The **World Health Organization** has authored a reference “*Guidelines for Community Noise*”. In these guidelines the international literature on the health effects of community noise was reviewed and used to derive guideline values for community noise.

A relevant recommendation - *“Municipalities should develop low-noise implementation plans.”*

Under Pressure

by Mark Cool
July 11, 2011

The Wind Turbine Wake Shedding Zone
What's happening behind the Turbine

Air Flow Behind Wind Turbines

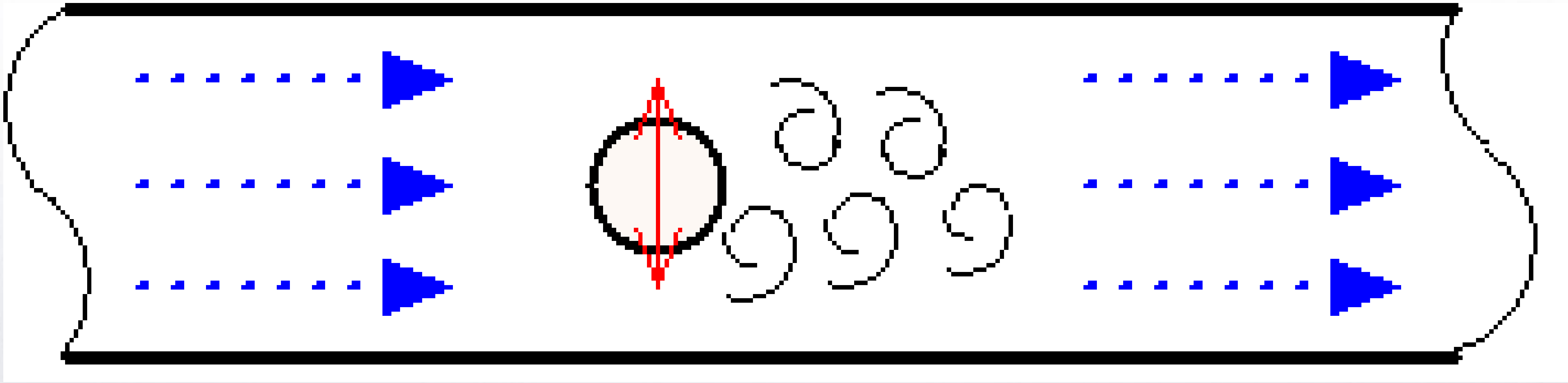
"**The wake effect has been modeled in wind tunnel studies and numerical models, but the atmosphere is different, it's more variable and complicated**."
(*Turbine Wake and Inflow Characterization Study, a Memorandum of Understanding on "Weather*-*dependent and Oceanic Renewable Energy Resources" signed by NOAA and the DOE in* ***January 2011***)

Wind turbines Wake Turbulence and Separation

The offshore wind farm at Horns Rev off the coast of Denmark has been famously photographed to show wind turbine wake effects.

The wind industry, in it’s effort to better understand wake effect to improve turbine performance, have identified these wake pockets.

Wind turbine developers examine downstream wake decay distances.
If they build two or more, they want to know how far away from the first, the next turbine would need to be to regain optimum wind capacity for best production output.



"Industry accepted turbine separation is 6 to 7 rotor diameters in the direction of the prevailing wind directions and 3 rotor diameters perpendicular to the prevailing conditions."
(*R. Holland, Arising Technology Sys. Pty Limited*)

This equates to 1614 or 1883 feet using Falmouth's Wind I in prevailing wind direction.

"At higher wind speeds, the effect of a wind turbine wake, now may take as many as 16 rotor diameters for the airstream to recover back to the initial free-airflow." (*Ralph Holland, Arising Technology Sys. Pty Limited*)

This would represents 4304' between Falmouth's municipal turbines.

They are separated by approximately 1200 feet - 4.5 rotor diameters and their relative position to each one another is north and south.
The more important component of the wake is the mechanically induces low atmospheric pressure bubble that possibly extends 16 rotor diameters downwind.

The blue bubble (cold air) is often represented on TV weather broadcasts as a **"L"**.

These are associated with colder temperatures and varying degrees of precipitation.

It stands to reason, downwind Wind I, a person is caught in and surrounded by the turbines own homogeneous low pressure cell.

Low Pressure Cell Characteristic

- moisture (relative humidity)
- lowering of ambient air temperature

Cold air is more dense than warm because water molecules compress.
Sound pressure waves travel faster and better through a more dense material.

Therefore, a sound pressure wave's travel distance is a function of relative humidity and air temperature. When the atmospheric pressure drops, the air get cooler, the relative humidity increases, and a sound pressure wave travels further.

"**A *sound wave* is effected by the motion of the medium itself.**"
(*Wind Turbine Wakes Control and Vortex Shedding by D. Medici [**2004**]*)

Note that the medium is actually the wake of low pressure, it's momentum carrying it as many as **16 rotor diameters** [4304'] downwind.

"A surprising feature of the flow behind a turbine is a low-frequency fluctuation both in the wake and in the air flow outside the wake."
(*Measurements on a Wind Turbine Wake: 3D Effects and Bluff Body Vortex Shedding* *by D. Medici and P.H. Alfredsson [2006]*)

"As a surprise to many people, hearing does not stop at 20 Hz... the sound becomes a sensation of pressure at the ear drums... the sensation turns into discontinuous separate puffs..."

"Infrasound is (still) often claimed inaudible... it is reported that it can only be heard by especially sensitive people - which is all wrong."

"Weighting curves are misunderstood or (mis)used to give the impression of dramatically high or negligibly low levels."
(*H.Moller and C. S. Pedersen. Journal Acoustical Society of America. [June 2011]*)

This **published peer reviewed research** from June 2011 has found that: ...results confirm... wind turbine noise moves down in frequency with increasing turbine size. The relative amount of emitted low frequency noise is higher for large turbines than for small turbines.

It should be noted that;

“**The one-third-octave band spectra *at lower frequencies*, the highest levels are shown to be associated with the highest wind speeds and the highest power outputs**.”
(*NASA technical papers; H. H. Hubard and K. P. Shepard. “Aeroacoutics of large wind turbines.” [1991]*)

The Board of Selectmen, by their 23 mph wind restriction on Wind I, unknowingly reduced the highest levels of low frequency impact on neighbors. The resulting Town Complaint Log entries after March 2 will, I’m sure, demonstrate this.

Infrasound is measured with the G-weighting curve.
(ISO 7196. Acoutics - Frequency Weighting Characteristics for Infrasound Measurements [International Organization for Standards 1996])

The weighting system most commonly used to correlate with people's response to noise is "A-weighting" and the resultant noise level is called dB(A). A-weighting significantly de-emphasizes those parts of the frequency spectrum from a noise source at lower frequencies (those below about 500 Hz).
(HMMH Falmouth Wind Noise Report 20 Sept. 2010. Appendix A Description of Noise Metrics)

"The result is that the midrange frequencies (100 to 1000 Hz) tend to dominate the A-weighted spectrum at large distances."

(*NASA technical papers; H. H. Hubard and K. P. Shepard. "Physical characteristics and perception of low frequency noise from wind turbines" [1991]*)

Frequency components below 100 Hz may not be significant in terms of audible noise, but they can be significant in terms of vibration effect. This is a body vibration table:

Symptoms
Frequency *General feeling of discomfort* *4 Hz – 9Hz*
Head symptoms *13 Hz – 20Hz*
Influence on speech *13 Hz – 20Hz*
Chest pains *5 Hz*
– 7Hz *Abdominal pains* *4*
Hz – 10Hz (G. Rasmussen. Human body Vibration exposure and it's measurement. [1982])

Low frequency noise issues have been researched extensively in Portugal and have been found to cause a complex disease known as vibro-acoustic disease.

Although this research has been mainly concerned with high levels of low frequency noise, it is felt that <u>over years lower levels of low frequency noise may cause similar problems</u>.

“Atmospheric conditions deserve some attention. It is normally assumed that the wind speed increases logarithmically with increasing height above ground. The wind speed in a height of 10m is used as a reference for measurements of wind noise. Several studies have shown that actual wind speed profiles vary a lot and often deviate substantially from the assumed logarithmic profile.”

“The effect is more prominent with large wind turbines where the difference in wind speed between rotor top and bottom can be substantial. An example might be that when there is more turbine noise at 10m while it is all quiet at the ground. The turbine noise will not be masked with the natural wind induced sound as it might have been with the assumed logarithmic wind profile..”

(H.Moller and C. S. Pedersen. Journal Acoustical Society of America. [June 2011])

“As distances increase, atmospheric absorption causes the levels of higher frequency components to decay faster than those of the lower frequencies.”

(*H. H. Hubard and K. P. Shepard. “Aeroacoutics of large wind turbines.” [1991]*)

“This reduced decay rate in the downwind direction at very low frequencies is believed to result from atmospheric refraction.”

(*H. H. Hubard and K. P. Shepard. “Physical characteristics and perception of low frequency noise from wind turbines.” [1991]*)

“It affects mainly the high frequencies, and the result is that the shift of the spectrum towards lower frequencies become even more pronounced. It is thus beyond any doubt that the low-frequency part of the spectrum plays an important role in the noise at the neighbors and that the low-frequency sound must be treated seriously in the assessment of noise from large turbines.”

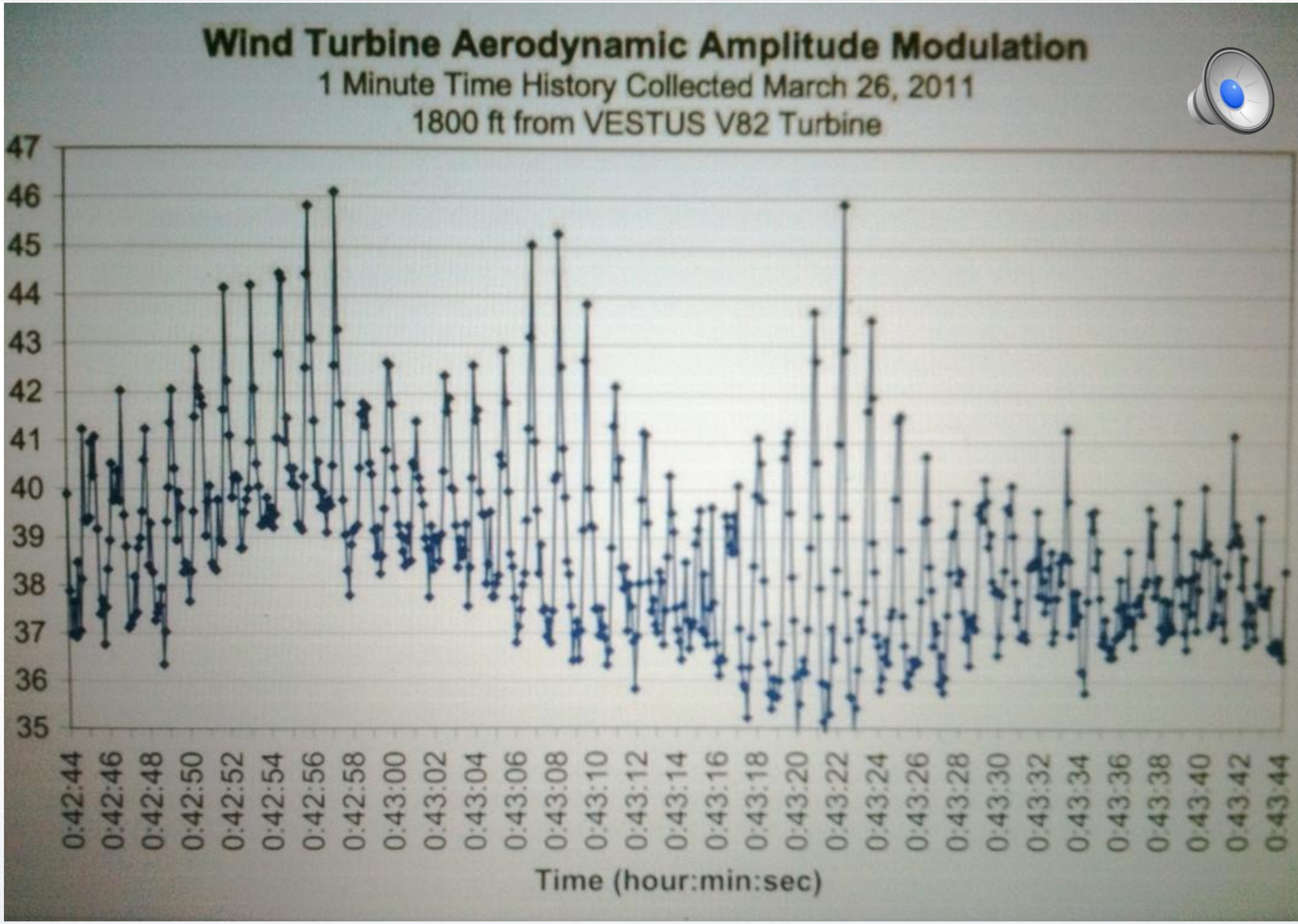
(H.Moller and C. S. Pedersen. Journal Acoustical Society of America. [June 2011])

dB(A) Level

NOTE

A-weighted doesn’t accurately evaluate low/infrasound frequency

higher broadband frequency dissipates faster than low/infrasound frequency



“For continuous noise, to avoid sleep disturbance, WHO recommends an indoor limit of 30 dB for the A-weighted sound pressure level, but also noted that if the noise includes a large proportion of low frequency noise, “a still lower guideline value is recommended. because low-frequency noise ... can disturb rest and sleep even a low sound pressure levels.”

(B. Berglund. T. Lindvail. and D.H. Schwela {eds.}. Guidelines for Community Noise. [World Health Organization 1999])

Dr Geoff Leventhall, a British acoustics consultant,...”as environmental noise control criteria are A-weighted, they tend to under-rate potentially problematic low frequency environmental noise.

(*Australian Federal Senate Wind Farms Report. June 2011*)

Low and infrasound frequencies are
- not well evaluated by the “A” weighting curve
- travel distances greater than the midrange frequencies (200 to 1000 Hz)
- and have a vibratory, rather than an audible noise character

“***The effects of low frequency infrasound (less than 20Hz) on humans are not well understood***” (National Research Council of the National Academies. Environmental Impacts of Wind-Energy Projects. NRC, 2007). This continues to be the accepted scientific and medical research fields contention.Yet regulators undertake literature reviews to make evidence based decisions
regarding the health impacts of wind turbines and conclude adverse health consequences are not justified by the evidence. Doesn't it strike you odd that the evidence, regulators use to base their decisions,
is classified as “not well understood” but they remain willing to risk the health of residents?

"**noise travels farther in calm night air... residents as far as 1.9km (6233') away were disturbed by noise... those downwind bear the brunt of the sound.**"
(*G. P. van den Berg, The Sound of High Winds, Thesis, The University of Groningen [2006]*).
Currently, regulators rely on the state's generalized community noise standards in examining wind turbines.

There are no standards addressing noise pollutants you can't hear, yet can feel.

I'm sorry to report, Falmouth noise regulations are not providing the same protections from wind turbine noise as they do from other noise sources.

Low frequency and Infrasound Risk Management analysis is needed.
Where public health is at stake, public health risk must hold precedence over Wind Turbine operational strategies.