Docket No. 7156
Exhibit UPC-Cross- P613
Admitted: ____________

Docket No. 7156
Response of UHS and RPI to UPC's 4th Set
of Discovery Requests
September 21, 2006

Questions Related to Testimony and Exhibits of Mr. Guldberg

Q.UPC:UHS/RPI.4-47: Regarding A.UPC:UHS/RPI.2-23c: On what basis do you make the claim that "the beating, or amplitude modulation, of noise from turbines requires relatively close spacing of the turbines?" Identify and produce copies of all documents supporting your opinion that beating requires "relatively close spacing."

A.UPC:UHS/RPI.4-47:

The beating, or amplitude modulation, of audible noise from many closely-spaced wind turbines is described by G. P. van den Berg in his article from the Journal of Low Frequency Noise, Vibration and Active Control (Attachment A.UPC/UHS/RPI.1-1.1077):

> "An important contribution to the low frequency part of the sound spectrum is due to the sudden variation in air flow which the blade encounters when it passes the tower: the angle of attack of the incoming air suddenly deviates from the angle that is optimized for the mean flow." (Page 1)
>
> "The blade passing frequency modulates well audible, higher-frequency sounds and thus creates periodic sound: *blade swish*. This effect is stronger at night because in a stable atmosphere there is a greater difference between rotor averaged and near-tower wind speed. Measurements have shown that additional turbines can interact to further amplify this effect." (Page 1)
>
> "Near the Rhede wind farm we found that, because of the *near*-synchronicity of several turbines, sometimes two or three were in phase and the blade passing pulses coincided, and then went out of phase again. This would lead to a doubling (+3 dB) or tripling (+5 dB) of pulse height. If in a (very) stable atmosphere individual swish pulse heights are 3-5 dB (see section 3a above), synchronicity at the Rhede wind farm or similar configurations would thus lead to pulse heights of 6-10 dB." (Page 6)
>
> "Our experience at distances of approx. 700 to 1500 m from the Rhede wind farm with the wind turbines rotating at high speed in a clear night and pronounced beating audible, is that the sound resembles distant pile driving." (Page 15)

One of the examples given of sound level measurements taken "where a distinct beat was audible" (Page 12) involves a house (dwelling P) that is relatively close to, and almost equidistant from, four wind turbines:

> "Turbines 12 and 11 are closest at 710 and 750 m, followed by turbines 9 and 14 at 880 and 910 m. Other turbines are more than 1 km distant and have at least 4 dB lower immission level than the closest turbine has." (Page 12).

Referring to Exhibit UPC-CB-3, the two residences on Berry Hill Road labeled P21 are closest to, and almost equidistant from, four wind turbines at distances of 650, 730, 930 and 810 meters (m), with all other turbines more than 1 km distant. Thus, a configuration of turbines near residences exists for the UPC wind project that is very similar to one studied at the Rhede Wind Park, where residents heard a distinct and audible beating noise.

The impulse noise from four turbines near the P21 residences is now examined to show that beating requires relatively close spacing of the turbines. The proposed wind turbine has a sound power of 105.3 dBA (CB-2). The equation in acoustics for relating the sound power level (Lw) to the sound pressure level (Lp) at a distance r (meters) is:

$$Lp = Lw - 20[\log r] - 8$$

This equation assumes no ground absorption and hemispherical wave spreading. (The following demonstration works equally well if one assumed full ground absorption and spherical wave spreading; all sound pressure levels would be 3 dBA lower). Thus, the broadband sound levels from the four turbines nearest to the P21 residences are (rounded to the nearest decibel and using UPC figures from Exhibit UPC-CB-3): 41, 40, 38 and 39 dBA. These four turbines are labeled 1, 2, 3 and 4 in the figure provided as Attachment A.UPC:UHS/RPI.4-47. Turbine 1 is the closest turbine to the P21 residences at a distance of 650 m. Assume each turbine produces an impulse noise that peaks 3 dBA above the steady-state noise and assume the turbines operate synchronously for a period of time. The sum of the individual turbine pulses of 44, 43, 41 and 42 dBA at the P21 residences equals 49 dBA.

Now, assume the position of Turbine 1 is fixed and the spacing of turbines 2, 3 and 4 is increased to 1,000 meters along the same directional vector as shown on the UPC Noise Study Map (CB-3). An enlargement of the UPC Map that illustrates this wider spacing, where the relocated turbines are labeled 2A, 2B and 2C, is shown in Attachment A.UPC:UHS/RPI.4-47. The distances from the four turbines 1, 2A, 2B and 2C to the P21 residences are 650, 1140, 1630 and 1220 m, respectively, and the broadband sound levels heard at P21 are (rounded to the nearest decibel): 41,36, 33 and 36 dBA. Note that sound levels from the 2nd through 4th nearest turbines are now substantially lower, being 5 to 8 dBA below that from turbine 1.

As before, assume each turbine produces an impulse peak of 3 dBA and these coincide for a period of time. The sum of the individual turbine pulses of 44, 39, 36 and 39 dBA at the P21 residences equals 45 dBA. Thus, the wider spacing of the turbines at 1,000 meters (the approximate turbine spacing in the Cape Wind Project) lowers the potential noise pulse height by 4 decibels in any amplitude modulation or beating. This demonstrates that if several turbines are to produce beating of audible noise from near-synchronous operation, it is necessary that their noise pulses both coincide in time and be of a similar magnitude. If the turbines are spaced farther apart, wave pulses arriving at a residence from more distant turbines will be weaker in amplitude and the amplitude modulation or beating will be diminished.

Person Responsible for Response: Peter Guldberg
Administrative Unit: Acoustic Consulting
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