Location, Location, Location

An investigation into wind farms and noise by The Noise Association

Noise - 'unwanted sound' – can ruin people's well-being and environment

"Peace and quiet is the single most important factor people have in mind when buying a home – with one in five prospective homebuyers rating it as the most important consideration when choosing where they will buy." **Alliance and Leicester Survey, 3/6/02**

The Noise Association, which published this report, is the research arm of the UK Noise Association. Both organisations are based at 2nd Floor, Broken Wharf House, 2 Broken Wharf, London EC4V 3DT, tel 020 7329 0774, email info@ukna.org.uk www.ukna.org.uk

Contents

Preface

The old windmill is remembered with fond nostalgia. Today's wind farms, by contrast, are causing much controversy. For a variety of reasons they are dividing local communities, green pressure groups, politicians and environmental experts. This report aims to map out a constructive way forward with respect to one of the principal areas of controversy – noise. The report assesses noise from onshore wind farms; it is not concerned with offshore wind farms or any other aspect of the wind farm debate.

We discovered that there is some disagreement amongst acousticians on the impact of wind farm noise. This report reviews the latest evidence. But, in many ways, more important than the theory, is what people who are living with wind farms are saying. We sought their views too, but found that they don't speak with one voice either!

While surveys suggest that wind turbines are not causing a noise problem for the majority of communities, there are people who are suffering badly as a result of the noise generated by neighbouring wind farms. While opponents of wind farms tend to raise noise as an important part of their case against wind power, the wind power industry and its allies can refuse to acknowledge the extent of the suffering that this noise can cause and they sometimes deny its very existence.

Our own conclusion, after reviewing the evidence, is that there is a practical way forward. There are mechanical improvements that can be made to wind turbines, but the key lies in the title of our report – 'Location, Location, location'. So much depends on the location of the wind farm relative to where people live. In the following pages we explain why we have reached this conclusion and suggest a way in which on-shore wind farms can be built without causing unacceptable noise problems.

I hope you find the report a constructive contribution to the debate.

John Stewart

Introduction

The UK, along with other countries in the world, particularly the rich countries, needs to find ways to cut its 'greenhouse gas' emissions. The UK produces about 2.6% of reported global emissions, CO_2 being the most significant of those gases and one which most scientists believe to be the principal cause of climate change. Electricity generation currently accounts for 28% of these CO_2 emissions and, with a very high proportion of UK electricity sourced from fossil fuels, there appears to be a clear need to develop technologies which do not emit greenhouse gases.

The other factor driving the Government's desire to find alternatives is the diminishing reserves of oil. Scientists differ on when the world will become seriously short of accessible supplies of oil, but there is no dispute that it will happen. Governments across the world, therefore, are trying to develop alternative sources of energy.

The UK Government has set a target of generating 10% of the country's electricity from renewable sources by 2010. Wind farms could be part of the answer. Government policy is to encourage industry to invest in wind farms through a system of subsidies financed by the electricity consumer. The ultimate aim is that between 60% and 70% of UK wind power will be generated off-shore but most of the first turbines are being built inland as these are cheaper to build and provide an opportunity to test out the technology before going off-shore.

Over the last few years there has been a huge growth in the number of wind farms. By the middle of last year there were over 100 wind farms in the UK, with a further 19 under construction, another 62 having been given consent, and 150 awaiting planning permission.

This officially-sanctioned growth has delighted the supporters of wind farms, but has lead to the emergence of vocal opposition. Green pressure groups – notably Greenpeace, Friends of the Earth and the World Wildlife Fund (WWF) – have supported the idea of developing wind farms. The Royal Society for the Protection of Birds (RSPB) has given general support, except in cases where birds would be badly affected. The Campaign to Protect Rural England (CPRE) has been much more wary.

Some local opposition groups have been assisted by Country Guardian and, latterly, the Renewable Energy Foundation (REF). Visual intrusion and the impact on the landscape are the reasons most frequently cited by opponents of wind farms. At a policy level, some of the opponents question the viability of wind farms and dispute the amount of electricity they will actually generate.

Wind farms have also divided noise experts. There is an on-going technical debate about the noise and vibration produced by wind farms. The debate has led some acousticians to question whether the Government's noise guidelines for wind farms are rigorous enough.

It is to noise we now turn

How Turbines Work

Wind turbines consist of:

- a tower which is between 25 and around 100 metres high;
- a nacelle (similar to the device used in the outer casting of the engine of an aircraft) containing the gearbox and the generator, which is mounted on top of the tower,
- 3 blades, which can reach a significant tip height, that rotate around a horizontal hub protruding from the nacelle.

There are two potential sources of noise: the turbine blades passing through the air as the hub rotates, which creates aerodynamic noise; and the gearbox and generator in the nacelle, which creates mechanical noise.

Mechanical Noise

In the turbines erected during the last ten years, the manufacturers have been able to reduce the mechanical noise from the gearbox and generator to the point where it is generally accepted that it has ceased to become a problem. In any event, the mechanical noise in new turbines is at a level below the aerodynamic noise.

Aerodynamic Noise

As the blades past through the air, they create aerodynamic noise. This noise can come from the speed at which the blades are turning, the angle at which they are set, and indeed the way they are designed. It is the blades which are the cause of the "swish, swish, swish", the thudding sound which is the main noise people complain about. This thumping sound can be made worse if wind turbines on a particular site are placed too close together – the turbulence from the more upwind turbine can create additional thumping from the blades of turbines sited downwind of it. The turning of the blades can also generate low-frequency noise in certain atmospheric conditions (*see low-frequency noise pages for details*).

Modern, Larger Turbines

New turbines are generally mechanically quieter than those installed in the early 1990s. But there are two important caveats to this. Recent research from the Netherlands **(1)** suggests that the larger modern turbines may be significantly noisier than previously thought. Fritz Van den Berg, a physicist at the University of Groningen, has published a study which argues that the methods used to predict noise from turbines are flawed. He challenges the assumption that wind speeds measured at a height of 10 metres are representative of wind speeds at the greater heights of modern turbines (often 100 metres and above) – because the wind speeds can be markedly greater than at 10 metres.

Van den Berg argues that this is particularly the case at night when wind speeds may fall at ground level to near zero, but remain fast enough at the height of the turbine to turn the blades. His measurements show that wind speeds at night are 2.6 times higher than would be expected. The result can increase the noise experienced by residents at ground level by 10 decibels in areas where there is limited background noise to mask it.

He is supported by other acousticians. Paul Botha wrote: "The historical use of 10 metre high wind speed measurements for the acoustic assessment of both wind turbines and wind farms has the ability to create inaccuracies and sometimes confusion around sound power levels, noise predictions and even demonstration of wind farm compliance. The use of 10m high wind speed measurements appears to be largely historic and there are advantages in using hub height wind speeds throughout the noise assessment process." **(2)**

Eja Pedersen also acknowledges Van den Berg's work: "Common hub height of the operating wind turbines today in Sweden is 40-50 meters. The new larger turbines are often placed on towers of 80 – 90 meters. The wind speed at this height compared to the wind speed at the ground might (up to now) have been underestimated." **(3)**

The other concern is that the substantially larger blades the bigger turbines use can make more noise than smaller blades as they cut through the air.

Low-Frequency Noise

Wind turbines also produce low-frequency noise. When the wind and turbulence are high, the movement of the turbine's blades through the air can produce low-frequency noise. Wind farms sited on the very top of hills are particularly prone to such turbulence. Dr Geoff Leventhall, the man whose name has become synonymous with low-frequency noise, put it like this in his paper to a recent Berlin Conference: "All wind turbines produce low frequencies, mainly mechanical noise, which has been reduced to low levels in modern turbines, but there are circumstances in which turbines produce increased levels of low frequency noise. This is mainly when inflow air to the turbine is very turbulent and there are interactions between the blade and the turbulence." **(4)**

Wind Farms and Noise – the official guidelines

Acoustics is no different from any other area of science – the scientists don't agree! There are several technical disputes raging amongst acousticians about the impact on noise and vibration from wind turbines. There is no reason to suppose that they won't go on for many a year. But it is worth understanding some of the key points being made because they could point to a realistic and constructive way forward.

The Government Stance

The starting point has to be the Government's noise guidelines for companies applying for planning permission to install wind turbines. They are called *The Assessment and Rating of Noise from Wind Farms (ETSU-R-97)*, issued by the Department of Trade and Industry (DTI).

There are separate, though similar, ones for Scotland called *A Planning Advice Note on Renewable Energy Technologies (PAN 45)*, issued by the Scottish Office Environment Department in January 2002.

These guidelines are the starting point because, at present, planning departments and planning inspectors rely upon them when evaluating the potential noise impact of a proposed wind farm. Critics of ETSU R 97 say that it does not deal adequately with amenity issues.

The government guidelines recommend that:

- Daytime noise levels outside the properties nearest the turbines should not exceed 35-40dB(A) or 5dB(A) above the prevailing background, whichever is the greater.

- Night noise limits outside the nearest property should not exceed 43dB(A) or 5dB(A) above the prevailing background, whichever is the greater.

- That a penalty should be added to the predicted noise levels if a tonal component is present in the noise.

The British Wind Energy Association, a trade organisation which supports wind power, argues, with the support of some acousticians, that these guidelines are adequate to deal with the noise impacts of turbines, but this view is not accepted universally in the acoustic community. We assess the adequacy of the guidelines on later pages in this report.

Facts about Noise

- Noise can be defined as unwanted sound.

- Noise levels are normally expressed in decibels (dB). A one decibel change in the noise level is just perceptible; a three decibel change is clearly perceptible while a ten decibel change is heard as a doubling or halving of the perceived level.

- Noise levels are usually measured using 'A' weighting - dB(A). Sometimes noise is averaged out over a period of time – to give a reading dB(A) LAeq

- 'A' weighting is the subject of some controversy. Some acousticians argue that 'C' weighted measurements should be taken in addition to capture low frequency noise.

- In addition to the decibel level (measuring loudness), the 'frequency' of noise is measured in terms of Hertz (Hz). Frequency is to do with the pitch of the noise rather than its loudness. It is the combination of the pitch and the loudness that determines what people hear. It can also have a bearing on a person's health.

Wind Farms and Noise - what the surveys reveal

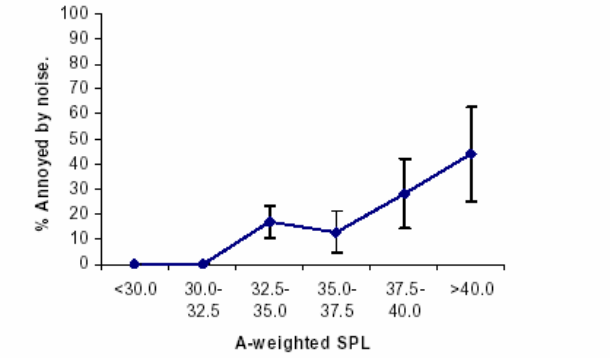
The most comprehensive surveys into people's attitudes to wind farm noise have been carried out in the Northern European countries.

EU Study

In the early 1990s a major study, partly financed by the European Community, was carried out in the Netherlands, Germany and Denmark.(6) The majority of residents questioned experienced noise levels of around 35 decibels (within the limit where noise is officially considered to be a problem for most people). The study was presented in two parts – the German/Dutch findings and the Danish findings. In Germany and the Netherlands, 6.4% of people said they were annoyed by the noise. In Denmark, 7% said they were "rather annoyed" and 4% "very annoyed".

Swedish Study

In 2000 a study by Pedersen was carried out in Sweden.(7) It found that annoyance increased with noise levels.



No residents were very annoyed at levels below 32.5 dBA LAeq. 20% were very annoyed at levels between 37.5 and 40dBA LAeq and 36% when levels were above 40dBA LAeq. Pedersen's study also compared the reactions of people who described themselves as noise sensitive with those who did not. It found there was little difference at levels below 35dBA LAeq, but that at higher levels noise sensitive people rapidly became more annoyed.

All the European studies found that there was a statistically significant link between noise annoyance and annoyance at the flicker effect created by the blades of the turbines.

MORI Survey

In this country MORI conducted a poll for the Scottish Executive in 2003.(8) MORI surveyed people living within 20 kilometres of Scotland's operational wind farms. It asked them about the strengths and shortcomings of living in their areas. It found that, unless prompted, less than 0.5% mentioned wind farms at all. When specifically asked about wind farms, 20% of residents felt they had a broadly positive impact on their area, with 7% feeling they had a negative effect, and 1% saying they were noisy. Most people felt they had neither a positive nor negative effect, even those living within 5 miles of the turbines, but, MORI did not do detailed work with people living within ear-shot of wind farms, the critical area in assessing the impact of wind farm noise. It means the study is of little value to us which is a pity because their general approach, which avoided asking people directly if they were disturbed by wind farm noise (when negative responses rise sharply), is applauded by most social scientists.

Wind Energy Study

In 1994, the British Wind Energy Association commissioned a study of 250 local residents near the 12 turbine wind farm at Kirkby Moor in Yorkshire, six months after it started up. It revealed 83% were "not all concerned" or "not very concerned" about the noise they made.

These studies suggest that, while some people relatively close to wind farms do not consider noise to be a major problem, it is a big concern for others. This is illustrated by statements <u>below:</u>

"*Our small cottage is just over half a mile from one of these turbines and approximately 200ft lower in elevation. The noise from this one turbine is at times unbearable. At best we get a constant pulsating thump from the blades as they cut through the air. During the summer months it sometimes becomes impossible for us to sit out in our garden. When we go inside it becomes unacceptable for us to have our windows open because the pulsating noise is so invasive.*"
Letter in the Carmarthen Journal May 2005

"*I'm as green as the next man and the developers assured us that the windmills would cause hardly any disturbance, but once they began operating I couldn't work in my garden anymore – the noise was unbearable. It was as if someone was mixing cement in the sky.*" **Daily Telegraph 24/1/05**

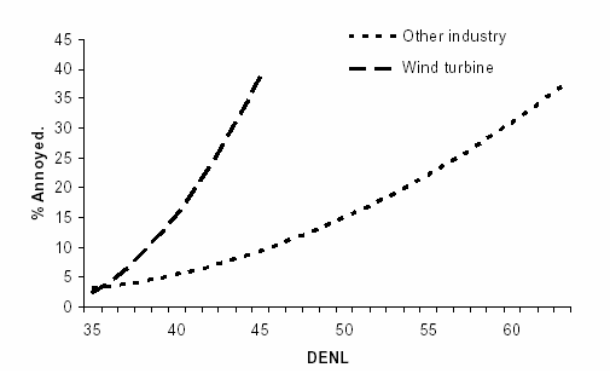
"*A recent settler in Caithness claimed yesterday his life is being blighted by ghostly noises from his new neighbours, the county's first large-scale wind farm: 'The problem is particularly bad at night when I try to get to sleep and there's a strong wind coming from the direction of the turbines. They just keep droning on. It's a wooh wooh type of sound, a ghostly sort of noise. It's like torture and would drive anyone mad'.*" **Aberdeen Press and Journal, 25th May 2005**

"For existing wind farms we are satisfied that there are cases of individuals being subject to near-continuous noise during the operation of the turbines, at levels which do not constitute a statutory nuisance or exceed planning conditions, but which are clearly disturbing, unpleasant and may have some psychological effects."
The conclusion of the Welsh Affairs Select Committee after investigating wind farms. (9)

Wind Farm Noise – the general impact

There is little or no dispute that the "swish, swish, swish" of the blades of a wind turbine as they pass through the air make a noise.

Most noise complaints about wind farms are about this swish. What is interesting is that wind farm noise generates many more complaints than equivalent levels of noise from most other sources, including road noise. It is worth trying to find out why this is.



The results when Pedersen and Persson Waye looked at how annoyed people become by different noises

Pedersen and Persson Waye in as yet unpublished work following up their 2002 study *Storiningar fran Vindkraft* found that, once the noise levels exceeded the 35 decibel mark, the percentage of people annoyed by wind farm noise rose much more rapidly than with the other 'stationary' noises. They have tried to assess the reasons for this. Pederson, in a paper **(10)** (presented to a major conference held in Berlin on Wind Farm Noise last October) based on her work, wrote: "the informants' descriptions of their feelings when exposed to wind turbine noise, as well as shadows and the rotating movement of the rotar blades, were in our analysis interpreted as an intrusion into private domain. The noise was physically perceived in the living environment, e.g. in the garden, in spite of the bushes and fences put up to keep out invaders, and was to those who could not mentally shut it out, an obstacle to pleasant experiences decreasing the joy of daily life at home. For some informants, the intrusion went further into the most private domain, into themselves, creating a feeling of violation that was expressed as anger, uneasiness, and tiredness."

The noise was physically perceived in the living environment……..…to those who could not mentally shut it out, an obstacle to pleasant experiences, decreasing the joy of daily life at home.

What is interesting is that wind farm noise generates many more complaints than equivalent levels of noise from most other sources, including road noise. It is worth trying to find out why this is

Pedersen's view that it is the combination of the noise, the flickering shadows and the rotating rotar blades that creates the big problems with wind farms is echoed by Dr Amanda Harry, who has done work with communities complaining about the effects of wind farms in Cornwall. We return to her work and explore some of these points in some detail in the *Noise and Health* section of the report.

A major expansion of wind farms could not be justified if it were to result in these problems being replicated across the country.

Recommendations

1. There needs to be a clear and public recognition by the Wind Power Industry that wind turbines are causing significant noise problems for some people.

2. The industry should continue its work to develop quieter turbines.

3. There is case for a moratorium on the installation of the very tall turbines until trials have been undertaken to accurately assess the noise they actually make.

4. Wind farms should only be located in areas where the "swish, swish" of the turbines will not cause noise problems for people.

5. There needs to be further research into the link which has been identified between noise annoyance and the annoyance of the flicker effect created by the blades of the turbines – and the potentially harmful effect this may have on people's health – *see noise and health section*.

Wind Farm Noise – the impact on areas of low background noise

Mid-Wales – a land of hills and valleys. A place where the wind blows frequently and the population tends to be thinly spread. Ideal for wind farms. And, not surprisingly, many are planned.

The best place very often for the turbines to catch the wind is close to the top of a hill. It means that the wind turbines can be at their most productive.

But it also means that the noise may cascade down the surrounding valleys. To makes matters worse, many of the scattered hamlets within the valleys snuggle into corners protected by the hills and the mountains where the background noise level is very low indeed. You only need to visit these areas to hear the 'swish, swish, swish' of the turbines – particularly downwind – over a mile away from the wind farm.

It would appear that the current government guidelines aren't robust enough to deal with areas where the background noise is so low.

The guidelines state:

- daytime noise levels outside the properties nearest the turbines should not exceed 35-40 dB(A) *or 5 dB(A) above the prevailing background, whichever is the greater.* (my emphasis)

- night noise limits outside the nearest property should not exceed 43 dB(A) *or 5 dB(A) above the prevailing background, whichever is the greater.* (my emphasis)

Very low background noise levels

But what if the background level drops as low as 15–20 decibels – as has been recorded in mid-Wales? It means that a turbine creating the maximum amount of noise permitted – 40 or 43 decibels – is way above the background level.

We could trace no study which looked at the impact of wind turbine noise in areas where background noise was unusually low. But a number of studies have been carried out into the impact of aircraft over flying 'wilderness' areas. The most important of these was carried our by Fidell in the USA.**(11)** It found that people said they were highly annoyed by levels of aircraft noise 7 decibels lower than they would have been in a built-up area.

Are the guidelines adequate?

There is a lot of concern about what the ETSU recommendations say in areas where the background noise levels are low. They aim to give "*indicative noise levels to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable restrictions on wind farm development or adding unduly to the costs and administrative burdens on wind farm developers or planning authorities.*"

This is quite different from the procedures required by other industries:

*"The assessment compares the noise source with existing background noise. A background noise survey must be performed during the proposed operating hours. The worst hour during day time is measured, and the worst 10 minutes at night. Following analysis and corrections to the data in accordance with BS4142 the difference between the source and existing noise level is determined. A difference of +10dB is a positive indication that complaints are likely. A difference of -10dB is a positive indication that complaints are unlikely. A difference of +5dB is said to be of marginal significance."***(12)**

In other words, the noise levels are not expected to reach decibels significantly above the background noise level. This is the policy that has been adopted by the Dutch province of Utrecht (actually a relatively urban area) as a result of initial opposition to wind farm proposals for the area. Local authorities in Utrecht are required to go through detailed procedures to ensure that wind farm noise does not exceed the levels of background noise. **(13)**

Recommendation

That the wind farm guidelines (ETSU) be revised to make them more meaningful to areas where the background noise level is unusually low. Revised guidelines, taking account of low background noise levels, which led to wind turbines being more sensitively sited in rural areas – such as mid-Wales, Cornwall and Devon and the Scottish Highlands – would be a constructive step that would reduce conflict and promote consensus.

Wind Farm Noise - the impact of infrasound and low-frequency

What is low-frequency noise?

There is a strong low-frequency element in many of the gadgets we have these days. It's found in the hum of the fridge, the washing machine or the air conditioning. It's very much present in the bass of a sound system. It is not conventionally 'loud' - frequency is to do with the pitch of the noise rather than its loudness. Low-frequency is generally defined as noise between 0-150/200 hertz (Hz), with sounds at the lowest range, 0-20 hertz, known as infrasound.

We all can hear some low-frequency noise – particularly if it reaches a high decibel level – but there are variations in the audibility threshold from person to person which means that some people can hear low-frequency sounds not audible to the rest of the population – **see box**. For these people something like their neighbour's central heating, if it is making a noise, can sound like "living inside an organ pipe." **(15)**

The source of low-frequency noise can be difficult to trace as it can travel, both through the ground and through the air, much further than conventional sound. Some sources of low-frequency noise, if traced, can be dealt with. For example, a dodgy fan may just need to be properly encased. Other sources – such as oil pipelines – are more problematic.

Noise, at any frequency, can penetrate buildings but the effect is greater in the case of low-frequency noise. The result is that low-frequency noise is much more disturbing indoors than outside. Sometimes the low-frequency noise, from an external source, has embedded itself within the walls of the building and it is that which the low-frequency sufferer is hearing. It means that measurements of low-frequency noise should be taken indoors as well as outside.

Measuring low-frequency noise

To correctly assess the impact of low-frequency noise, both the loudness of the noise (decibels) and the pitch (hertz) must be measured. It is the combination of the two that determines whether and how badly people will be affected by the noise.

Many acousticians would argue that, when measuring low-frequency noise, 'C' weighting should be used rather than the conventional 'A' weighting which doesn't pick up the lowest sounds. They are backed up by the noise experts at the World Health Organisation who argue that "when prominent low-frequency components are present, noise measures based on 'A' weighting are inappropriate. The difference between dB(C) and dB(A) will give crude information about the presence of low-frequency components in noise, but if the difference is more than 10dB, it is recommended that a frequency analysis of the noise is performed."**(14)** Other people argue that only when there is a 20dB difference is there likely to be significant low-frequency present. ('G' weighting is usually recommended for infrasound).

Dr Geoff Leventhall agrees there are times when 'A' weighting is not entirely adequate: "Audible low-frequency noise does have annoying characteristics which are not shown in conventional environmental noise measures, such as A-weighting."**(4)** But still most wind turbine measurements continue to use 'A' weighting.

The Low-Frequency Noise Sufferer

Hazel Guest, a low-frequency noise sufferer and a former lecturer in mathematics at London's City University, wrote **(15)** "the audibility threshold varies considerably from person to person. But for those who do hear low-frequency, it can be very distressing. It has been described as 'like living inside an organ pipe'." It is not the same as tinnitus. If it were tinnitus, it would mean there was a 'ringing in the ears' all the time. That is not the case with low frequency noise; it is location specific. Guest argues that the noise can be heard, if it is loud enough, when the frequency is below 20 Hz. The low-frequency sufferer seems to hear something quite different from 'conventional' noise. Hazel Guest has described it "like living inside an organ pipe". Others have talked about "a thunder in the ears", though this is likely to be a problem of either hyperacusis or an extreme stress response. Manley, Styles and Scott in their paper, **(16)** argued that, while most people cannot hear noise between 20 hz and 4hz unless it reaches 80 and 107 decibels respectively, "there is no doubt that there is a link between tonal activity above a certain level and the effects experienced by some sufferers…..the difficulty is that while the cause may be real, the precise frequencies and levels at which individuals are affected may vary from person to person, with perhaps only a few percent of the population able to detect them." Hazel Guest is of the view that the unexplained health effects of low frequency noise could be down to the way it interferes with the brain.

When do people hear infrasound and low-frequency noise?

Whether or not people hear low frequency and infrasound depends on the relationship between the loudness of the noise (decibels) and its frequency (hertz).

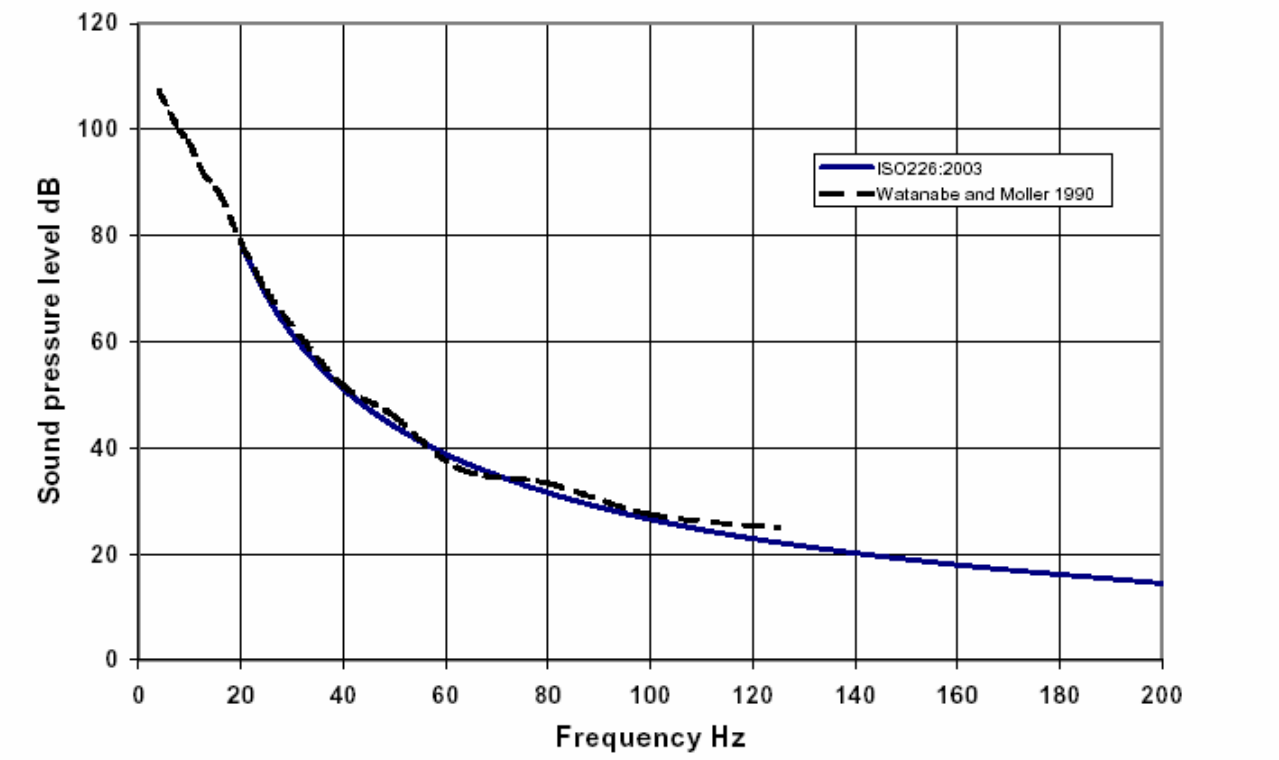


Fig 2. Low frequency threshold

Infrasound

- The median threshold for hearing infrasound at 4Hz is 107 decibels.
- At 10 Hz it is 97 decibels.
- At 20 Hz it is 80 decibels.
- The standard deviation of the threshold measurements is about 6dB, so there will be a very small number of people who may have 12dB or more sensitivity to the mean. For most people, though, noise levels need to be high before infrasound is heard by human beings.

The measurements in the above table, produced by Watanabe and Moller in 1990, are 'G' weighted to best capture infrasound

Low-Frequency

- At 30 Hz, the median frequency is around 60 decibels
- At 40 Hz, it is around 56 decibels
- At 60 Hz, it is around 39 decibels
- At 80 Hz, it is around 37 decibels
- At 100 Hz, it is around 23 decibels.

Wind Farms, Infrasound and Low-Frequency Noise

Are people hearing infrasound from wind farms?

There has never been any dispute that wind turbines generate infrasound. A major study undertaken for the Ministry of Defence (MOD) by Keele University to assess the effect that wind farms might have on its key monitoring facility in Eskdalemuir **(17)** concluded "we have clearly shown that wind turbines generate low frequency sound (infrasound) and acoustic signals which can be detected at considerable distances (many kilometres) from wind farms in infrasound detectors and on low-frequency microphones." The lead author, Professor Peter Styles, concluded that seismic signals from wind-turbines registering up to 7.5hz can be detected 10 miles from the wind farm. In the report Styles doesn't spell out the levels of infrasound close to the turbines, but he did this in an earlier paper published with Dr David Manley and others.**(18)** They took measurements at a wind farm in Wales with about 10 turbines. (It is unclear what noise weighting was used).

The survey obtained the following results:

1/3 Octave Frequency Hz

4	5	6.3	8	10	12.5	16	20

Decibel level at100 metres from turbines

62	60	63	66	63	60	60	60

Decibel levels that would be problematic

102	98	94	90	86	82	78	71

These levels are clearly below those that would be problematic, even allowing for a considerable variation in individuals' ability to hear infrasound.

Noise Association Measurements

In the preparation of this report, The Noise Association measured noise levels around three wind farms: Bearsdown and Bradworthy in Cornwall and Blaen Bowi in Wales. The focus of the work was to measure the low-frequency noise, including infrasound. Details in Appendix 1.

The findings in summary:

At 10hz, the noise from the wind farms ranged from negligible (upwind from the turbines) to 75dB(C) (downwind). Because Watanabe and Moller figures are 'G' weighted and the UK Noise Association used 'C' weighting only approximate comparisons are possible. But these findings are well within the 97 decibels where it would become a noise problem at 10hz, whatever the weighting.

At 20hz, the noise from the wind farms ranged from a low of 10dB(C) (upwind of the turbines) to a high 82dB(C) (downwind), with the great majority of the results falling in the 40-70dB(C) range. Again, a direct comparison is not possible with Watanabe, but it is clear that at these levels the noise will be heard by few people.

Conclusion on Infrasound

The findings suggest that at 20hz, the very upper range of the infrasound range, there might be a problem for a few people in very specific circumstances, but that infrasound noise from wind turbines will not be heard by most people.

Is low-frequency noise from wind turbines causing people problems?

The important question to be answered here is whether the decibels levels are high enough at low-frequencies (20 – 100/200 Hz) for there to be a noise problem.

Noise Association Findings

At 40hz, the noise from the wind farms ranged from 25dB(C) to 77dB(C). Watanabe found that the noise can't be heard below 56dB(G). Our findings suggest that some low-frequency noise can be heard at times from turbines at 40hz.

At 60hz, the noise from the wind farms ranged from 15dB(C) to just over 80dB(C), with the majority of readings in the 40-70dB(C) bracket. Many of these readings exceed the Watanabe figure of 39 decibels. At this frequency low-frequency noise is being heard at times.

At 125hz, the noise from the wind farms ranged from 20dB(C) to 74dB(C), with the majority of readings between 40-60dB(C). This indicates that at 125hz, the low-frequency content of the "swish" sound is audible.

Comment on the findings

The readings were all taken within about one and a half miles of the turbines. There were variations in the low-frequency levels depending on wind direction and air turbulence. It was usually just when people were downwind and the air was turbulent that low frequency formed a significant part of the noise.

The Noise Association also tested for low-frequency noise indoors

We chose a property in mid-Wales whose residents had been complaining for some years about the effect of the Blaen Bowi wind farm in mid-Wales. The residents have complained, not just about the noise, but the physical effects it is having on their health. The property is in a sheltered valley, about two miles from the turbines which are close to the top of a hill. Detailed results on pages 28 and 29.

The results we obtained were these:

At 10 hz, the noise levels ranged from 44 to 48 decibels, well below the levels at which the noise would be heard.

At 20 hz, the noise levels ranged from 40 to 48 decibels, again well below audible levels.

At 60 hz, the noise levels ranged from 44 to 63 decibels, which suggests that low-frequency noise is being heard at times.

At 100 hz, the decibel levels ranged from 42 to 52 decibels, which indicates that the 'swish' sound is being heard, containing a low-frequency content.

The problems experienced by the two people in this house are very real. They claim that they can 'feel' the noise. Our results certainly suggest that, at times, they can hear the noise. What our results can't provide is any explanation for the claims that they can 'feel' the noise. We can just speculate on the possibility that, in this case, the low-frequency noise, as it can do, has embedded itself within the walls of the property and that it is this, in part, which the occupants are reacting to.

Conclusions

1. There is a low-frequency content in the noise from wind farms that can be heard. It is most marked at the higher range of low-frequency. This means that it is likely it is difficult to separate it out from the 'swish, swish' sound that causes most complaints, but also that it could increase annoyance from the swish sound.

2. The low-frequency content of wind turbines is likely to cause 'low-frequency noise sufferers' a problem. The problem may be no greater, though, than many of them would experience from other potential sources of low-frequency noise, such as air-conditioning or central heating. But it could be amplified in the small number of cases where it resonates with the walls of a building.

3. There is a case for 'C' weighting to be used in measuring wind farm noise as 'A' weighting doesn't fully capture the low-frequency content. 'G' weighting is most appropriate for measuring infrasound.

The Impact on People's Health

People in the United Kingdom have been complaining of health problems since the construction of the wind farms near their homes. In Europe, Australia and North America people have reported similar problems. The range of symptoms mentioned by complainants includes headaches, sleep disturbance, anxiety, depression, stress, vertigo and tinnitus. On pages 18 and 19 we highlight some of the quotes. This section seeks to explain why the symptoms and health problems could be caused by the wind turbines.

There are three ways in which turbines could be affecting people's health.

First, the stress from the noise. When people become seriously annoyed by any noise, they can become stressed out and irritated. This can affect their sleeping patterns, their performance at work or school and their general social and physical well-being. In this respect the "thud, thud, thud" of wind turbines is no different from any other type of noise.

Secondly, the combination of the noise and 'the flicker' from the turbines. We alluded to this on page seven when looking at why noise from wind turbines appears to distress a lot of people much more than noise at similar levels from other sources. We looked at the work of Pedersen and Persson Waye who found that people complain not just about the noise, but also about the vibration and shadow flicker (caused by rotation of the blades and the reflection of the sun). It is this combination, Pedersen and Persson Waye suggest, that could be the reason why wind turbines can have such a devastating effect on some people and on their health: "For some, the intrusion [of the noise, shadows and the rotating movements of the rotor] went further into the most private domain, creating a feeling of violation that was expressed as anger, uneasiness, tiredness."**(10).**

Thirdly, the overall impact of wind turbines on the body. Some people talk of 'feeling' the noise, in addition to, or even instead of, hearing it. This idea of 'feeling' noise is controversial and complex and not one currently accepted by the majority of acousticians. But there are a number of medical people who are beginning to argue that the dramatic impact which wind farms have on some people's health cannot be explained by the noise and the flicker alone. They argue that the low-frequency content of wind turbine noise (even if it is not heard), along with the 'flicker', can destabilise the human body.

In a paper expected to be published shortly Dr Amanda Harry says, "The low frequencies contribute to the overall audible noise but also produce a seismic characteristic which is one of the common complaints from people when they say that not only can they hear the noise but they can also feel it. This happens because the various parts of the body have a specific natural frequency or a resonance frequency. The human body is a strongly damped system, therefore, when a part of it is excited at its natural frequency, it will resonate over a range of frequencies instead of at a single frequency." (fig 1)

The doctors receive support from the National Academy of Medicine in Paris, presided over by Professor Claude-Henri Chouard. It argues that people living near the towers, the heights of which vary, sometimes complain of functional disturbances similar to those observed in syndromes of chronic sound trauma. It points to studies conducted in the neighbourhoods of airports which have demonstrated that chronic invasive sound involves neurobiological reactions associated with an increased frequency of hypertension and cardiovascular illness.

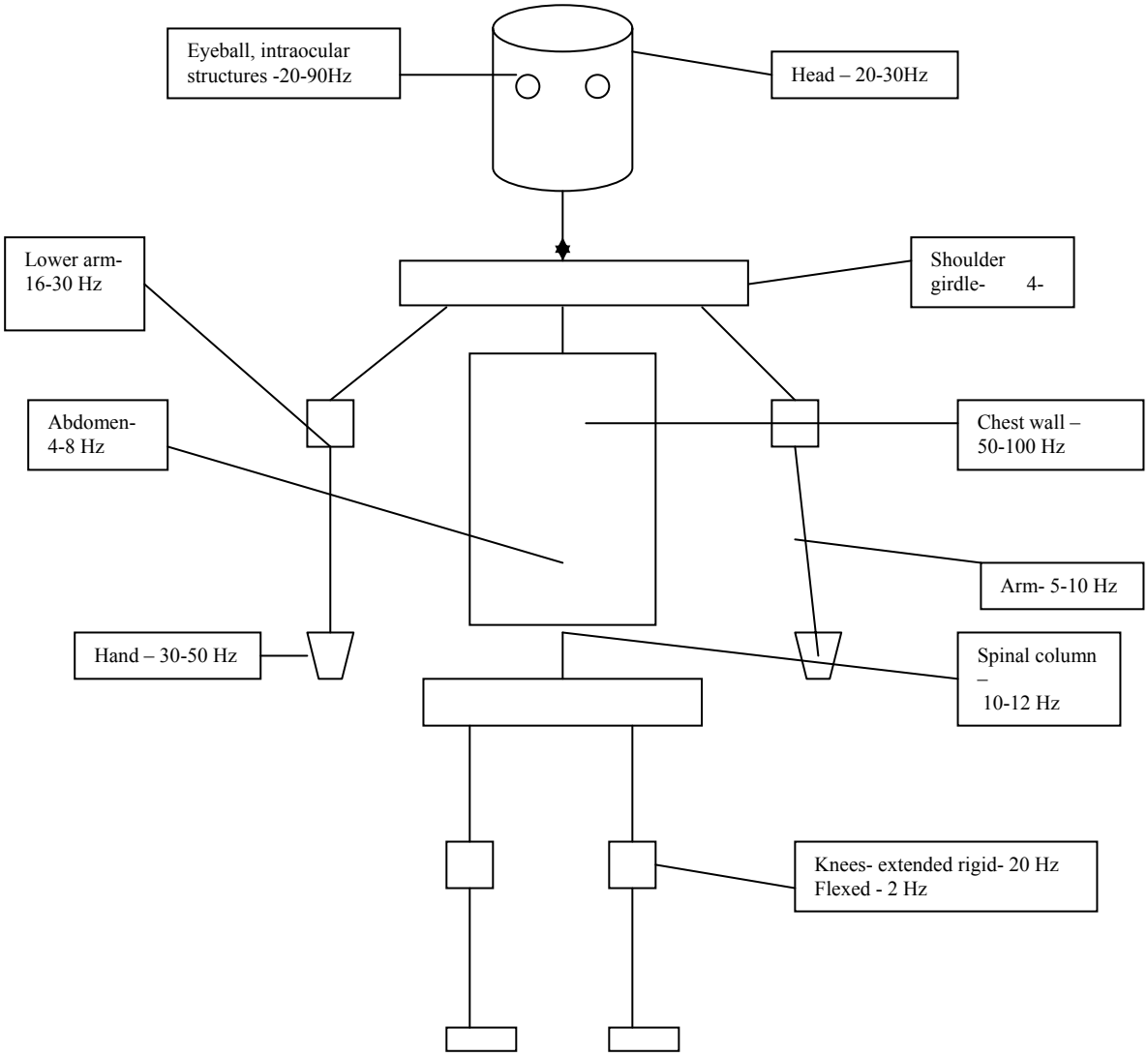
In Portugal, where low frequency noise has been researched extensively, a link has been found with a complex illness known as vibroacoustic disease. Although this research has been mainly concerned with high levels of low frequency noise, it is felt that prolonged exposure to lower levels of low frequency noise may cause similar problems. Certainly the symptoms which some people living around wind turbines complain of are very similar to those of vibroacoustic disease.

Over the years the military has been aware of the way a combination of persistent low-frequency noise, infrasound and visual strobing can destabilise the human body. Some doctors are arguing it at least merits serious investigation to understand whether this sort of cocktail can explain the extreme effect wind farms have on some people's health, an effect seemingly out of all proportion to the noise they make.

Certainly Dr Harry is scathing of the refusal of most acousticians to even look at this area: "On searching through the current literature I can find no papers written showing that turbines are harmless, only statements from acousticians giving their personal thoughts. I feel that these comments are made outside their area of expertise and should be ignored until proper medical, epidemiological studies are carried out by independent medical researchers".

Fig. 1

The resonance frequency ranges for various parts of the human body- values taken from the International Standards Organisation –ISO standards 2631



A research paper by G Rasmussen (ref) looked at body vibration symptoms vibration exposure at frequencies exposure at frequencies of 1-20 Hz

Symptoms	Frequency
General feeling of discomfort	4Hz – 9Hz
Influence on speech	13Hz – 20 Hz
Lump in throat	12 Hz – 16Hz
Chest pains	5Hz – 7Hz
Abdominal pains	4Hz – 10Hz
Urge to urinate	10Hz – 18Hz
Influence on breathing movement	4Hz – 8Hz

Also in the region 60-90Hz disturbances are felt which suggest eyeball resonances, and a resonance effect in the lower jaw/skull system has been found between 100-200

How Wind Farms Affect My Health - what people are saying

I first realised there might be a problem associated with wind turbines when I was introduced to a couple living near a wind farm in Cornwall. The distance from their home to the nearest turbine is about 400 meters. They told me about poor sleep, headaches stress and anxiety symptoms brought on when the wind was blowing in certain directions. At times, they told me that they have been so disturbed by the noise that after several disturbed nights sleep, they have sought refuge in a nearby bed and breakfast establishment (far enough away not to be similarly affected by the noise).

Dr Amanda Harry went on to conduct a survey on wind farms and health. These results will form part of an academic paper which is expected to be published shortly. The quotes on this page are taken from her work.

I get little sleep when the noise from the turbines is constant in its low frequency noise. I feel so depressed I want to get away and stay away until I know the wind direction has changed.

My symptoms are due to lack of sleep when the wind is in the east or northeast

Constant worry about noise. I feel sick when the turbines are running fast and towards the property. I came here to a rural area for peace after a busy city life. I feel this has been ruined by the turbines.

I get headaches frequently especially when the turbines are running at a fast rate towards us.

Stressed and extremely anxious, as I am constantly disturbed by them when they are turning fast and facing towards me. We are having to live our lives around them due to the constant noise when they are working causing wind pressure throbbing.

I get headaches and thumping in the ears. I also find its continual noise very distressing.

Irritating noise from wind farm in easterly winds. You can almost feel it as well as hear it. It drives you mad over extended periods because of the nature of the noise, not the level per se. Unable to have front doors/windows open when winds are easterly, or use front bedroom if all 7 turbines are in operation.

Suffer with headaches more and feel tired more so find daily tasks difficult to do.

The strobing even when curtains are closed is "HELL". The noise is a pain. TV blocks it, night and day. Can't sit and read a book or write letters.

I dare not sleep at home.

Tired, disturbed by noise. Feel it as much as hear it. Developers deny there are any problems. Unless we can prove it, but how can we do that?

Gwen's Diary

These wind turbines, they're 76m high, there are three of them, they have a looming presence over the beautiful Teifi Valley, I've been trying hard to come to terms with living within a mile of them ever since they appeared there on Moelfre hill twelve months ago.

I've lived here on my farm now with my husband for twenty six years, I know every nook and cranny of the fifty acres. Our farm is only two miles from the farm where I was born sixty years ago, I grew up looking towards Moelfre and was delighted to be farming within my own community. I've been teaching in local schools, I paint landscapes in a converted shed, I've enjoyed good health, twenty six years of hard but rewarding work, I had planned to spend my remaining days here.

Now I sleep in my outhouse shed, it's not comfortable, I don't want to sleep there, I don't choose to be so far from amenities all night and suffer the sounds of mice within a yard of my head. The trouble is that when I am in the house my heart beat seems to alter, there seems to be a repeated slightly thumping pressure on my lungs. There's a slight throbbing in my head, like a headache without the pain. I feel slightly sick. I know that slightly is a term I've used for all the ailments but it is not a normal state of well being. It makes me feel on edge. When I visit a friend on the other side of the valley that's when I feel normal, and that state of normality suddenly seems the most wonderful feeling on earth. To me this is a tragic turn of events. Compared to the total sum of human misery I admit it might sound trivial. Today we had the fire wood cut up for next winter, here we enjoy our own spring water, my garden, my roses and clematis, and oh the first violets and primroses in the woods. The seven thousand trees we've planted, my studio, this is what our life has been about! Now I feel robbed of all I hold dear, and to complicate the situation my husband is not affected by the turbines, he doesn't like the visual impact but they don't make him ill. The low frequency noise/vibrations from the turbines [not the blades] play havoc with my health.

Where do I go from here? When the company was granted permission for the development the local paper reported that this was a lifeline for the struggling Welsh speaking local farmer who otherwise would have had to leave the land, Hey I'm a Welsh speaking local too, where's my lifeline? I belong here, those turbines DO NOT.

A Shattered Dream

All they wanted was the good life in Cornwall, and they needed it for the sake of their health - but no sooner had Colin and Kathy Bird fled the city for a modest rural home than their dream was shattered by the noise from wind turbines.

Last year at Christmas the couple booked into B&Bs in Newquay rather than endure sleepless nights in their caravan home at St Eval. This year they have saved up £1,000 to live in Malta for a month because they cannot bear another winter at home when high winds turn the turbines.

When that noise from the Bears Down wind farm begins, says Kathy, it's like a "a deep throbbing, or a train that never gets there". For Colin it's worse. "You never rest your brain, you never get away from them," he says.

What makes it worse for the couple is that they moved to Cornwall to escape the noise of the city. Colin, 48, had suffered a nervous breakdown when he worked as a car factory worker in Coventry. But he was stirred by warm memories of boyhood holidays in Cornwall. And the couple spent six months each year for three years until 2000 in a rented caravan there, and found it blissfully peaceful. So they plunged what little money they had into their new life. They bought the neighbouring caravan and moved in one year before the 16-turbine wind farm opened in October 2001.

Their caravan is made mostly of aluminium, which exacerbates the tin can effect. But they point out that they were there before the wind farm, and they don't have the money to move anywhere else.

Kathy, 43, says: "I did put in a letter of complaint about the plans. I was very concerned about the wildlife - buzzards and peregrine falcons. Then, of course, noise was one of my concerns, but I never realised how bad it would be. At first I thought it was something in the home, but it was the turbines. "They get to a critical speed, which I believe is 40 knots, and then it disturbs us all the time. It's just as if we're in a box and it's reverberating all the time. "It's almost like a motion sickness, and it always seems to be worst at Christmas. "It's the constancy of them that gets to you, it can be for anything like three or four days, it's this deep throbbing."

The couple calculate that they booked into B &Bs four times last year to escape the turbines. But sometimes they just drive around until the wind dies down.

My plan was to stay here- in my newly converted barn (7 years old) (we farmed here) until I died. We have our own private water supply, a good supply of fire wood, my own painting studio- VERY IMPORTANT TO ME! And a good workshop for my husband; friends nearby, brother and sister nearby. I was born 2 miles away- Now WE HAVE TO MOVE. This move has been forced upon us. We planted 7,000 trees here. Etc.etc.etc……..

We will probably have to move, I can see no future for me here.

Noise disturbance at night – when wind in certain direction, interferes with sleep patterns, causing restlessness. During the day- makes it difficult to stay out of doors for any length of time through excessive thumping sound. Both can cause headaches, anxiety and irritability.

I feel generally off colour

I never suffered from any problems before the turbines. I am convinced that living in a continual state of anxiety over the past four and a half years since the noise nuisance started has contributed to my present problems. Prior to 1999 I always enjoyed excellent health and rarely visited the doctors surgery. As my husband and I have been retired since 1994 and our family grown up and living in different areas of the country we do not have any other problems that are likely to cause stress or anxiety.

The noise is like a whooshing noise. It is intrusive. It keeps me awake- it doesn't affect my husband as much as me but my being awake keeps him awake.

Our lives and home have been trashed and must be seen to be believed. We seem to be short tempered, unable to concentrate. Every thing we have such as mattress, duvets, cushions 4" thick, 3 rolls of sound deadening quilt, 3 sheets of corrugated asbestos, blankets, curtains, pillows, even floor carpet stacked against the walls to try and keep out the sound. Not the peace I volunteered to fight for.

Conclusions on Noise and Health

Pedersen's arguments are persuasive that the dancing shadows and the rotating blades can significantly add to the annoyance and stress caused by noise from the turbines.

The questions being asked by some in the medical profession as to whether this cocktail of effects – the noise, low-frequency, rotating blades, the shadows and the strobing – is leading to ill-health out of proportion to the noise turbines make, need serious examination.

Overall Conclusions

1. Wind Farm noise, in common with noise generally, affects different people in different ways, but the evidence suggests there is rarely a problem for people living more than 1-1.5 miles from a turbine.

2. For many people living relatively close to turbines, the noise does not present a problem. For those who are annoyed by the noise, it is overwhelmingly the "swish, swish, swish" of the turbines which troubles them.

3. For people who are not able to shut out the noise, the problem can be exacerbated by the rotating blades and the dancing shadows of turbines. This can mean that the noise from turbines can be much more intrusive that other noises of a similar decibel level.

4. For some people the impact of turbines can be overwhelming.

5. The noise can be a particular problem in rural areas where background noise levels are low.

6. The infrasound content of wind turbine noise is too low to be heard by most people.

7. At times, low-frequency will form an audible, but not major part, of the "swish" sound of the turbines and can, for people sensitive to low-frequency noise, create additional problems. But the low-frequency content of wind turbine noise is no greater than the low-frequency component found in several other noise sources and can only usually be heard down wind of a turbine when there is a fair bit of turbulence.

8. However, low-frequency may be underestimated because of the persistent use of 'A' weighting in measuring the noise, rather taking 'C' weighted measurements.

9. Research by medical doctors has unearthed persistent complaints from people saying they not only hear the noise from wind turbines, but can "feel" disturbance in their bodies. This has lead to complaints of illness. The symptoms people are complaining about are very similar to those associated with vibroacoustic disease. The suggestion is that the unique combination of noise (containing an element of low-frequency) and the strobing effects of the flickering blades, is having a physical effect on some people.

10. Modern turbines are mechanically quieter, but there is convincing evidence that the noise they emit is being underestimated because measurements continue to be taken at a height of 10ft from the ground, thereby underestimating the speed of the wind (particularly at night) at the top of the large, modern turbines, over 100 metres high.

Overall Recommendations

1. It would be prudent that no wind turbines should be sited closer than 1 mile away from the nearest dwellings. This is the distance the Academy of Medicine in Paris is recommending, certainly for the larger turbines and until further studies are carried out. There may even be occasions where a mile in insufficient depending on the scale and nature of the proposed development.

2. Wind farms should only be located in areas where the "swish, swish, swish" of the turbines will not cause noise problems for people.

3. There needs to be a clear and public recognition by the Wind Power Industry that wind turbines are causing significant noise problems for some people. This could open the door to constructive discussion.

4. The industry also should recognise that the evidence is persuasive that the noise problem can be exacerbated by the rotating blades and the dancing shadows of the turbines.

5. The official government guidelines for the siting of wind turbines need to be revised to take account of the more intrusive nature of the noise in areas where the overall background noise level is low.

6. The debate on wind farms would do well to recognise that the infrasound content of wind turbine noise is too low for most people to *hear.*

7. People need to be careful not to exaggerate the audibility of the low-frequency of the noise. It can be a problem at times, but over-emphasis on it can detract from the main noise problem: the 'swish, swish, swish' of the blades.

8. The guidelines should require the use of 'C' weighting (and 'G' weighting for infrasound) as well as 'A' weighting when measuring the noise from turbines in order to fully capture the low-frequency element.

9. Further work needs to be undertaken urgently to test the claims that the overall effect of turbines is having a physical effect on people to the detriment of their health.

10. There should be a short moratorium on the installation of the large, modern turbines until it is established, through trials, the amount of noise they actually emit.

Concluding Comment

Wind farms can play a role in reducing global warming emissions. But there is a very real danger that, in the enthusiasm to embrace clean technology, legitimate concerns about noise are being brushed aside. There is no doubt that some existing wind farms are causing real noise problems. This report has stopped short of arguing that those turbines should be shut down, though that possibility should never be ruled out. However, it would be quite unacceptable to our fellow citizens for this situation to be replicated in other parts of the country as new turbines come on stream. But this need not be the case. The positive conclusion of this report is that there is a constructive way forward. It simply requires sensible siting of the new wind farms. It's all about 'location, location, location'. It is in the interests of the wind power industry, environmental groups and local communities for us to get that right.

Appendix 1
Sample Measurements

(the full set of measurements runs to over 130 pages and is available from the Noise Association)

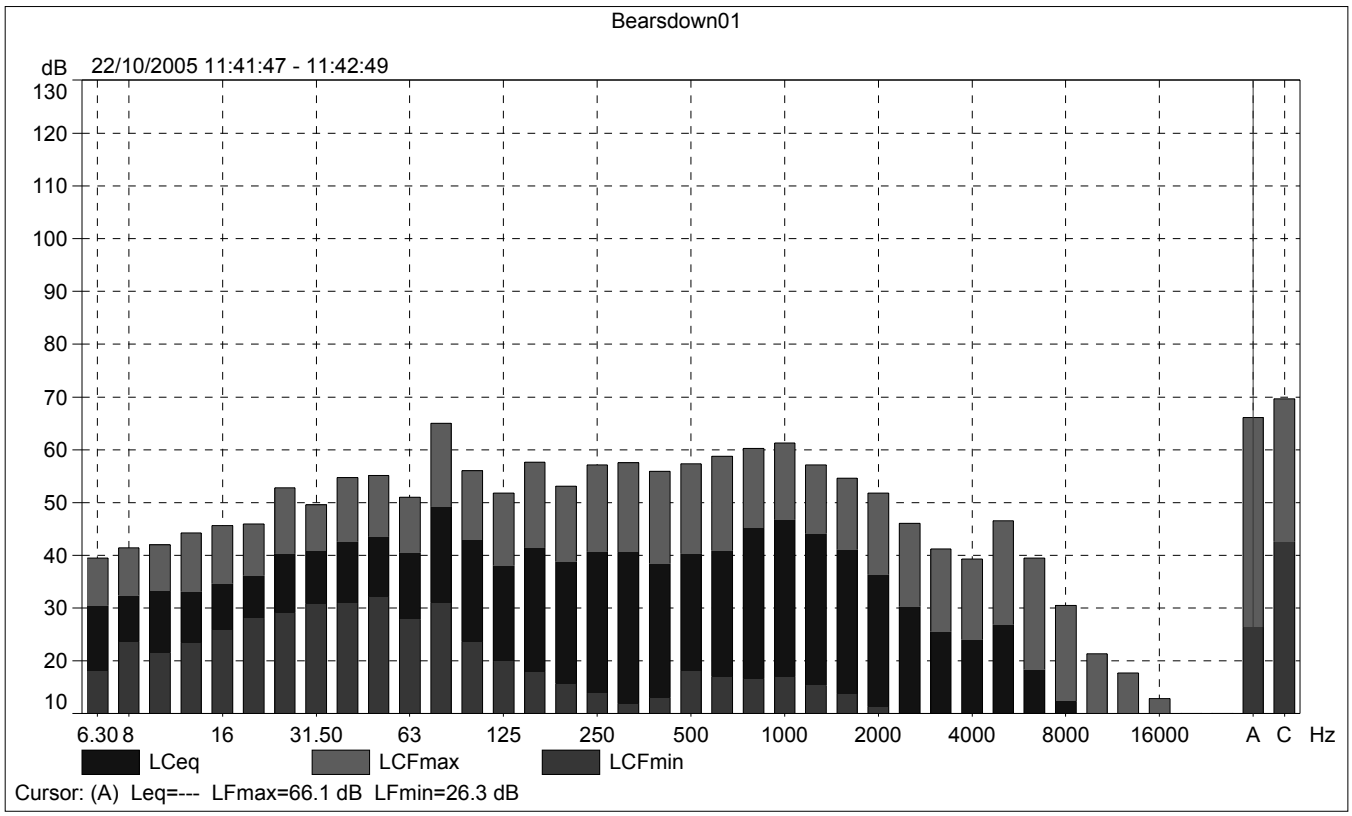
Bearsdown01, Nr St Eval, Cornwall, Wind Farm Noise Monitoring December 2005

Location	SH 893 676
Wind Speed	LOW
Wind Direction	NW
Microphone	Normal
Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	22/10/2005 11:41:47
End Time:	22/10/2005 11:42:49
Elapsed Time:	00:01:02
Bandwidth:	1/3-octave
Max Input Level:	140.44

	Time	Frequency
Broadband (excl. Peak):	FSI	AC
Broadband Peak:		C
Spectrum:	FS	C

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	UA 1650
Sound Field Correction:	Free-field
Calibration Time:	09/09/2005 14:47:53
Calibration Type:	External reference
Sensitivity:	53.03 mV/Pa

	Start time	End time	Elapsed time	Overload [%]	LAIeq [dB]	LAFmax [dB]	LAFmin [dB]
Value				0.00	54.7	66.1	26.3
Time	11:41:47	11:42:49	0:01:02				
Date	22/10/2005		22/10/2005				



Bearsdown02 Wind Farm Noise Monitoring December 2005

Location	SH 893 676
Wind Speed	LOW
Wind Direction	NW
Microphone	Normal
Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	22/10/2005 11:43:57
End Time:	22/10/2005 11:44:59
Elapsed Time:	00:01:02
Bandwidth:	1/3-octave
Max Input Level:	140.44

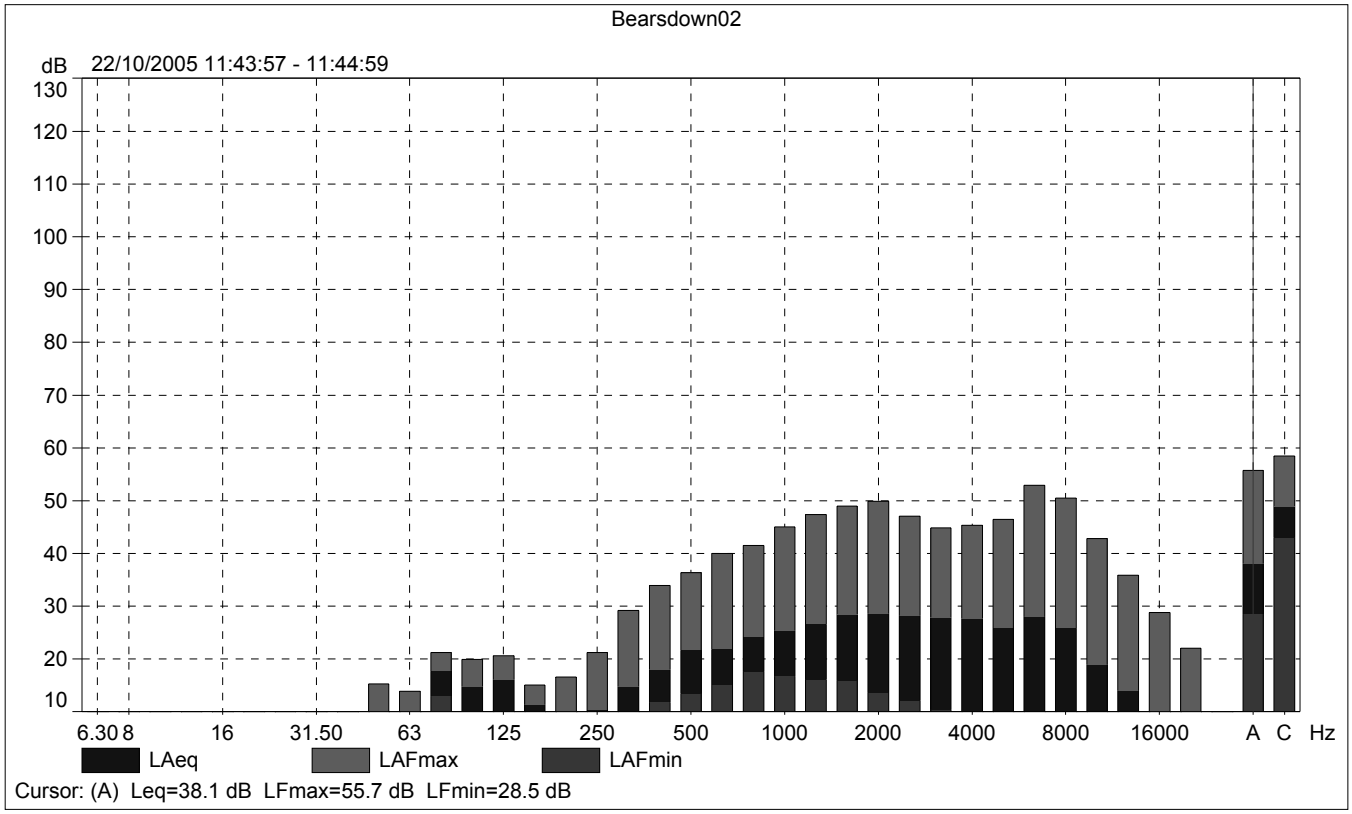
	Time	Frequency
Broadband (excl. Peak):	FSI	AC
Broadband Peak:		A
Spectrum:	FS	A

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	UA 1650
Sound Field Correction:	Free-field

Calibration Time:	09/09/2005 14:47:53
Calibration Type:	External reference
Sensitivity:	53.03 mV/Pa

Bearsdown02 Text

	Start time	End time	Elapsed time	Overload [%]	Overload [dB]	LAIeq [dB]	LAFmax [dB]	LAFmin [dB]
Value				0.00	48.8	55.7	28.5	
Time	11:43:57	11:44:59	0:01:02					
Date	22/10/2005	22/10/2005						



Bradworthy 01, Cornwall – Wind Farm Noise Monitoring December 2005

Wind Direction SW speed 14 – 27 MPH RAIN In Direct Wind

Location SS 304 135

Microphone - Normal

Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	07/12/2005 18:27:17
End Time:	07/12/2005 18:29:20
Elapsed Time:	00:02:03
Bandwidth:	1/3-octave
Max Input Level:	140.50

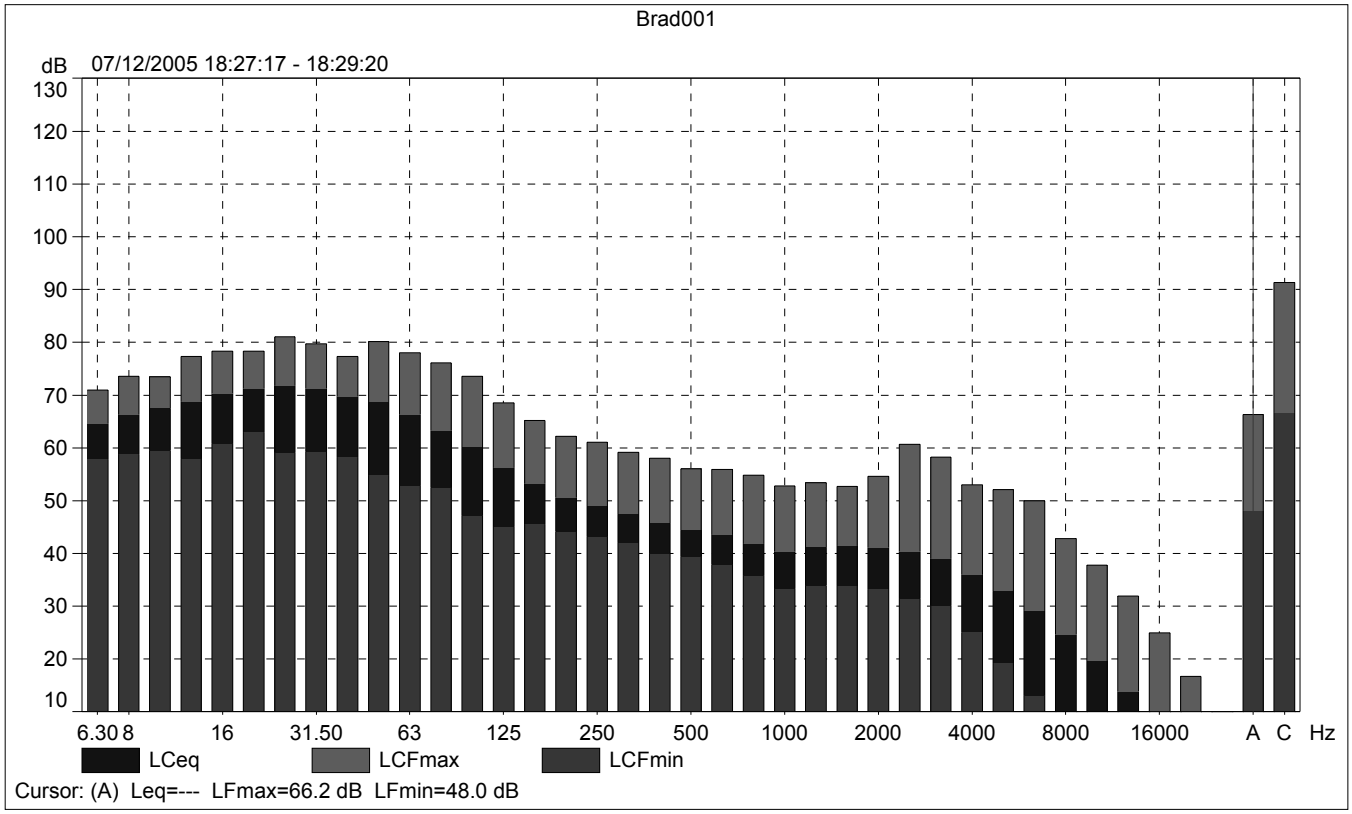
	Time	Frequency
Broadband (excl. Peak):	FSI	AC
Broadband Peak:		C
Spectrum:	FS	C

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	None
Sound Field Correction:	Free-field

Calibration Time:	07/12/2005 14:47:11
Calibration Type:	External reference
Sensitivity:	52.78 mV/Pa

Brad001 Text

	Start time	End time	Elapsed time	Overload [%]	[dB]	LAIeq [dB]	LAFmax [dB]	LAFmin [dB]
Value				0.00	57.8	66.2	48.0	
Time	18:27:17	18:29:20	0:02:03					
Date	07/12/2005		07/12/2005					



Bradworthy 02 - Wind Farm Noise Monitoring December 2005

Wind Direction SW speed 14 – 27 MPH RAIN
Shielded from Wind
Location SS 304 135
Microphone – 1Hz

Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	07/12/2005 18:32:15
End Time:	07/12/2005 18:34:22
Elapsed Time:	00:02:07
Bandwidth:	1/3-octave
Max Input Level:	140.50

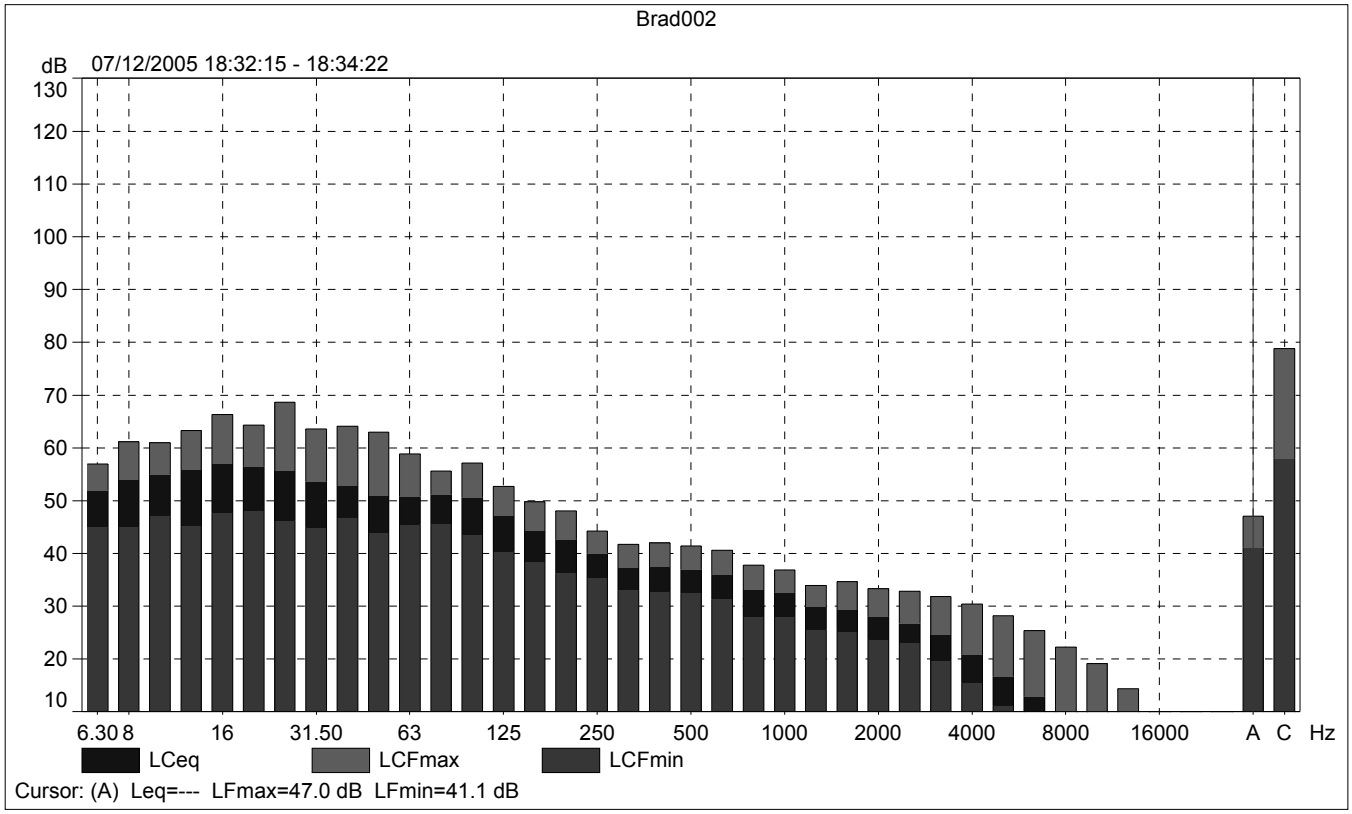
	Time	Frequency
Broadband (excl. Peak):	FSI	AC
Broadband Peak:	C	
Spectrum:	FS	C

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	None
Sound Field Correction:	Free-field

Calibration Time:	07/12/2005 14:47:11
Calibration Type:	External reference
Sensitivity:	52.78 mV/Pa

Brad002 Text

	Start time	End time	Elapsed time	Overload [%]	[dB]	LAIeq [dB]	LAFmax [dB]	LAFmin [dB]
Value				0.00	44.5	47.0	41.1	
Time	18:32:15	18:34:22	0:02:07					
Date	07/12/2005		07/12/2005					



Blaen Bowi, Wales - Wind Farm Noise Monitoring October 2005

Grid Ref SN 32792 BNG 35335

Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	13/10/2005 18:22:57
End Time:	13/10/2005 18:27:59
Elapsed Time:	00:05:02
Bandwidth:	1/3-octave
Max Input Level:	140.44

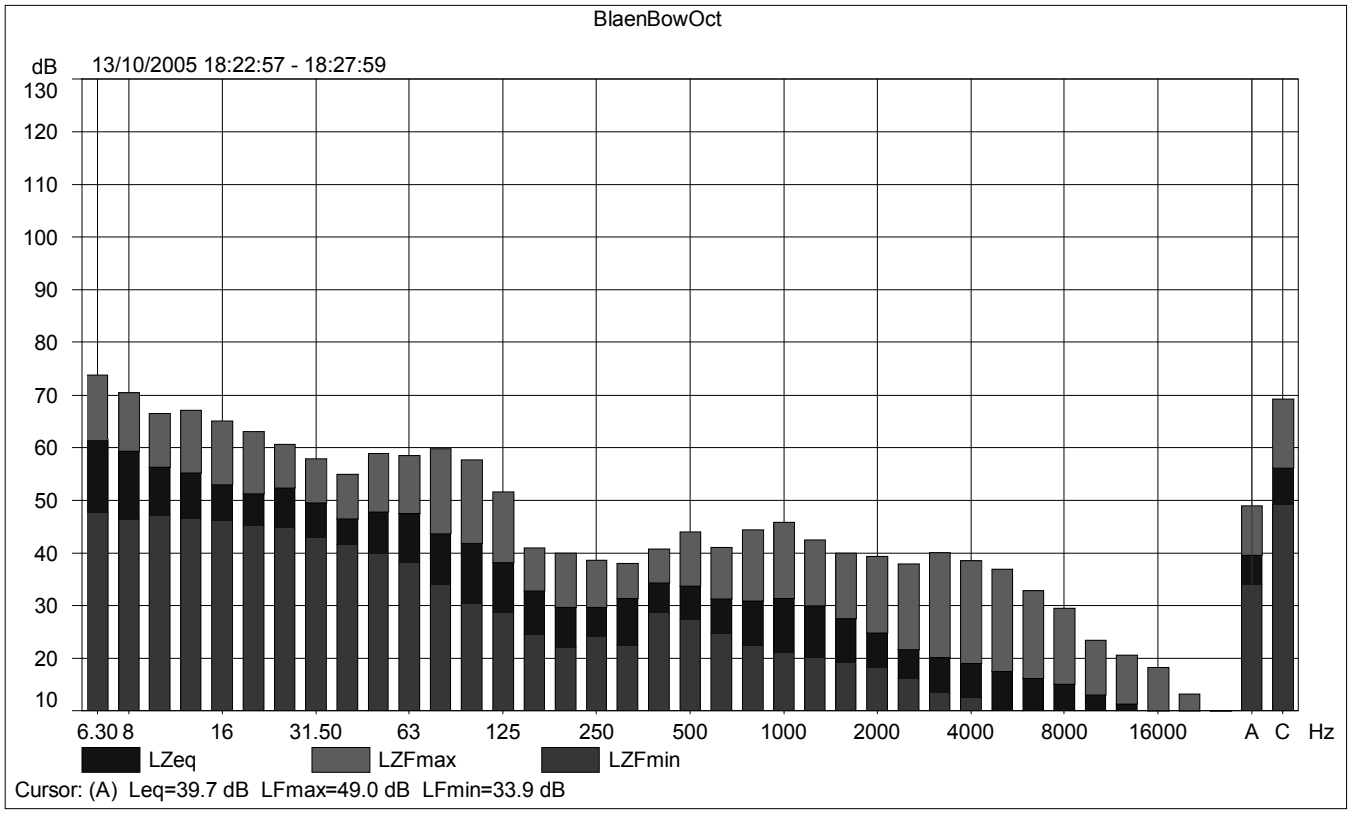
	Time	Frequency
Broadband (excl. Peak):	FSI	AC
Broadband Peak:		C
Spectrum:	FS	Z

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	UA 1650
Sound Field Correction:	Free-field

Calibration Time:	09/09/2005 14:47:53
Calibration Type:	External reference
Sensitivity:	53.03 mV/Pa

BlaenBowOct01 Text

	Start time	End time	Elapsed time	Overload [%]	[dB]	LAIeq [dB]	LAFmax [dB]	LAFmin [dB]
Value				0.00	41.1	49.0	33.9	
Time	18:22:57	18:27:59	0:05:02					
Date	13/10/2005		13/10/2005					



Blaen Bowi - Wind Farm Noise Monitoring October 2005

Grid Ref SN 32793 BND 35335

Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	13/10/2005 18:44:40
End Time:	13/10/2005 18:47:09
Elapsed Time:	00:02:29
Bandwidth:	1/3-octave
Max Input Level:	140.44

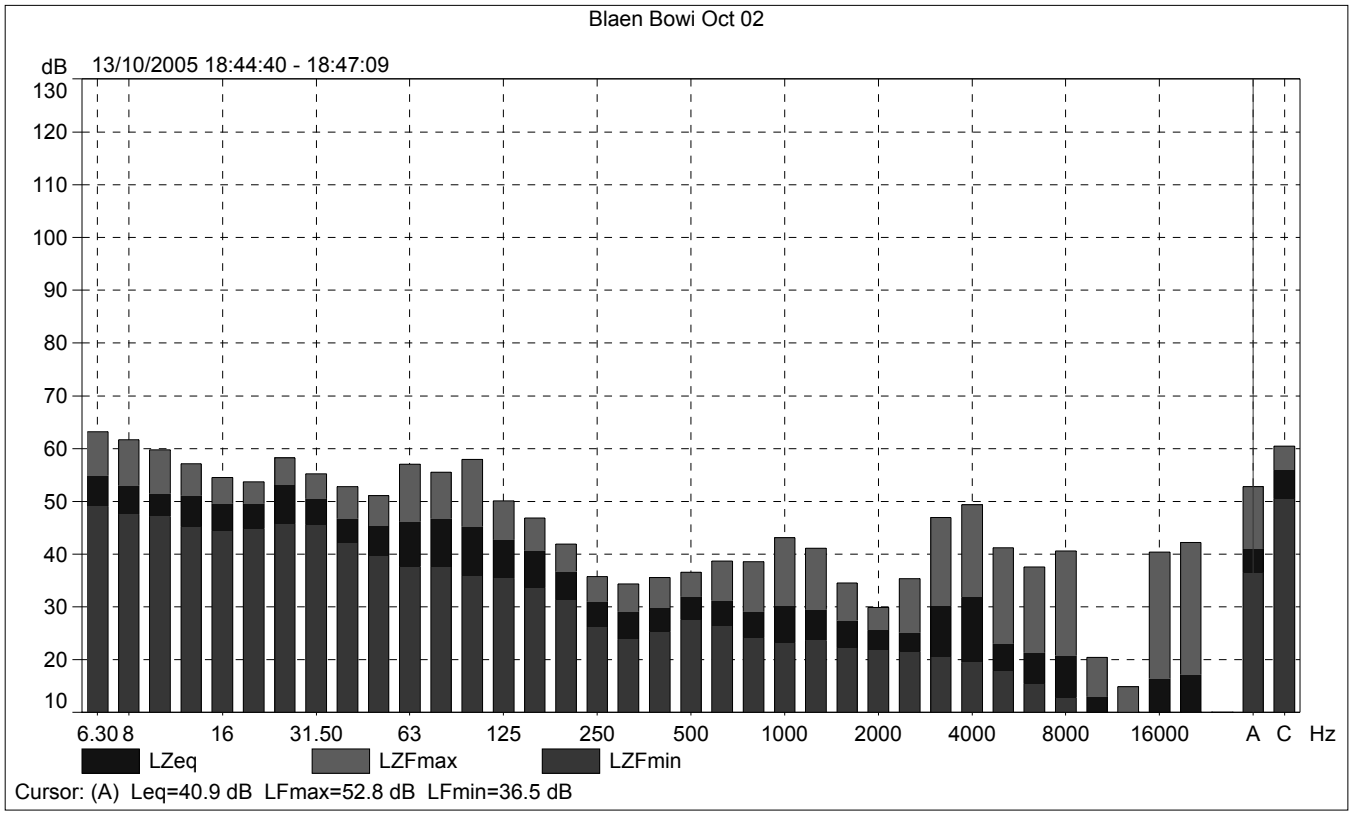
	Time	Frequency
Broadband (excl. Peak):	FSI	AC
Broadband Peak:		C
Spectrum:	FS	Z

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	UA 1650
Sound Field Correction:	Free-field

Calibration Time:	09/09/2005 14:47:53
Calibration Type:	External reference
Sensitivity:	53.03 mV/Pa

Blaen Bowi Oct 02 Text

	Start time	End time	Elapsed time	Overload [%]	[dB]	LAIeq [dB]	LAFmax [dB]	LAFmin [dB]
Value				0.00	44.3	52.8	36.5	
Time	18:44:40	18:47:09	0:02:29					
Date	13/10/2005		13/10/2005					



Blaen Bowi - Wind Farm Noise Monitoring October 2005

Defach-Velindre,Llandysul,Carmarthenshire (OS Grid Reference 33852 36332)

1hz Filter Installed

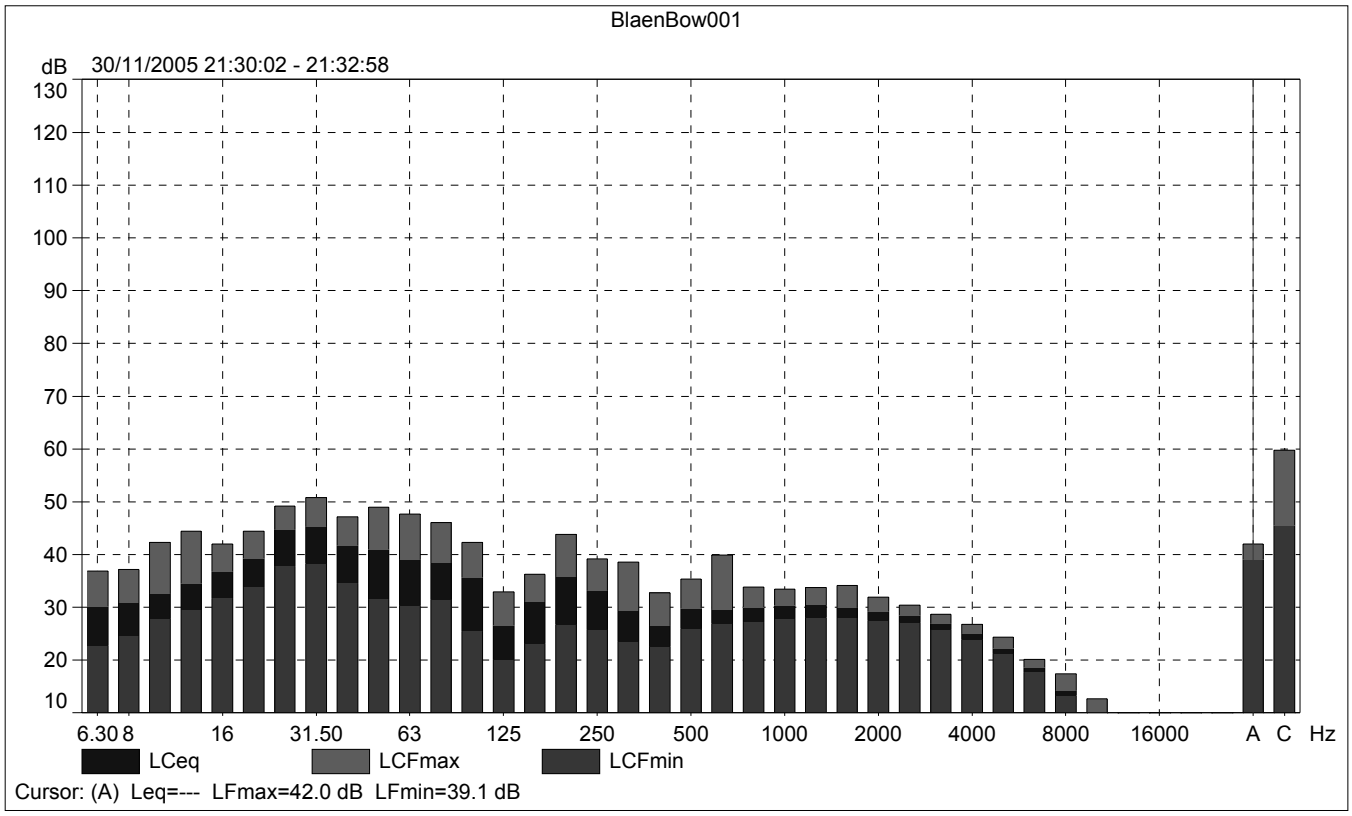
Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	30/11/2005 21:30:02
End Time:	30/11/2005 21:32:58
Elapsed Time:	00:02:56
Bandwidth:	1/3-octave
Max Input Level:	140.44

	Time	Frequency	
Broadband (excl. Peak):	FSI	AC	
Broadband Peak:		C	
Spectrum:	FS	C	

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	None
Sound Field Correction:	Free-field
Calibration Time:	09/09/2005 14:47:53
Calibration Type:	External reference
Sensitivity:	53.03 mV/Pa

BlaenBow001 Text

	Start time	End time	Elapsed time	Overload [%]	[dB]	LAIeq [dB]	LAFmax [dB]	LAFmin [dB]
Value				0.00	40.5	42.0	39.1	
Time	21:30:02	21:32:58	0:02:56					
Date	30/11/2005		30/11/2005					



Blaen Bowi - Wind Farm Noise Monitoring October 2005

Defach-Velindre,Llandysul,Carmarthenshire (OS Grid Reference 33852 36332)

1hz Filter Installed

Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	30/11/2005 21:34:04
End Time:	30/11/2005 21:34:49
Elapsed Time:	00:00:45
Bandwidth:	1/3-octave
Max Input Level:	140.44

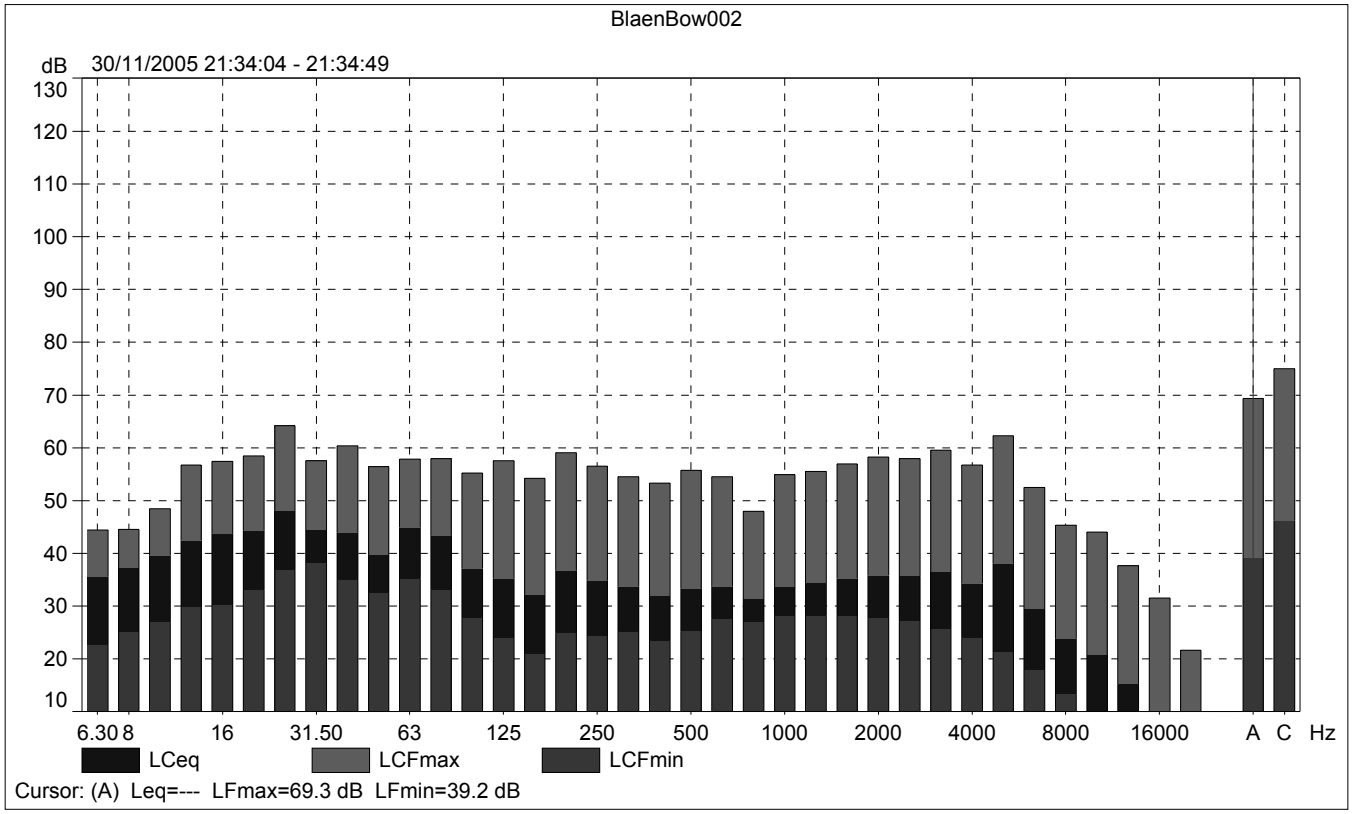
	Time	Frequency
Broadband (excl. Peak):	FSI	AC
Broadband Peak:	C	
Spectrum:	FS	C

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	None
Sound Field Correction:	Free-field

Calibration Time:	09/09/2005 14:47:53
Calibration Type:	External reference
Sensitivity:	53.03 mV/Pa

BlaenBow002 Text

	Start time	End time	Elapsed time	Overload [%]	[dB]	LAIeq [dB]	LAFmax [dB]	LAFmin [dB]
Value				0.00	59.1	69.3	39.2	
Time	21:34:04	21:34:49	0:00:45					
Date	30/11/2005		30/11/2005					



References

(1) Effects of the wind profile at night on wind turbine sound by Fritz van den Berg, published in the Journal of Sound and Vibration, 2004)

(2) The Use of 10 metre Wind Speed Measurements in the Assessment of Wind Farm Developments, paper given by Peter Botha at Berlin Conference.

(3) Noise Annoyance from wind turbines – a review, August 2003, published by the Swedish Environmental Protection Agency.

(4) How the Mythology of Infrasound and Low Frequency Noise Related to Wind Turbines Might Have Developed, Dr Geoff Leventhall Oct 2005.

(5) Mitigation measures for night time wind turbine noise, paper presented to Berlin Conference, Fritz van den Berg Oct 2005.

(6) Wolsinki et al Annoyance from wind turbine noise on sixteen sites in three countries, 1993.

(7) Pedersen and Persson Waye, Storiningar fran Vindkraft 2002.

(8) Public Attitude to Windfarms, Scottish Office, 2003.

(9) Paper by David Craig submitted to Enterprise and Culture Committee – Renewable Energy in Scotland Inquiry, 10/2/04.

(10) Human Responses to Wind Farm Noise – Annoyance and Moderating Factors. Berlin Conference Oct 2005.

(**First International Conference on Wind Turbine Noise, Berlin, October 17/18th 2005)**

(11) Fidell et al. Effects of aircraft over-flights on wilderness recreationists 1996.

(12) British Standard 4142, Method for rating industrial noise affecting mixed residential and industrial areas.

(13) Mitigation measures for night-time wind turbine noise, van den Berg, October 2005.

(14) Guidelines for Community Noise

(15) UKNA Briefing, Hazel Guest, 2004

(16) Perceptions of the Public of Low Frequency Noise, Manley, Styles and Moorhouse, published in the Journal of Low Frequency Noise, Vibration and Active Control (2002),

(17) Microseismic and Infrasound Monitoring of Low Frequency Noise and Vibrations from Windfarms, Styles, Keele University

(18) Low Frequency Noise & Vibration Levels at a Modern Wind Farm, 1996, by Styles, Manley et al - the work was funded by ETSU on behalf of the DTI.

Acknowledgements

Location, Location, Location **has been researched, written and designed by John Stewart, who chairs the UK Noise Association. He received invaluable help from Hazel Guest, Peter Haddon, Dr Amanda Harry, Paul Harry (who took the measurements), Richard Hendin, the late Dr David Manley, Monica Robb, Henry Thoresby and Val Weedon. Thanks also to Dr Geoff Leventhall who made the proceedings of the Berlin Conference on wind farms available free of charge.**

We are particularly grateful to the Ashden Trust for their grant in funding the research

Published by The Noise Association Printed by RAP Spiderweb July 2006