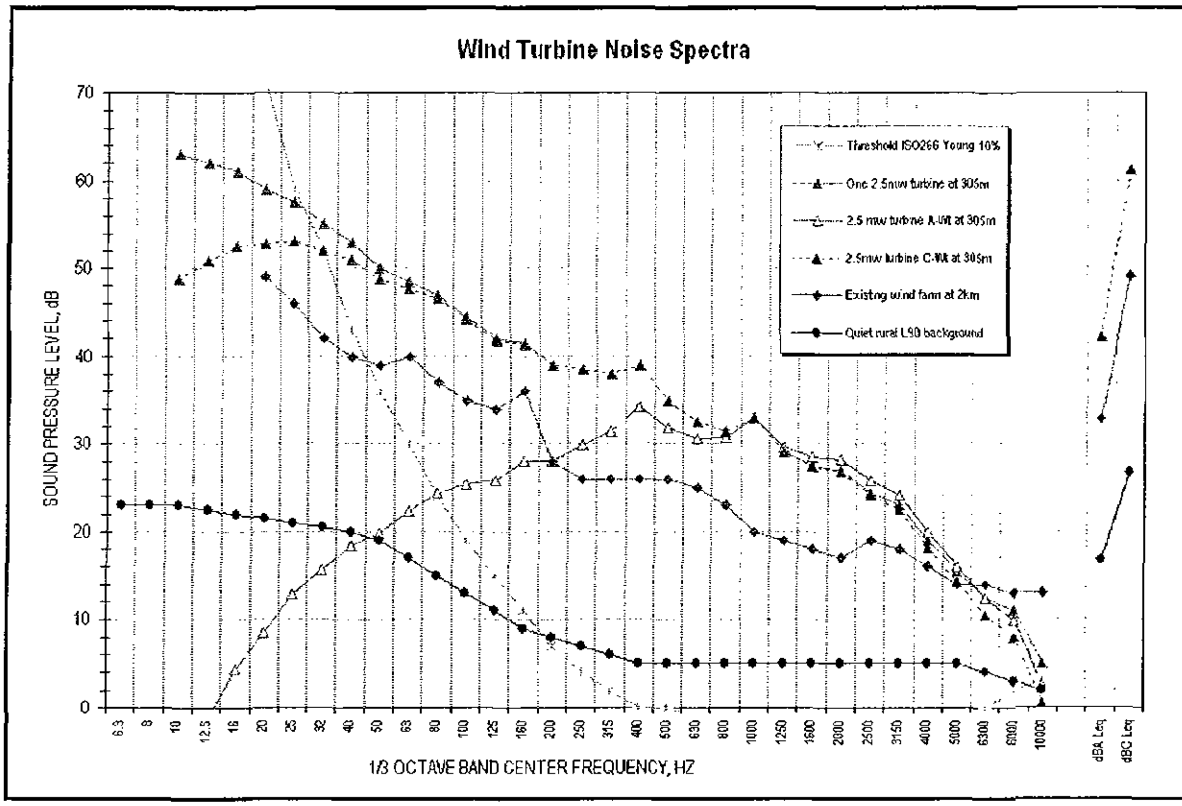

Figure 1-Graph Of Wind Turbine Sounds Vs. Rural Background And Threshold Of Perception

(Note: The lowest L_{Aeq} and L_{Ceq} shown at right are measured background L_{A90} and L_{C90}. The Leq values could be 0-5 dB higher)

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.

An example of a condition that complies with

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.[13]" 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.[14] 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.

Amplitude modulation is a continuing change in the sound level in synchronization with the turning of the wind turbine's blades. An example of amplitude modulation is shown in the figure 2 below. This figure shows the constantly varying dBA sound level in the graph at the top. The sound level varies from a low of 40 dBA to a high of 45 dBA repeating every 1.3 seconds continuously when the turbine is operating. The turbine is located approximately 1200 feet from the farmhouse. The photo shows the turbine that was dominant during this test.

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[13] 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)

[14] 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

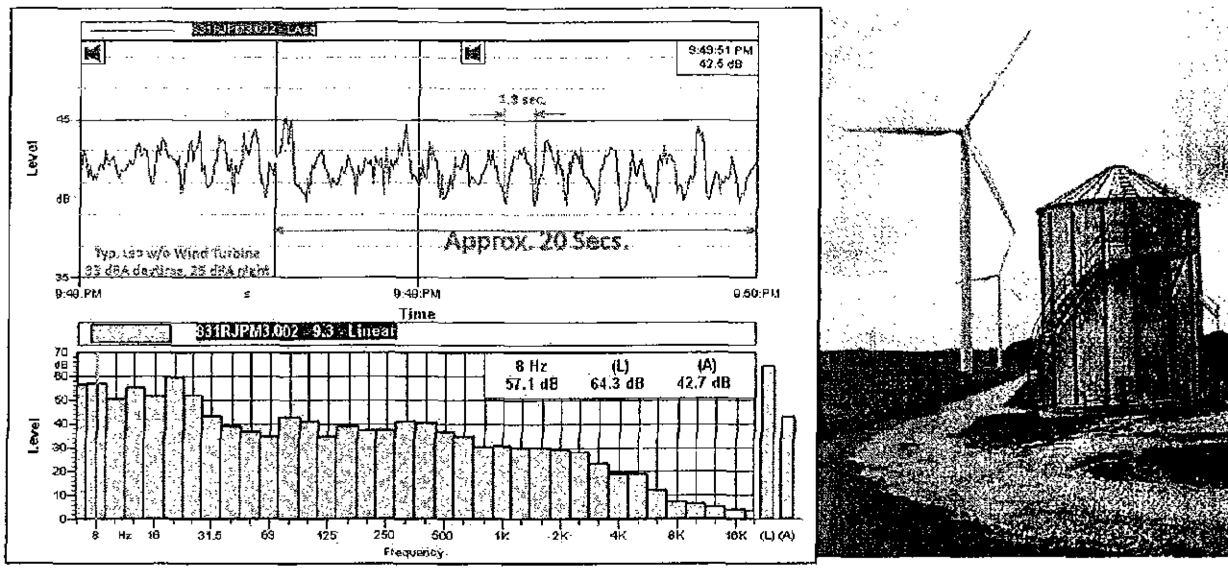

Figure 2 Amplitude Modulation at a farmhouse (Study sponsored by CCCRE, Calumet, Wisconsin)

It is worth noting that this measurement averages about 43 dBA (L_{eq}) which is very close to the sound level predicted for a single turbine at 1000 feet in Figure 1 (solid red line with solid triangle markers). The lower graph shows the frequency spectrum at approximately 9:49 PM at a low point in the amplitude modulation. (The frequency chart's cursor is the vertical line at the upper graph's midpoint.) Note the dominance of sound energy in the lower frequency range. This was also present in the model's predictions in Figure 1.

It is not hard to understand why many people in this community feel that they have been forced to accept noise pollution as a side effect of the wind project. Even though the 40 to 45 dBA sound levels in this example may comply with the 50 dBA limits adopted by the host county from the Wisconsin Model Ordinance the impact on the people near the wind project are subjected to noise pollution. This example demonstrates why criteria set at 50 dBA or higher do not protect the health and economic welfare of people living in the host communities. Adopting criteria such as those recommended later in this essay can prevent these situations from occurring.

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.

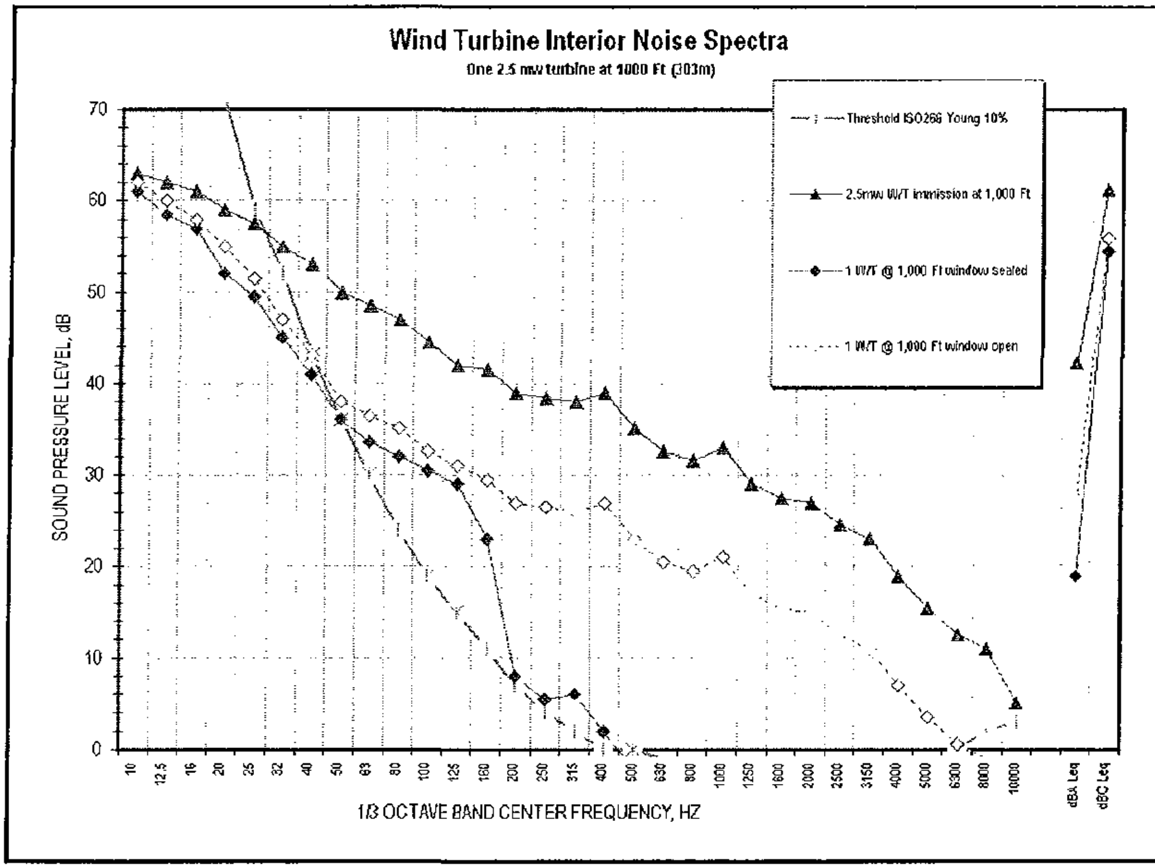

Figure 3-A Single Wind Turbine Sound Inside Home @ 1000 Feet

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 Figure 1 showing the effect of a single turbine (propagation model based on sound power level test data) at 1000 feet and then in Figure 4 projected the impact of 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 and one mile as the upper graph line respectively. 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 threshold curve the sounds will be perceptible to at least 10% of the population (which includes most children).

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[15]. One curve represents the condition of no open windows and the other represents one open window.

With just one turbine at 1,000 feet there is a significant amount of low frequency noise above hearing threshold within rooms having exterior walls without windows or very well sealed windows. Even with the windows closed the sound pressure levels in the 63 Hz to 200 Hz one-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 inside homes whenever the turbines are operating.

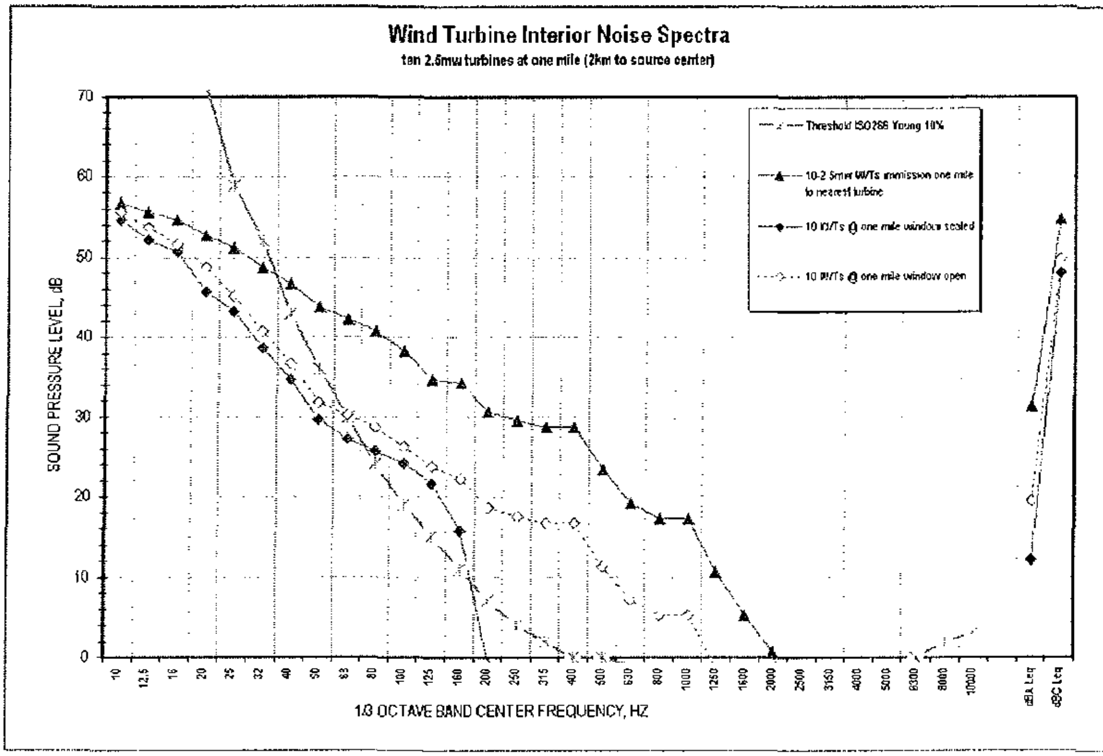

Figure 4-Sound from Ten (10) Wind Turbines inside home at One Mile

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[16,17,18]. If we looked only at dBA it would appear that the home's

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[15] 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.

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

[17] "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

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 (1-1/4 miles) from the receiver. These results are presented in Figure 4. 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.

There is one other characteristic of wind turbine sound that increases the sleep disturbance potential above that of other long-term noise sources. The amplitude modulation of the sound emissions from the wind turbines create a repetitive rise and fall in sound levels synchronized to the blade rotation speed. Many common weather conditions increase the magnitude of amplitude modulation. Most of these occur at night. The graph in Figure 5 shows this effect in the first floor bedroom of a farm home in the U.K. The home is located 930 meters (3,050 feet) from the nearest turbine. The conditions documented by an independent acoustical consultant show the sound level varying over 9 dBA range from 28 to 37 dBA. The pattern repeats approximately every second often for hours at a time. For many people, especially seniors, children and those with pre-existing medical conditions, this represents a major challenge to restful sleep.

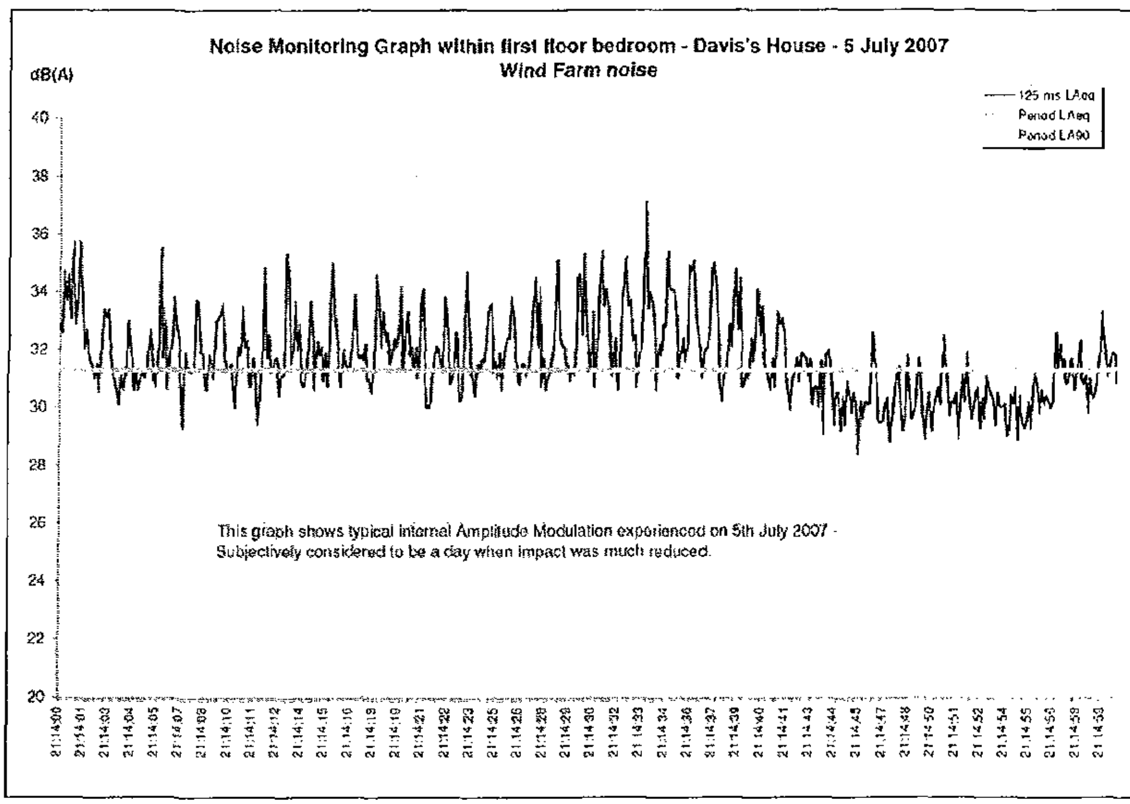

Figure 5- Amplitude modulation in a home 930 meters (3000 feet) from the nearest turbine.[19]

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

[18] 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

[19] This chart used with permission of Mike Stigwood, MIOA, FRSH, MAS Environmental, U.K. and the Davis family.

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[20].

III. Development of Siting Criteria

Basis For Using L_{A90} 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 WT sound emissions. A recent compendium of these standards was presented in the report "Wind Turbine Facilities Noise Issues."[21] 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 was 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. The focus is 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.[22] 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 soundscape, or it may be more complex. In either case, it is a legitimate response to wind turbine sound documented in peer-reviewed research.

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[20] Hessler Jr., George F., "Proposed criteria in residential communities for low-frequency noise emissions from industrial sources," 52(4), 179-185, (July-Aug 2004)

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

[22] 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 Report Project no. 044628, University of Gothenburg and Medical Center Groningen, Netherlands June 3, 2008

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 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 generally accepted 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 allowing the wind turbine development to increase this by 5 dB (e.g. L_{90A} +5) by the audible sounds from wind turbines. According to the New York State Energy Research & Development Authority:

- "… A change in sound level of 5 dB will typically result in a noticeable community response; and
- "… A 10 dB increase is subjectively heard as an approximate doubling in loudness, and almost always causes an adverse community response." [23]

To address the lower frequencies that are not considered in A-weighted measurements we are proposing to add limits based on dBC that follow the same scheme as used for dBA limits. 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 may result in an increased distance between wind turbines and the nearby

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[23] (*Wind Energy Development: A Guide for Local Authorities in New York*; page 30; New York State Energy Research & Development Authority, Albany, NY October 2002)

residents. For the conditions shown in Figure 1, the distances would need to be increased significantly. This would 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 with little or no low frequency sound from man-made noise sources and where the L_{A90} 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 smaller 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 a not-to-exceed immission limit of 35 L_{Aeq} and a site-specific limit of L_{A90} + 5 dBA at the closest property line, whichever is exceeded first. We also propose the use of C-weighted criteria to address complaints of wind turbine low frequency noise. For the C-weighted criteria, we propose a site-specific limit of L_{C90} + 5 dBC. We also require that the site-specific L_{Ceq} (dBC) sound level at a receiving property line not exceed the pre-existing L_{A90} dB background sound level + 5dB by more than 20 dB. In other words, the dBC operating immission limit (as L_{Ceq}) at the receiving property line should not be more than 20 dB above the measured dBA (as L_{A90}) pre-construction long-term background sound level + 5dB.[24] This criterion prevents an Immission Spectra Imbalance that often leads to complaints about rumble or other low frequency problems. We also include a not-to-exceed immission limit of 55 and 60 L_{Ceq} at the receiving property line.[25] Use of the multiple metrics and weightings will address the audible and inaudible low frequency portions of wind turbine sound emissions. Exceedances of any of the limits establish non-compliance.

Why should the dBC immission limit not be permitted to be more than 20 dB above the background measured L_{A90}+5 dB? The World Health Organization and others[26] 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_{A90} the <u>minimum</u> background noise level? Not exactly. This is the sound level that represents the quietest 10% of the time. It is often considered to be the sound level that represents the sounds one hears late in the evening or at night when there are no near-by or short term sounds present. It is very important to establish this "long term background" noise environment at the property line for a potentially impacted residence (L_{A90}) during the **quietest** sleeping hours of the night, between 10 p.m. and 4 a.m.. Why? Because nighttime sleep disturbance has generated the majority of wind farm noise complaints throughout the world those conditions should guide the design of wind projects. 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 using ten (10) minute long samples. This means that nature sounds not present during all seasons and wind noise are not to be included in the measurement. Following the procedures in ANSI S12.9, Part 3 for long term background sound the L_{A90} and L_{C90} can be measured with one or more 10-minute

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[24] Hessler Jr., George F., Proposed criteria in residential communities for low-frequency noise emissions from industrial sources, Noise Control Engineering Journal; 52(4), pg. 180 in "2. Purpose of Proposed Criteria," (July-Aug 2004)
[25] Ibid, pg. 180 in "3. Proposed Criteria."

[26] Ibid

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 ten (10) minute nighttime L_{A90} and L_{C90} plus 5 dB, a test for Spectra Imbalance, and not-to-exceed limits for the period of 10 p.m. to 7 a.m. Daytime Limits (7 a.m. to 10 p.m.) could be set using daytime measurements, but unless the wind utility only operates during the day, the nighttime limit will always be the limiting sound level. Thus, daytime limits are not normally needed.

A nearby industrial scale wind utility meeting these noise immission criteria would occasionally be audible to the residents during nighttime and daytime. However, it would be unlikely for it to be an indoor problem.

The method used for establishing the background sound level at a proposed wind farm in many of the studies in Table 1, does not meet the requirements set by ANSI S12.9 Part 3 for outdoor measurements and determination of long-term background sound levels. Instead, they use unattended noise monitors to record hundreds of 10-minute or one-hour un-observed measurements that include the short term sounds from varying community and wind conditions over a period of days or weeks. The results for daytime and nighttime are usually combined to determine the average wind noise at the microphone 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 wind turbine sound immissions or to potential for turbine noise impacts on nearby residents. They also do not comply with ANSI standards for methodology or 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 'pseudo-noise' is generated by instruments located in a windy environment that exceeds the capability of the instrument's wind screen to protect the microphone. In many cases, this unqualified data is used to support a claim that the wind noise masks the turbines' sound immissions.

The major complaints of residents living near wind farms is sleep disruption at night when there is little or no wind near ground level and the wind turbines located at a much higher elevation are turning and generating near or at maximum power and maximum noise emission. There is usually more surface wind and turbulence during daytime caused by solar radiation. Thus, the use of averaged data involving one or more 24-hour periods is of little value in predicting conditions that will result in people who cannot sleep in their homes during the night because of loud intrusive wind turbine noise.

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. This should be expected given the limitations of models based on ISO 9613-2[27]. They also do not consider the effects of a frequent nighttime condition when winds at the ground are calm and the winds at the hub are at or above nominal operating speed. This condition is often referred to as a "stable" atmosphere. During this condition, the wind turbines can be producing the maximum or near maximum power while the wind at ground level is calm and the background noise level is low. The Michigan rural night test data in the earlier figure shows how quiet a night can be in the absence of wind at the ground. This common condition is known to directly cause chronic sleep

[27] The ISO 9613-2 sound propagation model formulas have known errors of 3 dB even when the conditions being modeled are a perfect match to the limiting conditions specified in the standard. Wind turbines operate far outside the limits for wind speed, height of the noise source above the ground, and other factors identified in the standard thus increasing the likelihood for error above the specified 3 dB. In addition, there are known measurement errors in the IEC61400-11 test that add another 2 dB of uncertainty to the model's predictions.

disruption. Further, the studies report average sound levels and do not disclose the effects of amplitude modulation or low frequency sound which makes the turbine's sound more objectionable and likely to cause sleep problems.

Are there additional noise data to be recorded for a pre-wind turbine noise survey near selected dwellings? Yes. The precision measuring sound level meter(s) need to be programmed to include measurement of L_{Aeq}, L_{A10}, L_{A90}, L_{Ceq}, L_{C10}, and L_{C90}, with starting time and date for each 10-minute sample. The L_{10} results will be used to validate the L_{90} data. For example, on a quiet night one might expect L_{10} and L_{90} to show similar results within 5 to 10 dB between L_{10} and L_{90} for each weighting scale. On a windy night or one with nearby short term noise sources the difference between L_{10} and L_{90} may be more than 20 dB. There is also often a need to obtain a time-averaged, one-third octave band analysis over the frequency range from 6.3 Hz to 10 kHz during the same ten minute sample. The frequency analysis is very helpful for identifying and correcting for extraneous sounds such as interfering insect noise. An integrating averaging sound level meter meeting ANSI or IEC Type 1 standards has the capability to perform all of the above acoustic measurements simultaneously and store the results internally. There is also 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 must be less than 2 m/s (4.5 mph) during measurements of background noise (L_{90}), and the maximum wind speed for noise measurements during turbine operation must be less than 4 m/s (9 mph). Measurements should be observed (without contaminating the data) and notes identifying short-term noises should be taken 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 wind turbine noise. However, this is not true if the surface winds are calm. After sunset, when the ground cools (e.g. in the middle of the night), the lower level atmosphere can separate from the higher-level atmosphere. Then, the winds at the ground will be calm while wind at the turbine hub is very strong. Under this condition, the wind velocity at a 10-meter high wind monitoring station (such as those often used for weather reporting) may be ¼ to ½ the speed of the wind at the hub, yet drop to calm at ground level. The result is that no ground level wind noise is present to mask the sound of the wind turbines, which can be operating at or close to full capacity.

This condition is one of the major causes of wind turbine related noise complaints for residents within 3 km (1.86 miles) of a wind farm. When the turbines are producing high sound levels, it is quiet 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.[28]"

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 (L_{90}) 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 operating must be corrected using 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.

The following summarizes the criteria necessary when siting wind turbines to minimize the risk of adverse impacts from noise on the adjacent community[29]. For those not familiar with acoustical annotation the table and its formulas may seem overly complex, but the criteria are defined in this manner to be as unambiguous as possible. They will be clear for those who are familiar with acoustical terminology. Definitions are provided in a later section of this essay.

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

[29] 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.

NOISE CRITERIA FOR SITING WIND TURBINES TO PREVENT HEALTH RISKS[29]

1. Establishing Long-Term Background Noise Level

a. Instrumentation: ANSI or IEC Type 1 Precision Integrating Sound Level Meter plus meteorological instruments to measure wind velocity, temperature and humidity near the sound measuring microphone. Measurement procedures must meet ANSI S12.9, Part 3 except as noted in Section 4. below.

b. Measurement location(s): Nearest property line(s) from proposed wind turbines representative of all non-participating residential property within 2.0 miles.

c. Time of measurements and prevailing weather: The atmosphere must be classified as stable with no vertical heat flow to cause air mixing. Stable conditions occur in the evening and middle of the night with a clear sky and very little wind near the surface. Sound measurements are only valid when the measured wind speed at the microphone is less than 2 m/s (4.5 mph).

d. Long-Term Background sound measurements: All data recording shall be a series of contiguous ten (10) minute measurements. The measurement objective is to determine the quietest ten minute period at each location of interest. Nighttime test periods are preferred unless daytime conditions are quieter. The following data shall be recorded simultaneously for each ten (10) minute measurement period: dBA data includes L_{A90}, L_{A10}, L_{Aeq} and dBC data includes L_{C90}, L_{C10}, and L_{Ceq}. Record the maximum wind speed at the microphone during the ten minutes, a single measurement of temperature and humidity at the microphone for each new location or each hour whichever is oftener shall also be recorded. A ten (10) minute measurement contains valid data provided: Both L_{A10} minus L_{A90} and L_{C10} minus L_{C90} are not greater than 10 dB and the maximum wind speed at the microphone is less than 2 m/s during the same ten (10) minute period as the acoustic data.

2. Wind Turbine Sound Immission Limits

No wind turbine or group of turbines shall be located so as to cause wind turbine sound immission at any location on non-participating property containing a residence in excess of the limits in the following table:

Table of Not-To-Exceed Property Line Sound Immission Limits [1]			
Criteria	**Condition**	**dBA**	**dBC**
A	Immission above pre-construction background:	L_{Aeq} = L_{A90} + 5	L_{Ceq} = L_{C90} +5
B	Maximum immission:	35 L_{Aeq}	55 L_{Ceq} for quiet[2] rural environment 60 L_{Ceq} for rural-suburban environment
C	Immission spectra imbalance	L_{Ceq} (immission) minus (L_{A90} (background) +5) $\leq$ 20 dB	
D	Prominent tone penalty:	5 dB	5 dB
Notes			
1	Each Test is independent and exceedances of any test establishes non-compliance. Sound "immission" is the wind turbine noise emission as received at a property.		
2	A "Quiet rural environment" is a location >2 miles from a major transportation artery without high traffic volume during otherwise quiet periods of the day or night.		
3	Prominent tone as defined in IEC 61400-11. This Standard is not to be used for any other purpose.		

[1] Procedures provided in Section 7. Measurement Procedures (ANSI 12.9 Part 3 with Amendments) of the most recent version of **"The How To Guide To Siting Wind Turbines To Prevent Health Risks From Sound"** by Kamperman and James and the apply to this table.

3. Wind Farm Noise Compliance Testing

All of the measurements outlined above in 1. Establishing Nighttime Background Noise Level must be repeated to determine compliance with 2. Wind Turbine Sound Immission Limits. The compliance test location is to be the pre-turbine background noise measurement location nearest to the home of the complainant in line with the wind farm and nearer to the wind farm. The time of day for the testing and the wind farm operating conditions plus wind speed and direction must replicate the conditions that generated the complaint. Procedures of ANSI S12.9- Part 3 apply except as noted in Section 4. The effect of instrumentation limits for wind and other factors must be recognized and followed.

4. ANSI S12.9 Part 3 Selected Options and Requirement Amendments

For measurements taken to assess the preceding criteria specific options provided for in ANSI S12.9-Part 3 (2008) shall be followed along with any additional requirements included below:

- 5.2 Background Sound: Use definition (1): 'long-term'
- 5.2 long-term background sound: The L_{90} excludes short term background sounds
- 5.3 basic measurement period: Ten (10) minutes $L_{90(10\,min)}$
- 5.6 Sound Measuring Instrument: Type 1 Precision meeting ANSI S1.43 or IEC 61672-1. The sound level meter shall cover the frequency range from 6.3 Hz to 20k Hz and 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 to full-scale accuracy. The anemometer shall be located 1.5 to 2 meters above the ground and orientated to record maximum wind velocity. The maximum wind velocity, wind direction, temperature and humidity shall be recorded for each ten (10) minute sound measurement period observed within 5 m. of the measuring microphone.
- 7.1 Long-term background sound
- 7.2 Data collection Methods: Second method with 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 some complaint tests. 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 without exceeding instrument and windscreen limits and tolerances.
- 8.1(b) Measuring microphone with windscreen shall be located 1.2m to 1.8m (1.5 preferred) above the ground and greater than 8 m. from large sound reflecting surface.
- 8.3(a) All meteorological observations required at both (not either) microphone and nearest 10 m. weather reporting station.
- 8.3(b) For a ten (10) minute background sound measurement to be valid the wind velocity shall be less then 2m/s (4.5 mph) measured less than 5 m. from the microphone. Compliance sound measurements shall be taken when winds are less than 4m/s at the microphone.
- 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. The calibrator-covered microphone must demonstrate the results of this test are at least 5 dB below the immediately previous ten (10) 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.

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 the following sections 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 sound 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 part of the ambient sound environment but are <u>not to be considered part of the long-term background sound.</u>

"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_{Aeq} 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 the WES of interest, near-by birds and animals or people must be excluded from the background sound test data. Nearby electrical noise from streetlights, 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 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 $L_{A\,90}$ and $L_{C\,90}$ descriptors. It may be considered as the quietest one (1) minute during a ten (10) minute test. $L_{A\,90}$ results are valid only when $L_{A\,10}$ results are no more than 10 dB above $L_{A\,90}$ for the same period. $L_{C\,10}$ less $L_{C\,90}$ are not to exceed 10 dB 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. For example, to meet the requirement of L_{90A} + 5 dB = 31 dBA if the existing quiet nighttime background sound level is 26 dBA, the maximum wind turbine noise immission contribution independent of the background cannot exceed 29.3 dBA L_{eq} at a dwelling. When adding decibels, a 26 dBA background combined with 29.3 dBA from the turbines (without background) results in 31 dBA.

Further, background L_{90} sound levels documenting the pre-construction baseline conditions should be determined when the ten (10) minute maximum wind speed is less than 2 m/s (4.5 mph) near ground level/microphone location 1.5 m height.

"**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_{Ceq} 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 at a receiver (dwelling) is transmitted from noise source (wind turbine) that emitted sound energy (see "emission").

"Immission spectra imbalance" The spectra are not in balance when the C-weighted sound level is *more than 20 dB greater than the A-weighted sound level. For the purposes of this requirement,* the A-weighted sound level is defined as the long-term background sound level (L_{A90}) +5 dBA. The C-weighted sound level is defined as the L_{Ceq} measured during the operation of the wind turbine operated so as to result in its highest sound output. A Complaint test provided later in this document is based on the immission spectra imbalance criteria.

"Infra-Sound" sound with energy in the frequency range of 0-20 Hz is considered to be infra-sound. It is normally considered to not be audible for most people unless in relatively high amplitude. However, there is a wide range between the most sensitive and least sensitive people to perception of sound and perception is not limited to stimulus of the auditory senses. 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, the test for immission spectra imbalance will limit low frequency sound and thus, indirectly limit infrasound. See low-frequency noise (LFN) for more information.

"Low Frequency Noise (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. The criteria for this condition is the "Immission Spectra Imbalance" entry in the **Table of Not-To-Exceed Property Line Sound Immission Limits.**"

"**Measurement Point (MP)**" means location where sound 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 Points should be at quiet locations remote from street lights, transformers, street traffic, flowing water and other local noise sources.

"**Measurement Wind Speed**" For measurements conducted to establish the background noise levels ($L_{A90\ 10\ min}$, $L_{C90\ 10\ min}$, and etc.) the maximum wind speed, sampled within 5m of the microphone and at its height, shall be less than 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 maximum wind speed, sampled within 5m of the microphone and at its height, shall be less than 4m/s (9 mph). The wind speed at the WES blade height shall be at or above the nominal rated wind speed and operating in its highest sound output mode. 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 maximum wind speeds at the microphone to less than 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 L_{Aeq} and L_{Ceq} sound levels at the nearest non-participating properties to the WES. If there may be more than one set of nearby sensitive receptors, models for each such condition shall be evaluated and the results 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. It is represented on a plot plan view by a continuous line encompassing all WES(s) and related equipment associated with the WES project.

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

"**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). There are scientists and engineers in other professional fields that have been called upon by their local community for help in the development of a WES Noise Ordinance. Many of these scientists and engineers have recently spent hundreds of hours learning many important aspects of noise related to the introduction of WES into their communities. Then with field measurement experience with background data and wind turbine noise emission, they have become qualified independent acoustical consultants for WES siting. 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.

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"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. There is known measurement error in this test procedure that must be disclosed and accounted for in the computer models. Even with the measurement error correction it cannot be assumed that the reported L_w values represent the highest sound output for all operating conditions. 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 (at present) 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 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 but C-weighted values are preferred. This information is used to construct a model of the wind farm's sound immission levels at locations of interest in and around the WES. The frequency range of interest for wind turbine noise is approximately 6 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_{A10} and L_{C10} the noise level exceed for 10% of the ten (10) minute interval. This is commonly referred to as the average maximum noise level. L_{A90} and L_{C90} are the A-weighted and C-weighted sound levels exceeded for 90% of the ten (10) minute sample period. The L_{90} noise level is defined by ANSI as the long-term background sound level (i.e. the sounds one hears in the absence of the noise source under consideration and without short term or near-by sounds from other sources), or simply the "background level." L_{eq} is the A or C-weighted equivalent noise level (the "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 or tonality**" Tonal audibility. 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 electrical energy.

"**Wind Turbine" or "Turbine" (WT)** means an industrial scale 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 all turbines potentially used in this project,
- Sound Power Levels (L_w) for each 1/3 octave band from 6.3 Hz to 10,000 Hz, and
- A sound propagation model predicting the sound levels immitted into the community computed using at minimum 1/1 octave band sound power levels to compute the L_{Ceq} and L_{Aeq} levels to generate L_{Aeq} and L_{Ceq} contours in 5 dB increments overlaying an aerial view and property survey map from the WES property out to a distance to include all residential property within two (2) miles of the WES Property. Appropriate corrections for model algorithm error, IEC61400-11 test measurement accuracy, and directivity patterns of for each model of WT shall be disclosed and accounted for in the model(s). Predictions shall be made at all property lines within and outward for two (2) miles from the project boundary for the wind speed, direction and operating mode that would result in the worst case WT nighttime sound emissions.

The prediction model shall assume that the winds at hub height are sufficient for the highest sound emission operating mode. The projection 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 all these items should be identified and all other means used to adjust the model's output to account for these factors. The results shall be displayed as a contour map of the predicted levels as over-all L_{Aeq} and L_{Ceq} contours out to 2 miles from the WES property, and shall also include a table showing the 1/3 or 1/1 octave band sound pressure as L_{Ceq} levels for the nearest property line(s) for sensitive receptor sites (including residences) within the model's boundaries. The predicted values must include the over-all sound levels and 1/1 or 1/3 octave band sound pressure levels from 6 Hz to 10k Hz in data tables that include the location of each receiving point by GPS location or other repeatable means.

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 in the section on Measurement Procedures showing long-term background L_{A90} and L_{C90} sound levels. This must be completed and accepted prior to approval of the final layout and issuance of project permits.

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

   b. 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 L_{Aeq} and L_{Ceq} sound levels exceed any of the criteria specified in the **Table of Not-To-Exceed Property Line Sound Immission Limits** 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 of the long-term background sound levels against the predicted L_{Aeq} and L_{Ceq} sound levels reported for the model using the criteria in the **Table of Not-To-Exceed Property Line Sound Immission Limits**. The reasonably necessary costs associated with such a review 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 using the procedures specified in this ordinance. 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 WT units.

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_{A90} and L_{C90}) 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} and L_{90C} conditions have increased less than 3 dB from those measured under the pre-

construction nighttime 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 and hired 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 may ask to have its own consultant observe the publicly retained consultant at the convenience of the latter. The WES Licensee shall provide all technical information and wind farm data required by the qualified independent acoustical consultant before, during, and/or after any acoustical studies required by this document and for acoustical measurements.

3. Sound Limits

1. Establishing Long-Term Background Sound Level

a. Instrumentation: ANSI or IEC Type 1 Precision Integrating Sound Level Meter plus meteorological instruments to measure wind velocity, temperature and humidity near the sound measuring microphone. Measurement procedures must meet ANSI S12.9, Part 3 and Measurement Procedures Appendix to Ordinance following next Section.

b. Measurement location(s): Nearest property line(s) from proposed wind turbines representative of all non-participating residential property within 2.0 miles.
c. Time of measurements and prevailing weather: The atmosphere must be classified as stable with no vertical heat flow to cause air mixing. Stable conditions occur in the evening and middle of the night with a clear sky and very little wind near the surface. Sound measurements are only valid when the measured maximum wind speed at the microphone must be less than 2 m/s (4.5 mph).
d. Long-Term Background sound measurements: All data recording shall be a series of contiguous ten (10) minute measurements. The measurement objective is to determine the quietest ten minute period at each location of interest. Nighttime test periods are preferred unless daytime conditions are quieter. The following data shall be recorded simultaneously for each ten (10) minute measurement period: dBA data includes L_{A90}, L_{A10}, L_{Aeq} and dBC data includes L_{C90}, L_{C10}, and L_{Ceq}. The maximum wind speed at the microphone during the ten minutes, a single measurement of temperature and humidity at the microphone for each new location or each hour whichever is oftener shall also be recorded. A ten (10) minute measurement contains valid data provided: Both L_{A10} minus L_{A90} and L_{C10} minus L_{C90} are not greater than 10 dB and the maximum wind speed at the microphone is less than 2 m/s during the same ten (10) minute period as the acoustic data.

2. Wind Turbine Sound Immission Limits

No wind turbine or group of turbines shall be located so as to cause wind turbine sound immission at any location on non-participating property containing a residence in excess of the limits in the following table:

Table of Not-To-Exceed Property Line Sound Immission Limits [1]			
Criteria	**Condition**	**dBA**	**dBC**
A	Immission above pre-construction background:	$L_{Aeq} = L_{A90} + 5$	$L_{Ceq} = L_{C90} + 5$
B	Maximum immission:	35 L_{Aeq}	55 L_{Ceq} for quiet[2] rural environment 60 L_{Ceq} for rural-suburban environment
C	Immission spectra imbalance (C - A $\leq$ 20dB)	L_{Ceq} (immission) minus (L_{A90} (background) +5 dB) $\leq$ 20 dB	
D	Prominent tone penalty:	5 dB	5 dB
Notes			
1	Each Test is independent and exceedances of any test establishes non-compliance Sound "immission" is the wind turbine sound emission as received at a property.		
2	A "quiet rural environment" is a location 2 miles from a major transportation artery without high traffic volume during otherwise quiet periods of the day or night.		
3	Prominent tone as defined in IEC 61400-11. This Standard is not to be used for any other purpose.		
[1] Required Procedures provided in VIII Reference Standards including ANSI 12.9 Part 3 as Amended			

3. Wind Farm Noise Compliance Testing

All of the measurements outlined above in 1. Establishing Long Term Background Noise Level must be repeated to determine compliance with 2. Wind Turbine Sound Immission Limits. The compliance test location is to be the pre-turbine background noise measurement location nearest to the home of the complainant in line with the wind farm and nearer to the wind farm. The time of day for the testing and the wind farm operating conditions plus wind speed and direction must replicate the conditions that generated the complaint. Procedures of ANSI S12.9- Part 3 apply as amended in the Appendix to Ordinance. The effect of instrumentation limits for wind and other factors must be recognized and followed.

3. Operations

The WES/WT is non-compliant and must be shut down immediately if it exceeds any of the limits in the **Table of Not-To-Exceed Property Line Sound Immission Limits.**

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 independent 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.

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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 nighttime 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 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

SUPPLEMENT 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 L_{Aeq} and L_{Ceq} and 1/3 or 1/1 octave bands as part of the required information submitted with the application.

The over-all values shall be presented as overlays to the applicant's iso-level plot plan graphics and, for 1/1 or 1/3 octave data, 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 covers requirements for the sound propagation model to be supplied with the application.

Finally, if the project is approved, this section 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.

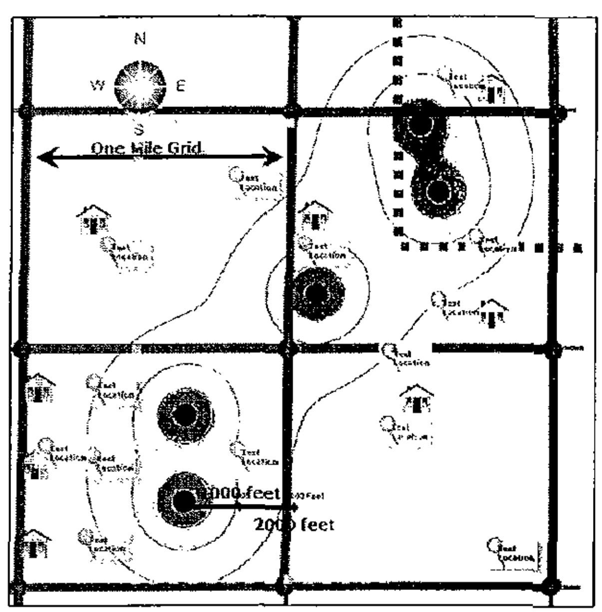
The characteristics of the proposed WES project and the features of the surrounding environment will influence the design of the sound and vibration study. Site layout, types of WES(s) selected and the existence of other significant local audible and low frequency sound sources and sensitive receptors should be taken into consideration when designing a sound study. The work will be performed by a qualified independent 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-line)

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 section. 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 L_{Aeq} and L_{Ceq} sound emissions of the proposed WES project will be overlaid on a map (or separate L_{Aeq} and L_{Ceq} 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 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 two (2) miles beyond the perimeter of the project boundary. This may be extended to more than two (2) miles 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 WT in the project. Usually, this will be the closest WT. If there is more than one WT 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 most likely be 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 1/3 octave band sound pressure levels if required) 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 (10) continuous minutes for all criteria 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_{A90} and L_{C90} values. The ten (10) 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 shall be made on a weekday of a non-holiday week. Weekend measurements may also be taken at selected sites where there are weekend activities that may be affected by WT sound.

Measurements must be taken with the microphone 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 qualified measurement period, provide each of the following measurements:

   a. L_{Aeq}, L_{A10}, and L_{A90}, and

   b. L_{Ceq} , L_{C10}, and L_{C90}

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 microphone (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 only when wind speeds are less than 2m/s (4.5 mph) at the microphone location will 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 distance between any Measurement Points and the nearest WT(s).
- 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 sound tests as specified elsewhere in this ordinance.

2. One set of measurements with the wind generator(s) running with wind speed at hub height sufficient to meet nominal rated power output or higher and less than 2 m/s 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 (less than 2m/sec) at the ground surface yet, at hub height, sufficient to power 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 WT 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 as required elsewhere in this ordinance for models.

Provide the manufacturer's sound power level (L_{Aw}) and (L_{Cw}) 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 sound power level information from 6.3 Hz to 10k Hz. Furnish the data using no frequency weighting. A-weighted data is optional. 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 L_{Aeq} levels of 30 dBA and above. The same area shall be used for reporting the predicted L_{Ceq} levels. Contour lines shall be in increments of 5 dB.

Present tables with the predicted sound levels for the proposed WES(s) as L_{Aeq} and L_{Ceq} 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 (L_{eq}) 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 (or likely to be tested) in the background study.

Provide a contour map of the expected sound level from the new WES(s), using 5dB L_{Aeq} and L_{Ceq} increments created by the proposed WES(s) extending out to a distance of two (2) miles from the project boundary, or other distance necessary, to show the 25 L_{Aeq} and 50 L_{Ceq} boundaries.

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} and L_{A90}
2. Report expected changes to existing sound levels for L_{Ceq} and L_{C90}
3. Report the expected changes to existing sound pressure levels for each of the 1/1 or 1/3 octave bands 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, preferably within two weeks of the anniversary date of the pre-construction background sound measurements, repeat the measurements. Post-construction sound level measurements shall be taken both with all WES(s) running and with all WES(s) off except as provided in this ordinance.

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

VIII. REFERENCE Standards and ANSI S12.9 Part 3 with Required Amendments

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 Selected Options and Requirement Amendments

For the purposes of this ordinance specific options 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'
5.2 long-term background sound: The L_{90} excludes short term background sounds
5.3 basic measurement period: Ten (10) minutes $L_{90(10\ min)}$
5.6 Sound Measuring Instrument: Type 1 Integrating Meter meeting ANSI S1.43 or IEC 61672-1. The sound level meter shall cover the frequency range from 6.3 Hz to 20k Hz and 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. to full scale accuracy. The anemometer shall be located 1.5 to 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 ten (10) minute sound measurement period observed within 5 m. of the measuring microphone..
7.1 Long-term background sound
7.2 Data collection Methods: Second method with 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

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meteorological requirements in ANSI S12.18 may not be applicable for some complaints. 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 without exceeding instrument and windscreen limits and tolerances.

8.1(b) *Measuring microphone with windscreen shall be located 1.2m to 1.8m (1.5m preferred)* 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 be less then 2m/s (4.5 mph) measured less than 5m from the microphone. Compliance sound measurements shall be taken when winds shall be less than 4m/s at the microphone.

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

NASA Technical Paper 3057
DOE/NASA/ 20320-77

1990

Wind Turbine Acoustics

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UNU Exh. 33

The text of this report is planned to appear as a chapter in a forthcoming book entitled *Wind Turbine Technology*. This is a joint project of the U.S. Department of Energy and the American Society of Mechanical Engineers, in which the NASA Lewis Research Center is responsible for technical editing and management. Production of the final text is under the sponsorship and direction of DOE's Solar Technical Information Programs Office. Book publication will be by the ASME.

Wind Turbine Acoustics

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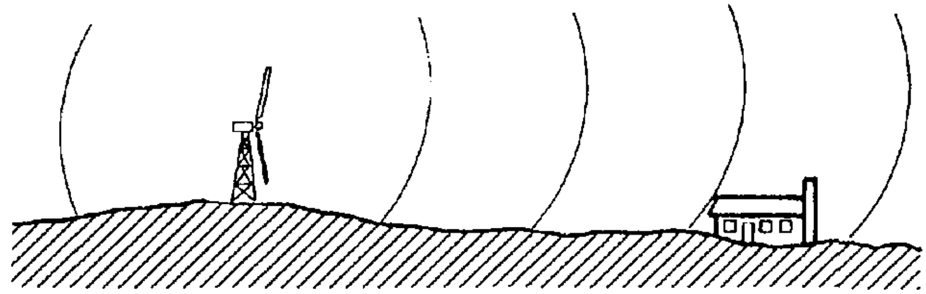
Introduction

Wind turbine generators, ranging in size from a few kilowatts to several megawatts, are producing electricity both singly and in wind power stations that encompass hundreds of machines. Many installations are in uninhabited areas far from established residences, and therefore there are no apparent environmental impacts in terms of noise. There is, however, the potential for situations in which the radiated noise can be heard by residents of adjacent neighborhoods, particularly those neighborhoods with low ambient noise levels. A widely publicized incident of this nature occurred with the operation of the experimental MOD-1 2-MW wind turbine (described in detail in Kelley *et al.* [1985]). Significant factors relevant to the potential environmental impact of wind turbine noise are listed in Figure 7-1.



Noise sources	Propagation paths	Receivers
• Aerodynamic	• Distance	• Ambient noise
• Mechanical	• Wind gradients	• Indoor/outdoor exposure
	• Absorption	• Building vibrations
	• Terrain	

Figure 7-1. Factors contributing to wind turbine noise

The noise produced by wind turbines ranges in frequency from low values that are sometimes inaudible to higher values in the normal audible range [Kelley *et al.* 1985]. Although increased distance is beneficial in reducing noise levels, the wind can enhance noise propagation in certain directions and impede it in others. A unique feature of wind turbine noise is that it can result from essentially continuous periods of daytime and nighttime operation. This is in contrast to the more common aircraft and road traffic noises that vary markedly as a function of time of day.

This chapter summarizes available information on the physical characteristics of the noise generated by wind turbines and includes example sound pressure time histories, narrow-band and broadband frequency spectra, and noise radiation patterns. This chapter also reviews noise measurement standards, analysis technology, and a method for characterizing the noise from wind turbines. Prediction methods are summarized for both the low-frequency rotational harmonics and the broadband noise components caused by inflow turbulence, and also for turbulent boundary layers on the blades and wakes from the blade trailing edge. Also included are atmospheric propagation data that illustrate the effects of distance and the effects of refraction caused by a vertical gradient in mean wind speed for both upwind and downwind directions.

Perception thresholds for humans are defined for both narrow-band and broadband spectra from systematic tests in the laboratory and from observations in the field. Also summarized are structural vibrations and interior sound pressure levels, which could result from the low-frequency noise excitation of buildings.

A bibliography is available that lists technical papers on all aspects of wind turbine acoustics [Hubbard and Shepherd 1988].

Characteristics of Wind Turbine Noise

Noise from wind turbines may be categorized as aerodynamic or mechanical in origin. Aerodynamic noise components are either narrow-band (containing discrete harmonics) or broadband (random) and are related closely to the geometry of the rotor, its blades, and their aerodynamic flow environments. The low-frequency, narrow-band rotational components typically occur at the blade passage frequency (the rotational speed times the number of blades) and integer multiples of this frequency. Of lesser importance for most configurations are mechanical noise components from the operating bearings, gears, and accessories.

boundary-layer interaction also contribute noise over a wide frequency range but are most significant at higher frequencies. On the other hand, the noise spectrum of the trailing edge wake is sharply peaked; the maximum for the example turbine is near 1250 Hz.

Figure 7-17 presents sound pressure levels calculated by using the methods of Grosveld and compares them with acoustic far-field measurements for a large, upwind-rotor HAWT and two different downwind-rotor HAWTs. Good agreement is shown in all cases. Note that the validation of Eqs. 7-3 to 7-7 has been limited to acoustic radiation in the upwind and downwind directions only.

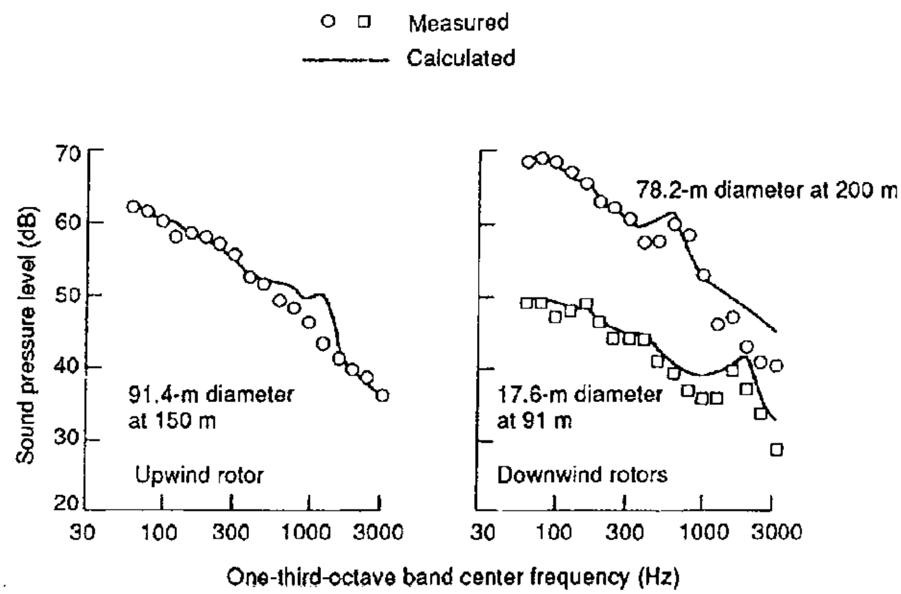


Figure 7-17. Measured and calculated broadband noise spectra downwind of various HAWTs [Grosveld 1985]

An alternative broadband-noise-prediction scheme is proposed in Glegg, Baxter, and Glendinning [1987] and includes unsteady lift noise, unsteady thickness noise, trailing edge noise, and noise from separated flows. Inflow turbulence at the rotor must be specified to predict unsteady lift and thickness noises. Using the turbulence data associated with the atmospheric boundary layer as input yielded poor agreement between calculated and measured noise levels. Thus, Glegg, Baxter, and Glendinning [1987] hypothesized that there was an additional source of turbulence: that each blade ran into the tip vortex shed by the preceding blade. Note that Grosveld [1985] also used atmospheric boundary layer turbulence but found that better agreement with acoutic measurements required an empirical turbulence model. The boundary layer and trailing edge noise formulations of Glegg, Baxter, and Glendinning [1987] and Grosveld [1985] both share the same theoretical background and therefore should give the same results.

Noise Propagation

A knowledge of the manner in which sound propagates through the atmosphere is basic to the process of predicting the noise fields of single and multiple machines. Although much is known about sound propagation in the atmosphere, one of the least understood factors is the effect of the wind. Included here are brief discussions of the effects of distance from various types of sources, the effects of such atmospheric factors as absorption in air and refraction caused by sound speed gradients, and terrain effects.

Distance Effects

Point Sources

When there is a nondirectional point source as well as closely grouped, multiple point sources, spherical spreading may be assumed in the far radiation field. Circular wave fronts propagate in all directions from a point source, and the sound pressure levels decay at the rate of −6 dB per doubling of distance in the absence of atmospheric effects. The latter decay rate is illustrated by the straight line in Figure 7-18. The dashed curves in the figure represent increased decay rates associated with atmospheric absorption at frequencies significant for wind turbine noise.

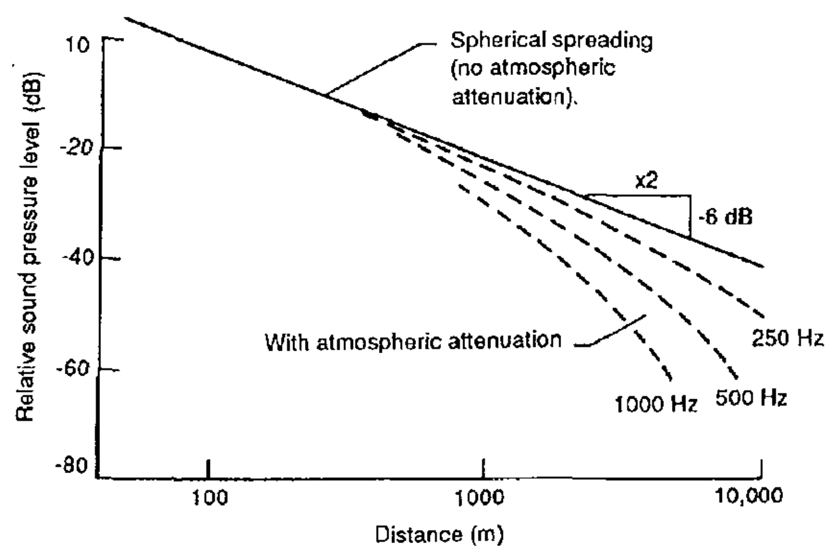


Figure 7-18. Decrease in sound pressure levels of pure tones as a function of distance *from a point source* [ANSI 1978]

Line Sources

For an infinitely long line source, the decay rate is only −3 dB per doubling of distance, compared with the −6 dB per doubling of distance illustrated in Figure 7-18. Such a reduced decay rate is sometimes observed for sources such as trains and lines of vehicles on a busy road. Some arrays of multiple wind turbines in wind power stations may also behave acoustically like line sources.

Atmospheric Factors

Absorption in Air

As sound propagates through the atmosphere, its energy is gradually converted to heat by a number of molecular processes such as shear viscosity, thermal conductivity, and molecular relaxation, and thus atmospheric absorption occurs. The curves in Figure 7-19 were plotted from ANSI values [1978] and show changes in atmospheric absorption as a function of frequency. In these examples, the ambient temperature varied from 0° to 20°C and the relative humidity varied from 30% to 70%. The atmospheric absorption is relatively low at low frequencies, increasing rapidly as a function of frequency. Atmospheric absorption values for other conditions of ambient temperature and relative humidity can be obtained from the ANSI tables; these values follow the general trend shown in Figure 7-19.

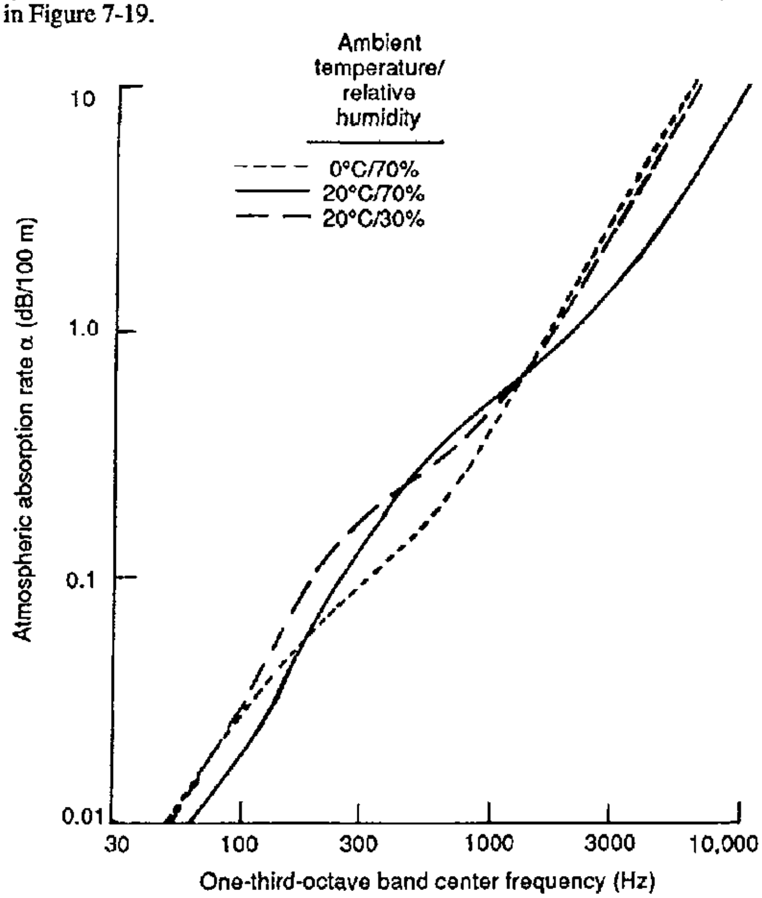


Figure 7-19. Standard rates of atmospheric absorption [ANSI 1978]

Refraction Caused by Wind and Temperature Gradients

Refraction effects arising from the sound speed gradients caused by wind and temperature can cause nonuniform propagation as a function of azimuth angle around a source. Figure 7-20 is a simple illustration of the effects of atmospheric refraction, or bending of

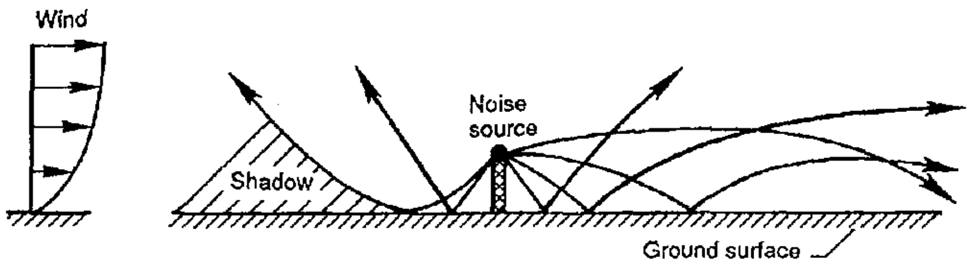


Figure 7-20. Effects of wind-induced refraction on acoustic rays radiating from an elevated point source [Shepherd and Hubbard 1985]

sound rays, caused by a vertical wind-shear gradient over flat, homogeneous terrain for an elevated point source. Note that in the downwind direction the wind gradient causes the sound rays to bend toward the ground, whereas in the upwind direction the rays curve upward away from the ground. For high-frequency acoustic emissions, this causes greatly increased attenuation in a shadow zone upwind of the source, but little effect downwind. The attenuation of low-frequency noise, on the other hand, is reduced by refraction in the downwind direction, with little effect upwind.

The distance from the source to the edge of the shadow zone is related to the wind-speed gradient and the elevation of the source. In a 10- to 15-m/s wind, for a source height from 40 to 120 m above flat, homogeneous terrain, the horizontal distance from the source to the shadow zone was calculated to be approximately five times the height of the source [Shepherd and Hubbard 1985].

Attenuation exceeding that predicted by spherical spreading and atmospheric absorption can be found in the shadow zone. This attenuation is frequency-dependent, and the lowest frequencies are the least attenuated. Figure 7-21 presents an empirical scheme for estimating attenuation in the shadow zone, based on information in Piercy, Embleton, and Sutherland [1977]; SAE [1966]; and Daigle, Embleton, and Piercy [1986]. The estimated

Frequency (Hz)	A_e (dB)
63	6
125	12
250	18
500	24
1000	30

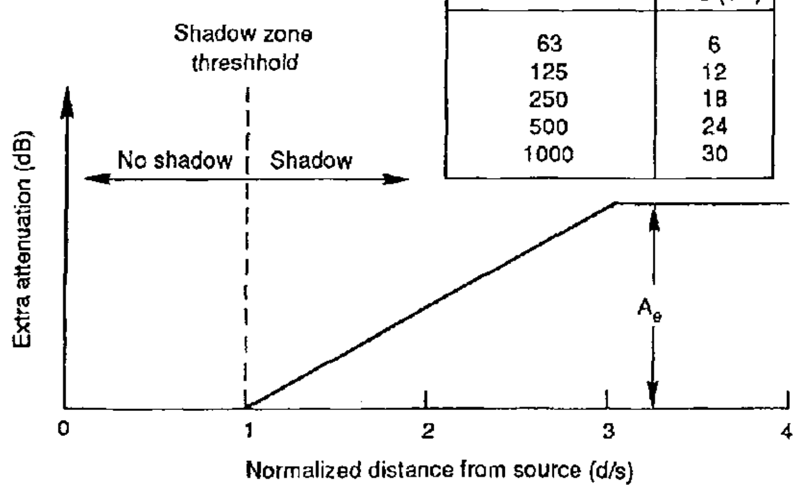


Figure 7-21. Empirical model for estimating the extra attenuation of noise in the shadow zone upwind of an elevated point source ($s = 5h$, $40 \leq h \leq 120$ m, where h = source elevation) [Shepherd and Hubbard 1985]

extra attenuation (A_e in Figure 7-21) is assumed to take place over a distance equal to twice that from the source to the edge of the shadow zone. The predicted decay in the sound pressure level from the source to the edge of the shadow zone is caused by atmospheric absorption [ANSI 1978] and spherical spreading. Within the shadow zone, extra attenuation should be added as estimated according to Figure 7-21.

Note that vertical temperature gradients, which are also effective sound speed gradients, will normally also be present. These will add to or subtract from the effects of wind that are illustrated in Figure 7-21. Effects of wind gradient will generally dominate those of temperature gradients in noise propagation from wind power stations.

Distributed Source Effects

Because of their large rotor diameters, some wind turbines exhibit distributed source effects relatively close to the machines. Only when listeners are at distances from the turbines that are large in relation to the rotor diameter does the rotor behave acoustically as a point source. As indicated in Figure 7-22, distributed source effects are particularly important in the upwind direction. In this figure, sound pressure levels in the 630-Hz, one-third-octave band are presented as a function of distance in the downwind, upwind, and crosswind directions. The measured data agree well with the solid curves, which represent spherical spreading and atmospheric absorption in the downwind and crosswind directions. In the upwind direction, however, the measured data fall below the solid curve; this

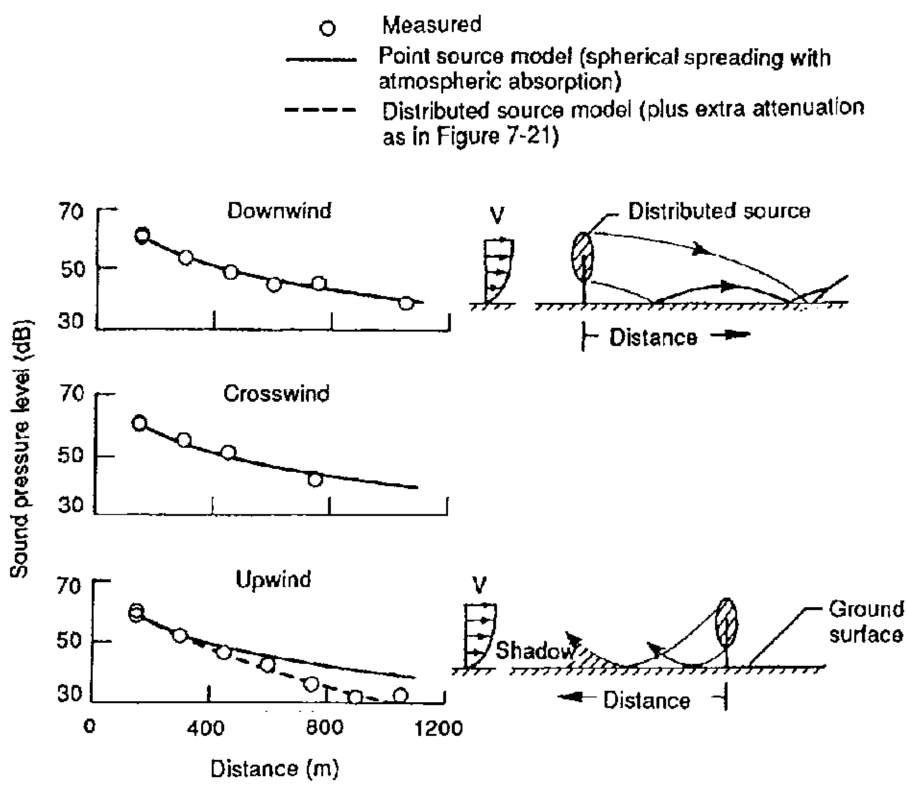


Figure 7-22. Measured and calculated sound pressure levels in three directions from a large-scale HAWT (one-third-octave band = 630 Hz, rotor diameter = 78.2 m) [Shepherd and Hubbard 1985]

indicates the presence of a shadow zone. An improvement in predicting upwind sound pressure levels is obtained when the noise source is modeled as being distributed over the entire rotor disk. Each part of the disk is then considered to be a point source, and attenuation is estimated by means of the empirical model shown in Figure 7-21. The resulting predictions are shown as the dashed curve of Figure 7-22 and are in good agreement with the sound measurements upwind of the turbine. In the downwind and crosswind directions, point-source and distributed-source models result in identical calculations of sound pressure levels.

Channeling Effects at Low Frequencies

Figure 7-23 illustrates the special case of propagation of low-frequency rotational-harmonics when the atmospheric absorption and extra attenuation in the shadow zone are very small. Measured sound pressure levels are shown as a function of distance for both the upwind and downwind directions. For comparison, the curves representing decay rates of −6 dB and −3 dB per doubling of distance are also included. Note that in the upwind case the sound pressure levels tend to follow a decay rate of −6 dB per doubling of distance, which is equal to the rate for spherical spreading. No extra attenuation from a shadow zone was measured.

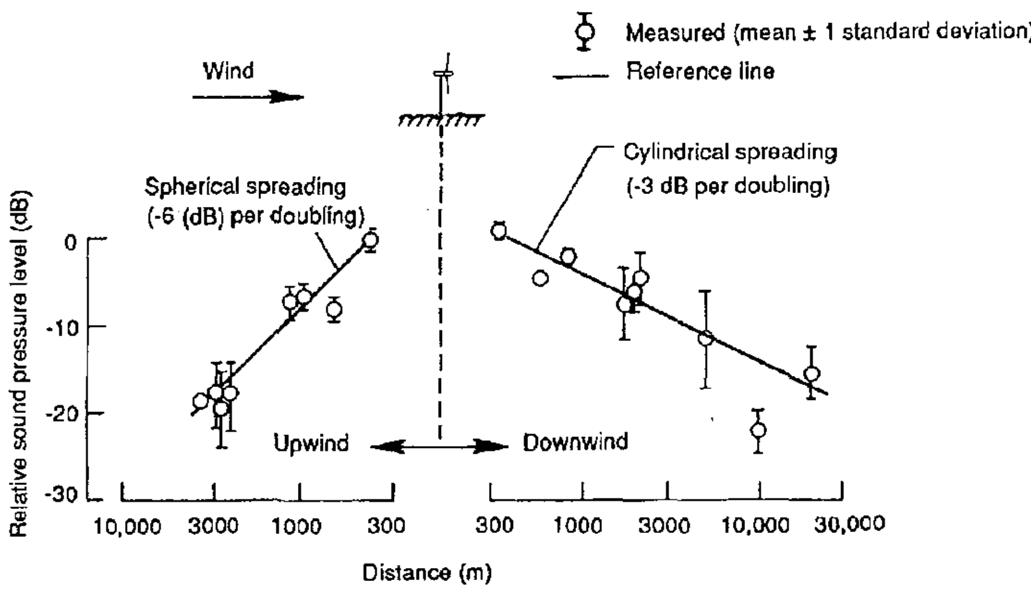


Figure 7-23. Measure effect of wind on the propagation of low-frequency rotational harmonic noise from a large-scale HAWT (harmonics with frequencies from 8 to 16 Hz, rotor diameter = 78.2 m) [Willshire and Zorumski 1987]

In the downwind direction, the sound pressure levels tend to follow a decay rate of −3 dB per doubling of distance, similar to that for cylindrical spreading. This reduced decay rate in the downwind direction at very low frequencies is believed to result from atmospheric refraction, which introduces a channeling sound path in the lower portions of the earth's boundary layer [Willshire and Zorumski 1987; Thomson 1982; Hawkins 1987].

Terrain Effects

Terrain effects include ground absorption, reflection, and diffraction. Furthermore, terrain features may cause complex wind gradients, which can dominate noise propagation to large distances [Kelley *et al.* 1985; Thompson 1982]. Wind turbines are generally located in areas devoid of trees and other large vegetation. Instead, ground cover usually consists of grass, sagebrush, plants, and low shrubs, which are minor impediments to noise propagation except at very high frequencies. At frequencies below about 1000 Hz, the ground attenuation is essentially zero.

Methods are available for calculating the attenuations provided by natural barriers such as rolling terrain, which may interrupt the line of sight between the source and the receiver [Piercy and Embleton 1979]. However, very little definitive information is available regarding the effectiveness of natural barriers in the presence of strong, vertical wind gradients. Piercy and Embleton [1979] postulate that the effectiveness of natural barriers in attenuating noise is not reduced under conditions of upward-curving ray paths (as would apply in the upwind direction) or under normal temperature-lapse conditions. However, under conditions of downward-curving ray paths, as in downwind propagation or during temperature inversions (which are common at night), the barrier attenuations may be reduced significantly, particularly at large distances.

Predicting Noise from Multiple Wind Turbines

Methods are needed to predict noise from wind power stations made up of large numbers of machines, as well as for a variety of configurations and operating conditions. This section reviews the physical factors involved in making such predictions and presents the results of calculations that illustrate the sensitivity of radiated noise to various geometric and propagation parameters. A number of valid, pertinent, simplifying assumptions are presented. A logarithmic wind gradient is assumed, with a wind speed of 9 m/s at hub height. Flat, homogeneous terrain, devoid of large vegetation, is also assumed. Noises from multiple wind turbines are assumed to add together incoherently, that is, in random phase.

Noise Sources and Propagation

Reference Spectrum for a Single Wind Turbine

The most basic information needed to predict noise from a wind power station is the noise output of a single turbine. Its noise spectrum can be predicted from knowledge of the geometry and operating conditions of the machine [Viterna 1981; Glegg, Baxter, and Glendinning 1987; Grosveld 1985], or its spectrum can be measured at a reference distance. Figures 7-9 and 7-10 are examples of spectral data for HAWTs. Also shown in Figure 7-10 is a hypothetical spectrum used in subsequent example calculations to represent a HAWT with a 15-m rotor diameter and a rated power of approximately 100 kW. The example spectrum is the solid line with a decrease of 10 dB per decade in sound pressure level with increasing frequency. This spectral shape is generally representative of the aerodynamic noise radiated by wind turbines. However, predictions for a specific wind power station should be based, if possible, on data for the particular types of turbines in the station.