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Renewable Energy Foundation Response to the:

IoA Consultation on the Supplementary Guidance Notes to "A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise"

1 Summary

1.1 The Renewable Energy Foundation (REF) welcomes the opportunity to respond to the Institute of Acoustics (IoA) on the *Supplementary Guidance Notes* that have been produced to follow the publication in June 2013 of *A Good Practice Guide to the Application of ETUS-R-97 for the Assessment and Rating of Wind Turbine Noise* (hereafter the GPG).

1.2 We are perturbed that the first round of consultation that preceded the publication of the *Good Practice Guide* itself was not followed up by a consultation response document in which the IoA addressed the issues raised by the consultees. There were a number of technical responses from well-qualified engineers drawing the IoA's attention to technical flaws in the fundamental science underpinning the GPG, and these required an answer. The credibility of the GPG is undermined by the failure of the IoA to provide an evidence-based defence of the guidance.

1.3 We consider that there are two fundamental problems with the IoA *Supplementary Guidance*, firstly the treatment of wind shear in *Supplementary Guidance* Note 4, where the IoA proposes two conflicting methodologies for measuring the wind speeds which are used to assess the noise impacts and to set the noise condition limits for a wind farm. We demonstrate below that the new and IoA-preferred methodology using the so-called 'standardised' 10m wind speeds results in increased noise limits compared with those formulated in ETSU-R-97, which are based on measured 10m wind speeds and already widely acknowledged to offer inadequate protection to residents.

1.4 The presentation of two conflicting methods will lead to further confusion and debate as to which of the two methodologies a planning Inspector or local authority should use in setting noise condition limits. We see this outcome as an inevitable (though unintended) consequence of the increasing complexity of wind farm noise guidance, which is poorly understood even by professionals, and even, apparently, by the IOA GPG authors.

1.5 Furthermore, the IoA have previously made it clear that their remit in producing the GPG was not to increase noise limits above the ETSU-R-97 limits, but unfortunately, this is, in point of fact, the effect of their recommended wind shear methodology. Moreover, the IoA methodology provides extra headroom for extra wind farm noise at times of high wind shear which occurs during evenings and night times when low background noise levels prevail. Consequently, the impact of these changes will be very significant and negative for wind farm neighbours.

1.6 The second major problem concerns the guidance provided for turbine noise predictions used in the planning system when assessing probable noise impacts. The key parameters are the turbine sound power levels, which are provided by turbine manufacturers, and a ground parameter used to account for sound reflected from the ground surface and interfering with the sound propagated directly from turbine to receiver.

1.7 Recommendations for these key parameters are made in the GPG and in *Supplementary Guidance* Note 3. However, no data is produced to demonstrate that these parameters correctly predict turbine noise. We have commented in the past that the code of conduct of the IoA includes the requirement that primary data used in any publication or report are available in a form that would allow for independent scrutiny. However, the GPG is not consistent with this recommendation since the evidence base for the recommended noise prediction methodology has, in spite of requests, not been published. Consequently, the reliability of the recommended method cannot be objectively tested, and must be regarded as of doubtful quality.

1.8 In fact, we have investigated in some detail two publications that cite results for a number of un-named wind farms, and find from that analysis that the conclusions adopted by the IoA GPG are not supported by this data.

1.9 Furthermore, we provide results of independent turbine noise measurements that not only exceed the predicted noise levels when derived using the IoA GPG methodology and parameters, but exceed them by a considerable margin.

1.10 The IoA must as a matter of urgency address the faults outlined above, and revise the *Good Practice Guidance* accordingly. Without such validation and revision the GPG has no credibility, and is manifestly unfit for purpose. Where it sought to clarify matters it has introduced further confusions; where it promised to give neighbours increased confidence in the protection, it has exposed them to a higher risk of noise disturbance.

2 Consultation Response Document

2.1 We have an overarching criticism of the process adopted by the IoA to-date concerning the treatment of previous consultation responses to the main Good Practice Guide. It is a normal requirement following a public consultation, that a consultation response document is generated in which the specific points raised by consultees are addressed. Where a consultee has made a recommendation or criticism of the original document, it behoves the IoA to explain either what adjustment to the guidance was made to accommodate the point, or, on what evidential basis was the point rejected.

2.2 To produce no such consultation response document undermines the credibility of the IoA Good Practice Guide and we feel has resulted in general disillusionment with the process to such a degree that we anticipate fewer responses to this second consultation. We feel that a belated consultation response document should be produced for the GPG as well as for the consultation on the Supplementary Guidance Notes.

2.3 We also have reservations about the anonymity granted by the IoA to the consultation responses in the first consultation round. Public trust in the independence of the process is undermined by permitting parties to comment anonymously.

2.4 The recent revision of the IoA website seems to have resulted in the consultation responses disappearing from the public domain. This too is unacceptable.

3 Supplementary Guidance Note 3 : Sound Power Level Data

3.1 The ability to predict accurate wind farm noise levels at dwellings that can be demonstrated to account for variation between individual turbines, turbine age and condition, meteorological conditions, topography and varying ground conditions is obviously necessary for a robust noise assessment. The IoA GPG recommends use of the ISO9613 noise prediction methodology where the key input parameters are the turbine source sound power levels (SPL) and a ground factor.

3.2 The IoA GPG recommends using the benign (to the wind developer) semi-hard ground factor of G=0.5 rather than the hard ground factor (G=0) even though it is acknowledged that the latter factor provides robust predictions in most situations. To mitigate in part the reduced noise levels predicted using G=0.5, the document spells out a complex set of rules concerning choice of sound power levels (para. 4.3.6).

3.3 However, the IoA advance no evidence that can be independently tested to demonstrate that the combined recommendations for SPL and Ground Factor result in accurate turbine noise predictions. It appears that the authors of the IoA GPG have relied largely on publications related to anonymous wind farms using data owned by wind farm companies who apparently refuse to release that data.

3.4 Moreover, the work relied upon involves multiple turbines in complex terrain which introduces a series of uncertainties in the results. The obvious requirement as a starting position is for data to be made available demonstrating that the recommended parameters for SPL and Ground Factor yield robust noise predictions for a single turbine in flat terrain over time and in different meteorological conditions. This is missing.

3.5 Of particular concern to us is that evidence is produced to demonstrate that the recommended noise prediction methodology correctly predicts noise levels at times of high wind shear because these are the times that appear to trigger noise complaints.

3.6 Analysis of the papers relied upon shows that these do not consider high wind shear specifically but, in any case, the evidence does not support the recommendations made by the IoA GPG. The first of these papers is reference iv in the IoA GPG: *Wind Farm Noise Predictions and Comparison with Measurements* by A. Bullmore, J. Adcock, M. Jiggins, M. Cand, (Proc. Wind Turbine Noise 2009 Conference, Aalborg Denmark, June 2009).

Critique of "Wind Farm Noise Predictions and Comparison with Measurements 2009"

3.7 This is a study comparing measured wind farm noise levels with predicted levels at 3 anonymous wind farms. It concluded that predictions using G=0 overstated actual turbine noise levels thus apparently supporting the use of G=0.5 for noise assessments which results in lower turbine noise predictions.

3.8 From the limited "Site Descriptions" information available, we can tell the three wind farms involve large numbers of turbines. The turbine models are not named but the description reveals they are the old-fashioned two speed, active stall type which has completely different noise characteristics to modern variable speed turbines. The terrain is clearly not representative of much of the UK because of the existence of peat bog. Data concerning the wind shear of the sites during the measurements is not published but we can infer that it was low because of the fact that high wind speeds and high rainfall is referred to, indicating there was low wind shear during the measurements.

3.9 We know the data was collected prior to 2007. The wind farms are described as comprising more than 20 turbines. The turbines in all three cases were two speed active stall regulated machines rated at over 2 MW generating capacity per machine, with hub heights of 60 to 70 meters. In 2007 there were only six wind farms - all in Scotland - which matched those criteria. All appear to have the two speed Bonus 2.3 MW model turbines which have since been discontinued. It is possible to guess the sites A, B & C as given in the following table.

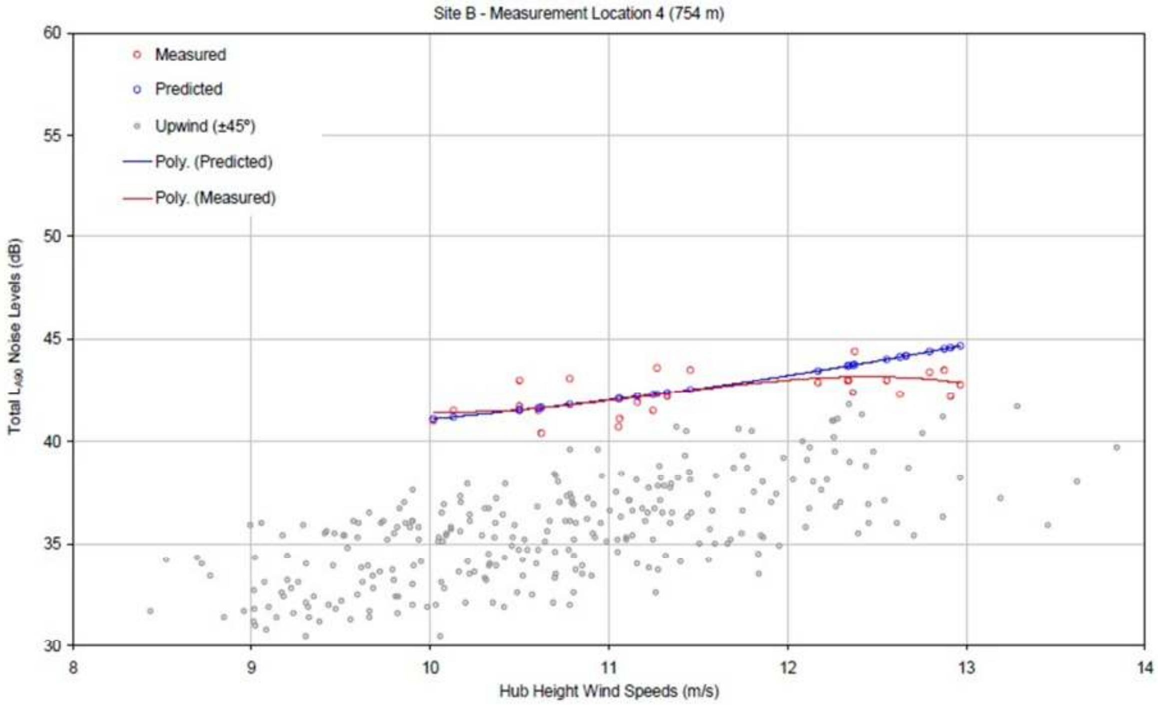
Table 1. Potential wind farm candidates for the 2009 study of wind farm noise

Wind Farm	**Number of Turbines**	**Turbine Capacity (MW)**	**Possible Wind Farm Site**
Black Law	54	2300	C
Causeymire	21	2300	B
Farr	40	2300	A
Hadyard Hill	52	2300	
Pauls Hill	28	2300	
Rothes	22	2300	

3.10 Site B has the most information in the paper and is described as flat. The detective work indicating Site B is Causeymire is not conclusive. However, this is far from crucial since it is useful to have a potential candidate wind farm to illustrate the flaws in the study. The following schematic shows the layout of Causeymire with a microphone sited 754 m slightly west of north of the wind farm as described in the report. Also shown is a +/- 15^{o} arc; this shows the range of wind directions used for the exercise as recommended by the international standard (IEC 61400-11).

3.11 The authors plotted measured and predicted noise levels at the microphone (Figure 2d in their paper). This appears to show that using G=0 results in most of the actual measured noise levels (red dots) falling below the predicted noise levels (blue dots).

Figure 1. Figure 2d from "Wind Farm Noise Predictions and Comparison with Measurements 2009" showing measured (red dots) and predicted (blue dots) wind farm noise levels. All downwind angles restricted to +/- 15 degrees. Predicted noise levels based on a single site wind speed reference and G=0.

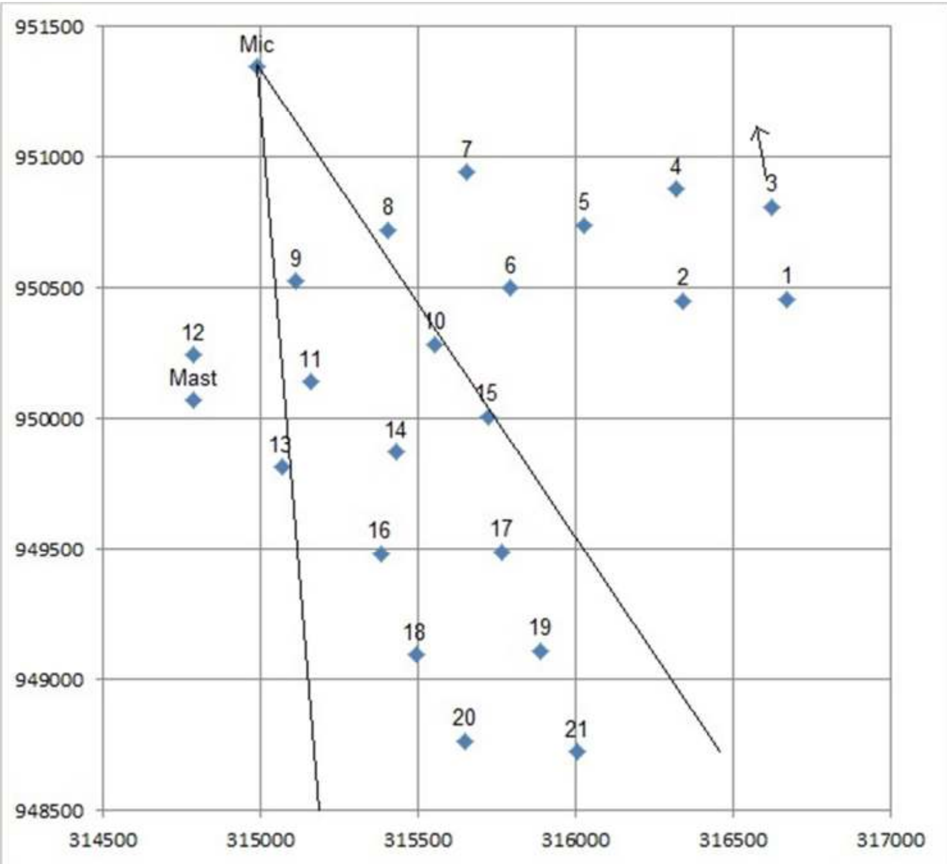


3.12 However, the plot is based on two unfounded assumptions: (i) that the microphone is equally downwind of all the turbines when the wind direction is within the +/- 15^o arc; and (ii) that all turbines experience the same wind speed when the wind direction is within the +/- 15^o arc.

Microphone not equally downwind of all turbines

3.13 As can be seen from the small arrow above turbine 3, when the wind direction is nearly northerly within the arc, noise from the east-most turbines is not directed at the microphone. The analogous situation applies to the west-most turbines. The assumption that all turbines in a large wind farm like this are equally downwind will result in erroneously high turbine noise predictions.

Figure 2. A schematic showing the turbine layout at Causeymire Wind Farm with a microphone 754m slightly to the west of north of the wind farm and a +/- 15^o arc centred on the microphone.



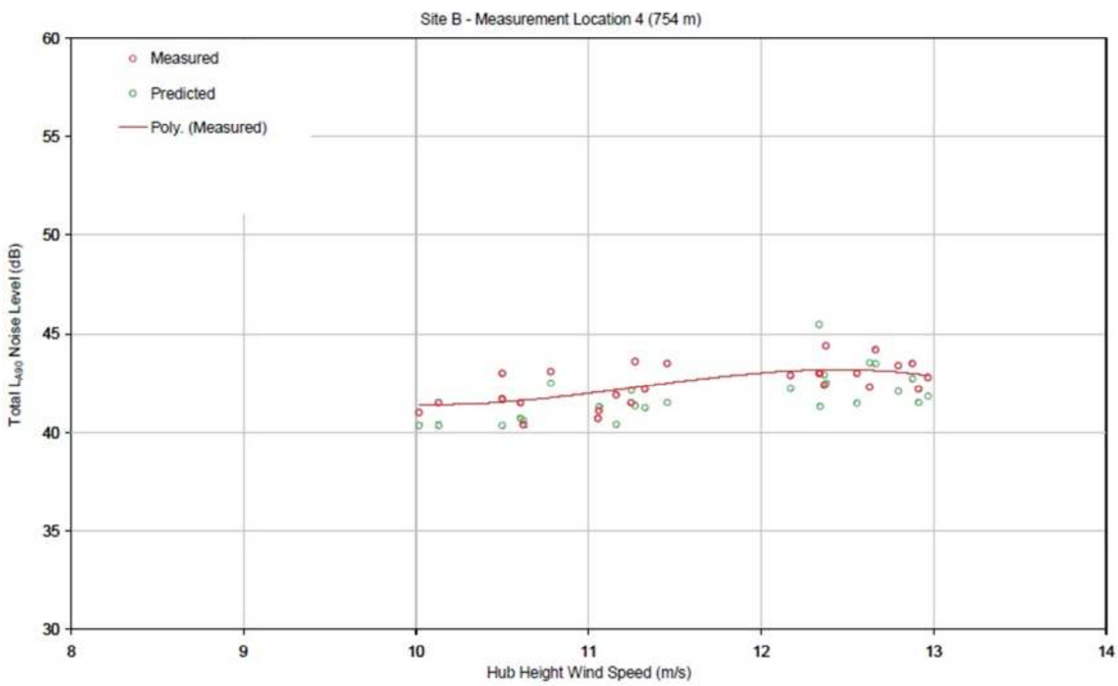
Wake effects not accounted for

3.14 The second assumption - that all wind turbines will experience the same wind speed is also wrong – downstream wind turbines lose 20% or 30% of their power, and sometimes even more, relative to the front row because of wake effects.[1] i.e. turbines 20 and 21 in the above figure will shelter turbines 18 and 19 which in turn will reduce the wind speed at turbines 16 and 17 etc.

3.15 The authors acknowledge there is a problem with the second assumption and provide a graph (Figure 3b of their paper) with predictions based on the actual wind speeds experienced by each turbine. However, this is not for the +/- 15^o arc but for a +/- 45^o arc. Increasing the total arc to 90^o will exacerbate the problem with the downwind angles described above very seriously. Again, the impression is given that the noise predictions with G=0 tend to overstate actual measured noise levels.

3.16 Clearly the correct graph to produce would be one comparing noise predictions and measured noise levels when the wind direction is (a) in an arc of +/- 15^o and (b) using the wind speeds seen by each turbine. Using computer software, it is possible to extract this data from Figures 2d and 3b to obtain the figure shown below.

Figure 3. Measured (red dots) and predicted (green dots) wind farm noise levels. All downwind angles restricted to +/- 15 degrees. Predicted noise levels based on a turbine specific wind speeds and G=0.



3.17 Using the correct set of data completely reverses the results. The following table summarises the data. From this we can see that whereas Figure 3b in the Hoare Lea paper suggests that 69% of the predicted points using G=0 are greater than the measured noise

[1] Professor David MacKay http://withouthotair.blogspot.co.uk/2010/01/wind-farm-wakes.html

levels, once corrected for wake effects and using their own data, the result, in fact, is that 73% of the measured noise levels are greater than the predicted levels using G=0.

Table 2. Table showing the degree of under-prediction of turbine noise when wake effects are correctly accounted for

	Prediction using G=0 exceeds actual noise level	Prediction using G=0 equal to actual noise level	Prediction using G=0 less than actual noise level
Hoare Lea Fig 3b (reproduced in Figure 1 above)	18 (69%)	1 (4%)	7 (27%)
Figure 3 which corrects for wake effects	6 (23%)	1 (4%)	19 (73%)

3.18 Therefore, we see that the Hoare Lea data relied on by the IoA GPG to recommend use of G = 0.5, properly analysed indicates that even using G=0, which results in higher turbine noise predictions, understates the actual measured noise levels at a receptor site.

Minimal data used

3.19 A further problem is that the conclusions are based on a tiny subset of the data collected. In spite of collecting data for 57 days, only 26 ten minute data points (0.3%) are used in the key graphs 3b and 3d. Thus, only 4 hours of data out of 57 days' worth inform the conclusions.

Study wind speeds atypical for most UK sites

3.20 The 26 data points range over hub height wind speeds of 10-13 m/s. These are high wind speeds compared with what is the norm at most onshore sites where most wind speeds are less than 10 m/s. It is well established that high wind shear is unlikely to occur when wind speeds are this high.

Critique of Cooper and Evans reports

3.21 Work of Australian acousticians, Evans and Cooper (reference vii in the IoA GPG) on turbine noise prediction is also cited as providing support for the use of the ISO9613 methodology with the ground parameter, G=0.5. However, close scrutiny of the very limited data provided by the authors does not accord with this conclusion.

3.22 The published work lists a table of differences between measured noise levels and predicted noise levels at anonymous wind farms with unidentified wind turbines of unknown size and number. Minimal results are published; essentially one column where G=0 was used for noise predictions and a second where G=0.5 was used. No uncertainties in the results are provided and it is not possible to see how the results varied with wind speed. The figures showing the difference between predicted and measured turbine noise levels are reproduced below.

Table 3. Results of Evans and Cooper measurements using Australian noise metrics and conventions

Wind farm	Distance	Terrain	Predicted - actual G=0 (1)	Predicted - actual G=0.5 (2)
A1	1000	Steady downward slope	5.8	2.2
A2	800	Steady downward slope	5.4	2.2
A3	800	Concave downward slope	-0.4	-3.5
B1	1500	Concave downward slope	-0.7	-3.8
B2	1000	Slight concave slope	1.0	-2.4
B3	1000	Concave downward slope	-0.4	-3.4
B4	3000	Concave downward slope	-0.3	-4.8
C1	600	Flat	2.9	1.0
C2	300	Flat	2.9	0.1
C3	700	Flat	2.6	-0.6
D1	300	Flat	3.2	0.0
E1	1200	Flat	2.5	-1.2
F1	700	Flat	2.1	-1.0

(1) Predicted LAeq using ISO9613 with G=0 minus measured LA90
(2) Predicted LAeq using ISO9613 with G=0.5 and receiver height 1.5m minus measured LA90

3.23 At first glance, it could be concluded that the data shows that using G=0 results in turbine noise predictions that are 2-5 dB higher than what is measured. However, the Australian acousticians use different metrics to what is use in the UK i.e. the predicted values are LAeq not LA90 and the receiver height used was 1.5m not 4m for G=0.5 as recommended in the IoA GPG. Converting the numbers above into the IoA GPG standard metrics, the table becomes:

Table 4. Results of Evans and Cooper measurements with IoA GPG metrics and conventions

Wind farm	Distance	Terrain	Predicted - actual G=0 (1)	Predicted - actual G=0.5 (2)
A1	1000	Steady downward slope	3.8	1.5
A2	800	Steady downward slope	3.4	1.5
A3	800	Concave downward slope	-2.4	-4.2
B1	1500	Concave downward slope	-2.7	-4.5
B2	1000	Slight concave slope	-1	-3.1
B3	1000	Concave downward slope	-2.4	-4.1
B4	3000	Concave downward slope	-2.3	-5.5

C1	600	Flat	0.9	0.3
C2	300	Flat	0.9	-0.6
C3	700	Flat	0.6	-1.3
D1	300	Flat	1.2	-0.7
E1	1200	Flat	0.5	-1.9
F1	700	Flat	0.1	-1.7

(1) Predicted LA90 using ISO9613 with G=0 minus measured LA90
(2) Predicted LA90 using ISO9613 with G=0.5 and receiver height 4m minus measured LA90

3.24 It can be seen that using G=0.5 under predicts measured turbine noise in 10 out of the 13 cases and by up to 5 dB. Using G=0 either under-predicts turbine noise or is within 1dB in 10 out of the 13 cases.

3.25 Furthermore, if one were to calculate the difference between the last two columns, it should reflect the difference between the two prediction calculations using G=0 and G=0.5 and should be around 1.7-1.8 dB. A number of the cases are conspicuously wrong on this test. These straightforward discrepancies cast doubt on the work as a whole and especially any attempt to use it to validate UK procedures.

3.26 It is also worth noting that the sound pressure levels used in the work were measured by the authors. It is not stated whether these levels agree with the warranted levels or test levels provided by manufacturers, or the IoA recommendations for sound pressure levels as described in the *Supplementary Guidance Note 3*, and therefore, it is impossible to draw any rigorous conclusions from the work.

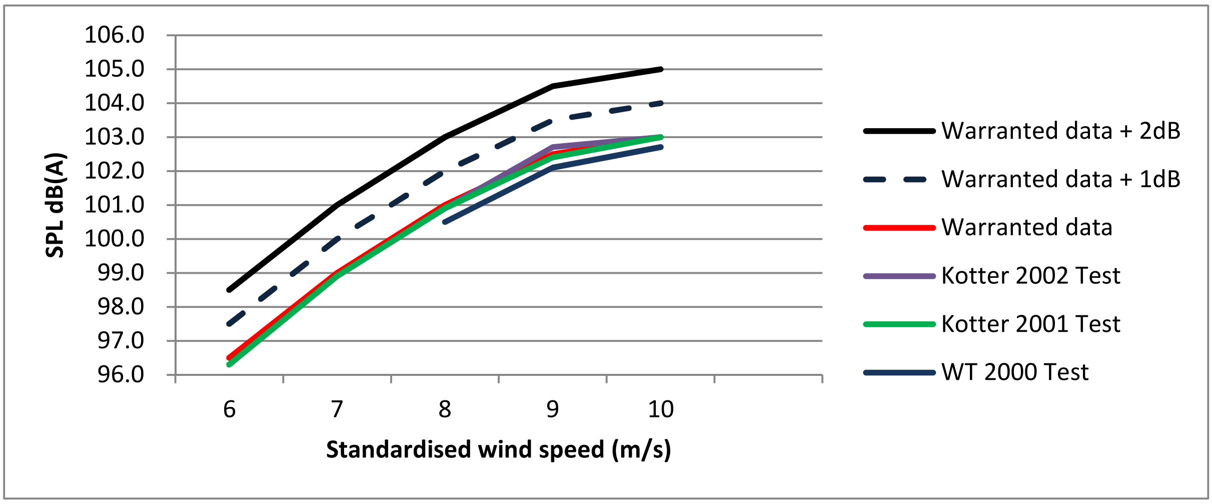
Test of the accuracy of the IoA GPG recommended parameters in predicting turbine noise levels

3.27 We have been able to obtain data to test the accuracy of the IoA GPG recommended sound power levels and ground factor in predicting turbine noise levels near to the single turbine located at Sporle Road in Swaffham. The turbine model is an Enercon E66 and the manufacturer’s generic noise warranty is at Appendix 1.

3.28 The following figure shows the sound power levels for the three sets of test data and the manufacturer’s warranty, which is not greater than the measured data. However, as noted in SGN3 in paragraph 2.1.1, the generic noise warranty document states that an additional 1dB should be added to noise calculations. That is shown below with the label ‘Warranted data + 1dB’.

3.29 For the purposes of this test, a further 1dB was added such that the warranted noise levels + 2dB were used in the noise prediction calculations to compare with the measured turbine noise levels.

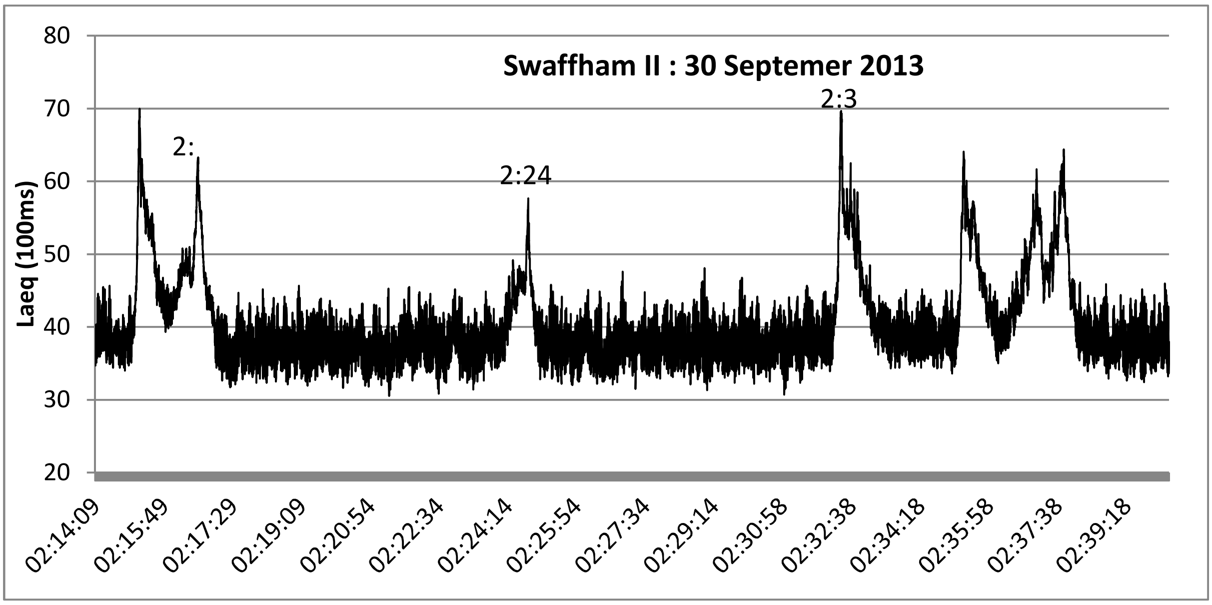
Figure 4. Test Sound Power Levels for the Enercon E66 compared with warranted Sound Power Level and Warranted Levels + 1dB and + 2dB.



3.30 Noise measurements were taken between 29 September 2013 22:30 BST and 03:00 30 September 2013 03:00 BST. The Sound Level Meter used was a Norsonic 140 connected to a remote microphone via a long lead and calibrated with a Norsonic calibrator. Among the data collected were LAeq measurements every 100 milliseconds. The location of the measurements was adjacent to a lay-by on the A47, 487m west of the turbine.

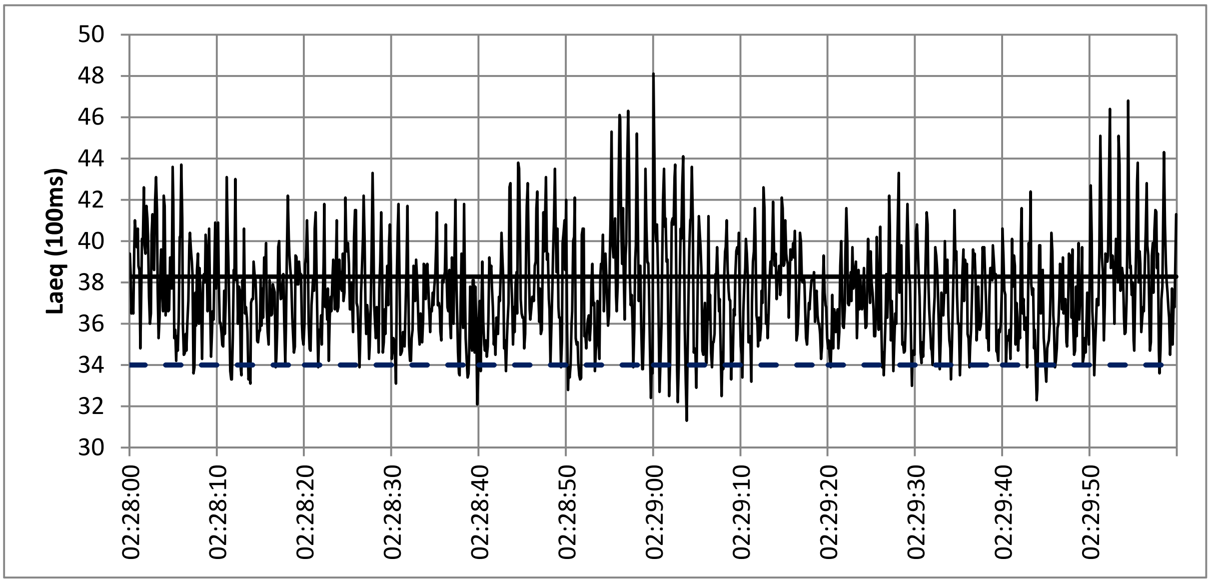
3.31 The difficulty with measuring noise adjacent to the A47 is the intermittent traffic. However, between midnight and 3 am there were sufficient clear periods without traffic for us to derive noise levels attributable only to the turbine (plus rural Norfolk background). The following figure shows gaps of up to 8 minutes between vehicles and also shows the relatively rapid return to base level after each vehicle passes.

Figure 5 Time series of turbine noise measurements showing Amplitude Modulated turbine noise and intermittent traffic noise



3.32 There was significant amplitude modulation of the turbine noise signal as can be seen in the trace below and other samples at Appendix 2.

Figure 6 Two minutes of Amplitude Modulated turbine noise measured at Swaffham. The blue dashed line at 34dB LAeq is the predicted turbine noise level using IoA GPG assumptions; the black line at 38.3dB LAeq is the measured turbine noise level.



3.33 The clarity of the amplitude modulation (AM) signal is evidence of the low background noise when the road was vehicle-free. If background noise had been higher, the AM signature would be either obliterated or significantly masked producing a much lower peak to trough variation.

3.34 We attribute the high degree of AM to high wind shear; there had been a succession of sunny, but windy days followed by clear nights with negligible winds near ground level. Wind speed measurements taken at the nearby weather station at Marham airfield at an altitude of 23m showed a constant 3.6m/s ENE wind prevailed from midnight to 3am BST.

3.35 Table 5 shows the comparison between measured sound levels for 2 minute clear periods and predicted sound levels using G=0 and G=0.5 and the warranted sound power levels plus 2dB. There is no warranted data for wind speeds lower than 6 m/s so where the standardised wind speed dipped below that point (identified by italics in the table) the conservative assumption was to use a wind speed of 6m/s.

3.36 We know from measurements elsewhere that background noise levels for wind speeds of 3.6 m/s[2] at 10m in an open Norfolk field tend to be less than 25dB. At this level, the contribution of ambient noise to the measured total would be negligible.

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[2] 3.6 m/s because this is the measurement at 23m elevation at Marham. In fact the 10m wind speed would be somewhat lower than this.

Table 5. Comparison of measured and predicted turbine noise levels. The predictions uses the IoA GPG recommended parameters of G=0.5 and the manufacturer's warranted sound power levels + 2dB.

Time	Standardised 10m wind speed (m/s)	Measured LAeq (2 mins)	Predicted LAeq G=0.5	Predicted LAeq G=0	Difference when G=0.5	Difference when G=0
00:24:00	6.0	36.6	33.2	34.9	3.4	1.7
00:28:00	6.0	37.8	33.2	34.9	4.6	2.9
00:30:03	6.1	37.5	33.5	35.2	4.1	2.4
00:32:00	6.1	37.6	33.5	35.2	4.2	2.5
00:36:00	6.1	38.9	33.5	35.2	5.4	3.7
00:46:00	6.1	38.1	33.5	35.2	4.6	2.9
00:58:00	6.1	38.2	33.5	35.2	4.8	3.1
01:06:00	*5.7*	38.9	*33.2*	*34.9*	5.7	4.0
01:38:00	*5.6*	38.9	*33.2*	*34.9*	5.7	4.0
01:58:00	6.2	39.8	33.7	35.4	6.1	4.4
02:06:00	6.1	38.9	33.5	35.2	5.4	3.7
02:18:00	6.1	38.2	33.5	35.2	4.7	3.0
02:22:00	6.3	38.2	34.0	35.7	4.2	2.5
02:26:00	6.3	38.1	34.0	35.7	4.1	2.4
02:28:00	6.3	38.3	34.0	35.7	4.4	2.7
02:30:04	6.2	38.5	33.7	35.4	4.8	3.1
02:38:00	6.2	39.1	33.7	35.4	5.4	3.7
02:46:00	6.3	37.5	34.0	35.7	3.6	1.9
02:48:00	6.3	37.7	34.0	35.7	3.8	2.1
Average	**6.1**	**38.2**	**33.6**	**35.3**	**4.7**	**3.0**
Std Deviation	**0.2**	**0.7**	**0.3**	**0.3**	**0.8**	**0.8**

3.37 The data in the table clearly shows that the predictions based on ISO9613 and using the generic warranty + 2dB and G=0.5 understate the actual noise level by nearly 5 dB. Furthermore, the predictions using the generic warranty and G=0 also understate the actual noise level by 3 dB.

3.38 These measurements clearly show that the recommended sound power levels in the IoA SPG and the *Supplementary Guidance Note 3* in conjunction with a ground factor of 0.5 under-predict actual turbine noise levels by a considerable margin.

3.39 In this instance, this could be for a number of reasons including the fact that the measurements were made at a time of high wind shear. Although it has been claimed that higher wind shear is taken into account by the ISO 9613 methodology, this is not borne out by the text of the standard itself. This issue was raised in the first consultation round and is covered particularly thoroughly in one of the consultation responses (See p127-157 of the collated consultation responses).

3.40 There is an inherent assumption in the recommendations of the *Supplementary Guidance Note 3* that the recommended sound power levels are invariant over time and for different meteorological conditions. We are not aware of evidence that confirms this position. Furthermore, we can see from the recently published Renewable UK documents on AM, that there is considerable variation in sound power level for different blade pitch settings (see Figure 4.6, p57 of *Work Package D Measurement and Analysis of New Acoustic Recordings*). There is a clear implication that the impact of higher wind shear across turbine blades is to increase source sound power levels. This evidence must be taken into account in the IoA guidance on noise predictions.

4 Supplementary Guidance Note 4 : Wind Shear

Wind Farm Noise Limits Increased by IoA GPG Preferred Methodology

4.1 The IoA GPG provides for three different methods of determining wind speed references for background noise surveys, denoted Methods A, B and C in the text. The results of these surveys are used to determine the noise impacts of the proposed development and dictate the noise levels set in the wind farm noise condition.

Table 6 Summary of IoA GPG Methodologies for determining wind speed references for background noise surveys

	Measured Wind Speed from:	**Condition based on :**
Method A	Anemometer at hub height	'Standardised' 10m wind speed
Method B	Measurements from two sub-hub height anemometers extrapolated to derive hub height wind speed	'Standardised' 10m wind speed
Method C	Measured at 10m as per ETSU-R-97	Measured 10m wind speed as per ETSU-R-97

4.2 However, there is a major flaw in this part of the guidance: the different methods result in different noise conditions with Method C providing the best protection for neighbours.

4.3 The guidance recommends Methods A and B in preference to Method C although it is not explained to the reader that the former methods deviate from the original ETSU-R-97 guidance and that they provide extra head-room for more wind farm noise at times of higher wind shear.

4.4 This can be readily demonstrated in the cases where both measured 10m wind speeds and the so-called 'standardised' 10m wind speeds have been obtained during the noise assessment. Standardised 10m wind speeds bear no resemblance to the actual 10m wind speed; instead they are a scaled down measure of hub height wind speed where the scale factor reflects low wind shear conditions. (Low wind shear conditions are unlikely to prevail at times of noise complaints.)

4.5 For example, a hub height wind speed of 8 m/s, where the hub height is 80m, has a standardised 10m wind speed of 5.7 m/s. This would be rounded to an integer value of 6 m/s when considering what noise limit to apply from the noise condition. For this hub height wind speed, the actual measured 10m wind speed could be 3 to 4 m/s given average wind shear conditions in large parts of England. An ETSU-R-97-compliant noise limit based on measured 10m wind speeds and for a measured wind speed of 4 m/s is typically lower than the IoA preferred noise condition limit for a standardised 10m wind speed of 6 m/s.

4.6 The following table gives examples from two different wind farm assessments where wind speed measurements were made at both 10m and hub height thereby enabling a straight forward comparison between methods A and C and their impacts on the noise condition. Four different hours are shown for different dates and different wind directions. (The latter is necessary to rebut the suggestion that this is an artefact of atypical direction-dependent wind shear.)

Table 7: ***Wind speed data demonstrating the increased noise limit arising from using Method A compared with Method C. Data covering 2 different hours for two different sites are shown and different wind directions*.**

	Method A			Method C		
Time	**Hub Height Wind Speed**	**Standardised 10m wind speed m/s**	**IoA Standardised Noise Condition Limit dB**	**Measured 10m wind speed m/s**	**ETSU Measured Condition dB**	**Increased noise limit dB**
Site 1: Date 1: Wind Direction 1						
17:00	12.6	9.3	43	5.9	38	5
17:10	13.0	9.6	45	5.5	38	7
17:20	13.4	9.9	45	5.6	38	7
17:30	13.8	10.2	45	5.5	38	7
17:40	11.5	8.5	43	4.5	35	8
17:50	12.9	9.5	45	5.2	35	10
18:00	13.2	9.8	45	5.7	38	7
Site 1: Date 2:Wind Direction 2						
09:00	13.2	9.8	45	7.6	43	2
09:10	13.0	9.7	45	7.3	41	4
09:20	13.1	9.7	45	7.5	41	4
09:30	13.0	9.6	45	7.4	41	4
09:40	13.1	9.7	45	7.3	41	4
09:50	12.4	9.2	43	7.4	41	2

Site 2: Date 3: Wind Direction 3						
21:00	10.4	8.0	40	6.3	37	3
21:10	9.9	7.7	40	5.9	37	3
21:20	9.2	7.1	37	5.9	37	-
21:30	9.6	7.4	37	6.0	37	-
21:40	11.0	8.5	43	6.5	39	4
21:50	10.9	8.4	40	6.5	37	3
Site 2: Date 4: Wind Direction 4						
21:00	9.4	7.3	37	4.5	35	2
21:10	9.6	7.4	37	4.9	35	2
21:20	10.0	7.7	40	5.1	35	5
21:30	9.4	7.3	37	4.6	35	2
21:40	8.7	6.7	37	4.1	35	2
21:50	8.2	6.4	35	4.0	35	-

4.7 For each site in the table above it was possible to derive a noise condition based on standardised 10m wind speeds following Method A and a traditional ETSU-R-97 noise condition following Method C. As can be seen in the rightmost column above, the IoA-recommended methodology (Method A) permits more wind farm noise than was envisaged by ETSU-R-97.

4.8 The effect of this is that the IoA GPG has recommended increased noise levels particularly at times of higher wind shear which normally occur during evenings and night times when background noise levels are at their lowest. This is the direct opposite to what a noise condition should do and not what ETSU-R-97 recommends. This means that during evening and night time hours, when background noise is low and turbine noise is high, the ETSU-R-97 indicative noise levels have been increased by virtue of the new guidance.

4.9 A further issue is that by endorsing alternative methodologies to treat wind shear effects that result in different noise conditions which offer different levels of protection for neighbours, the IoA GPG has made planning decisions impossible. Clearly, developers will favour noise conditions offering extra headroom for noise based on standardised 10m wind speeds whereas neighbours will want the extra protection afforded by the measured 10m wind speed methodology described in ETSU-R-97.

Other Issues

4.10 The table of data provided at 4.3.2 and Figure 3 showing how to use anemometry data to adjust 10m measured wind speed data for wind shear effects is useful but incomplete and would be improved by extra commentary. For example, it should be made clear that the average wind shear exponent needs to be derived for the standardised 10m wind speeds, not the measured 10m wind speeds. Although this can be inferred from the table, I have seen examples in noise assessments where the shear exponents have been averaged for measured rather than standardised 10m wind speeds resulting in erroneously low shear exponents and standard deviations and thus understating the range in turbine noise levels at a particular wind speed.

4.11 Also, the table would benefit from showing the standard deviation so that it can be appreciated the typical spread in wind shear exponents is not trivial.

4.12 Limiting consideration of wind shear exponents to the average plus or minus one standard deviation means that only 64% of the total range is considered significant. This is not normal scientific practice; consideration of 2 or 3 standard deviations covering 95% and 99.7% of the variation respectively is usual. The document needs to explain that 16% of the time, at critical wind speeds for noise complaints, turbine noise levels will be higher than accounted for by this methodology. An explanation why this is deemed satisfactory needs to be given because on the face of it, this is unreasonable.

5 Supplementary Guidance Note 6 : Noise Propagation over Water for On-shore Wind Turbines

5.1 This guidance note needs elaboration to improve its accessibility. For example, paragraph 2.1.3 refers to 'a Swedish report' but no reference is given. It would be helpful to provide this information. In 2.1.5 the footnoted reference link no longer works.

5.2 In 2.2.1 more information is needed for the calculation of the integrated frequency dependent absorption co-efficient so that the formula given in 2.2.1 may be used.

About The Renewable Energy Foundation

The Renewable Energy Foundation is a registered research and education charity encouraging the development of renewable energy and energy conservation whilst emphasizing that such development must be governed by the fundamental principles of sustainability. REF is supported by private donation and has no political affiliation or corporate membership. In pursuit of its principal goals, REF highlights the need for an overall energy policy that is balanced, ecologically sensitive, and effective.

Appendix 1.

Manufacturer’s warranty and test data for the Enercon E66

Guaranteed sound power level and tonality for the ENERCON E-66/20.70 with 2.000kW rated power, 70m rotor diameter and 65m hub height based on measurements of the ENERCON E-66/18.70 with 1.800kW and 70m rotor diameter.

	Measured Sound power level and tonality of the ENERCON E-66/18.70 with 70m rotor diameter and 65m hub height for reference wind speed of 6, 7, 8, 9 and 10m/s in 10m height			**Guarantee for ENERCON E-66/20.70 with 65m hub height**
Number	1. Measurement	2. Measurement	3. Measurement	**Guaranteed sound power level and tonality**
Institute	WINDTEST KWK	KÖTTER Consulting Engineers	KÖTTER Consulting Engineers	
Report	WT1618/00 dated 2000-12-21	KÖTTER 25716 -1.001 dated 2001-11-30	KÖTTER 26207 -1.001 dated 2002-05-28	
6m/s	-	**96,3 dB(A)** 0 dB	-	**96,5 dB(A)** 0-1 dB
7m/s	-	**98,9 dB(A)** 0 dB	-	**99,0 dB(A)** 0-1 dB
8m/s	**100,5 dB(A)** 0 dB	**100,9 dB(A)** 0 dB	**100,9 dB(A)** 0 dB	**101,0 dB(A)** 0-1 dB
9m/s	**102,1dB(A)** 0 dB	**102,4dB(A)** 0 dB	**102,7dB(A)** 0 dB	**102,5 dB(A)** 0-1 dB
10m/s	**102,7 dB(A)** 0 dB	**103,0 dB(A)** 0 dB	**103,0 dB(A)** 0 dB	**103,0 dB(A)** 0-1 dB

1. The values of the sound power level for 65m hub height based on calculations on the measurements of the sound power level of the E-66/18.70 with 1.800kW rated power and 70m rotor diameter, carried out by WINDTEST Kaiser-Willhelm-Koog-GmbH and KÖTTER Consulting Engineers according to their measurement reports WT1618/00 dated December 21st 2000, KCE 25716-1.001 dated November 30th 2001 and KCE 26207-1.001 dated May 28th 2002.
2. The measurement of the sound power level as well as the determination of the tonality and the impulsivity were carried out according to the FGW-guidelines (technical guidelines to determine the power curve, sound power levels and electrical characeristics of wind energy converters, Rev. 13, dated 01.01.2000, Brunsbüttel, Fördergesellschaft Windenergie e.V.), based on DIN EN61400-11 (wind energy converters, part 11: sound emissions) dated February 2000. The determination of the impulsivity is according to DIN 45645 (T1, „Uniform determination of performance levels for sound emissions“, dated July 1996). The determination of the tonality followed the technical guidelines according to DIN 45681 (draft, „Determination of tonality from sounds“, dated January 1992).
3. ENERCON turbines with their wear-resistant concept and the variable operational control guarantee that the given sound power level is being kept over the entire lifetime.
4.

5. Basically and essentially the sound power level of a wind turbine is determined by the aeorydynamic sound caused by the air flow around the rotor blades. Since the noise emission is depending on the blade tip speed to the power of five, the noise emission increases with rotational speed. ENERCONs E-66/20.70 wind turbines with 2000 kW rated power and 70 m rotor diameter represent a further development based on ENERCONs E-66/18.70 wind turbines with 1800 kW and also 70 m rotor diameter. In this case only the rated power has been increased, not the rotor diameter and not the rotational speed. Therefore the sound power level remains unchanged in comparison to the 1800 kW model.

   Taking the same rotational speed for the ENERCON E-66/18.70 and E-66/20.70 ENERCON into consideration, the same measured sound power levels of the ENERCON E-66/18.70 (cp. measurement reports mentioned on the top of page 1) can be guaranteed accordingly for the ENERCON E-66/20.70.

6. Official measurements of the sound power level for E-66/20.70 with 2.000kW and 70m rotor diameter will be carried out according to the latest guidelines (e.g. DIN/IEC guidelines 88/48/CDV Draft, March 1996, Wind energy converters, part 10: sound measurements) and DIN 45681 for the evaluation of tonality). According to the guidelines a measurement accuracy of 1 dB(A) will be assumed.

The sound power level of the ENERCON E-66 with 1,800kW rated power output and a rotor diameter of 70m is as follows:

Hub Height	**Measured Sound Power Level, Tonality and Impulsivity for 6 m/s in 10 m Height, KÖTTER Consulting Engineers**	**ENERCON Guarantee**
65 m	**94,9 dB(A)** Tonality K_{TN} = 0 dB Impulsivity K_{IN} = 0 dB	**95,0 dB(A)** Tonality K_{TN} = 0 - 1 dB Impulsivity K_{IN} = 0 dB
85 m	**95,4 dB(A)** Tonality K_{TN} = 0 dB Impulshaltigkeit K_{IN} = 0 dB	**95,5 dB(A)** Tonality K_{TN} = 0 - 1 dB Impulsivity K_{IN} = 0 dB
98 m	**95,7 dB(A)** Tonality K_{TN} = 0 dB Impulsivity K_{IN} = 0 dB	**96,0 dB(A)** Tonality K_{TN} = 0 - 1 dB Impulsivity K_{IN} = 0 dB

1. These data are based on the measurements of the E-66/18.70 sound power level carried out by KÖTTER Consulting Engineers, Rheine, according to their latest measurement report 25597-1.001 dated July 20, 2001 and is valid for a reference wind speed of 6 m/s in 10 m height. According to the guidelines a measurements accuracy of ± 1 dB is being confirmed in the measurement report.
2. The measurements of the sound power level have been carried out generally according to the German FGW-Richtlinien (Technischer Richtlinie zur Bestimmung der Leistungskurve, des Schalleistungspegels und der elektrischen Eigenschaften von Windenergieanlagen, Rev. 13, Stand 01.01.2000, Brunsbüttel, Fördergesellschaft Windenergie e.V.), which is based on the DIN EN61400-11 (Windenergieanlagen, Teil 11: Geräuschimmissionen) dated February 2000.
3. ENERCON guarantees that there is not Tonality or Impulsivity over the complete measured reference wind speed 5 m/s < v_{10} < 7m/s for all hub heights.
4. Zero (0 - 1 dB(A)) tonality corresponds to $\Delta L_{tn} = L_{pt} - L_{pn} \leq -2$ dB according to IEC standard 88/48/CDV (page 21/22).
5. ENERCON turbines with their variable operational control guarantee that a given sound power level is being kept over the entire life of the turbine.
6. The mechanical concept of the ENERCON turbines (no fast rotating parts - therefore no mechanical wear) guarantees that no increase of machinery noise will occur during the entire lifetime of the turbines.
7. Sound power levels for the hub height of 85m and 98m Nabenhöhe are calculated by measured values of the hub height of 65m according to the German FGW-Richtlinie.

Summary of measurement results from the noise emmission measurement on the wind turbine

Enercon E66/18.70

Report WT 1630/01 dated 2001-01-05

WINDTEST
Kaiser-Wilhelm-Koog GmbH

Wind turbine technical data:

Type: E66/18.70
Manufacturer: .... Enercon GmbH, Aurich
Rated power: .... 1800 kW
Hub height above ground: .... 65,7 m
Hub height above top of foundation: .... 65 m
Power limiting: .... pitch
Tower type: .... steel circular section
Rotor diameter: .... 70 m
Number of rotor blades: 3
Rotor blade manufacturer: .... Enercon
Rotor blade type: .... Enercon
Rotor speed (range): .... 8 - 22 min^{-1}
Gearbox manufacturer: .... n/a
Gearbox type: .... n/a
Generator type: .... ring form, synchronous

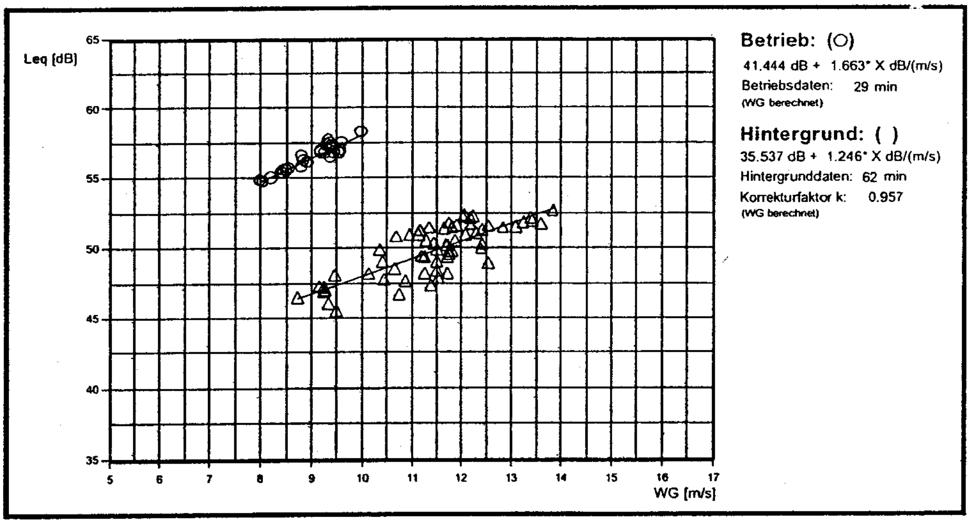
Measurement geometry:

Measurement distance R_0: .... 85 m
Height of foundation h_F: .... 0,7 m
Height of microphone h_A: .... 0 m
Plane of rotation ⇒ centre of tower d: .... 4,3 m

Measurement conditions:

Wind speed at a height of 10m,
1-min-averages, WS_{10m}: .... 6,9 – 13,1 m/s
Wind direction WD: .... WSW
Real electrical power $P_{e\ real}$: .... 103 - 1875 kW
Atmospheric air pressure p_{atmos}: .... 1001 hPa
Atmospheric air temperature T_{atmos}: .... 13,8 °C
Atmospheric air humidity: .... 80 %rel.

Determination of the sound power level according to the FGW-Standard:



Wind speed bin [m/s]	Bin range [m/s]	Bin average value [m/s]	No. of values [-]	Background noise corrected sound pressure level $L_{Aeq,c}$ at the bin average [dB]	Background noise corrected sound power level $L_{WA,c}$ [dB]
6	5,5 - 6,5	-	-	-	-
7	6,5 - 7,5	-	-	-	-
8	7,5 - 8,5	8,3	6	54,6	100,5
9	8,5 - 9,5	9,1	18	56,2	102,1
10	9,5 - 10,5	9,6	5	56,8	102,7

Bemerkungen:

- There is no data available in the lower bins.
- The 95 %-value of the rated power is 1710 kW which corresponds to 9,62 m/s at a height of 10 m.

Impulsivity according to FGW-Guideline/DIN 45645 T1 for reference conditions:

Wind speed bin [m/s]	Bin range [m/s]	Bin average [m/s]	Number of values [-]	Sound press. L_{Aeq} [dB]	Periodic max. L_{AFTm} [dB]	Impulsivity penalty K_{IN} [dB]
6	5,5 - 6,5	-	-	-	-	
7	6,5 - 7,5	7,4	2	55,1	56,3	1,2
8	7,5 - 8,5	8,2	90	55,3	56,3	1,0
9	8,5 - 9,5	9,0	180	56,4	57,4	1,0
10	9,5 - 10,5	10,2	1261	57,9	58,9	1,0

Third octave analysis for reference conditions (for 9,62 m/s at a height of 10 m):

25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630
65,7	68,2	71,9	75,4	78,1	80,9	83,1	85,3	88,0	86,3	88,6	91,2	92,2	92,6	93,2

800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
93,4	92,7	92,5	91,7	89,4	87,3	85,4	83,2	78,6	74,6	70,8	65,6

Octave analysis for reference conditions (for 9,62 m/s at a height of 10 m):

31,5	63	125	250	500	1000	2000	4000	8000
74,1	83,4	90,6	93,9	97,4	97,6	94,5	87,9	76,4

Determination of tonality according to FGW-Standard / EDIN 45681 for reference conditions:

Representative FFT - Spectrum for reference conditions (9,62 m/s at a height of 10 m):

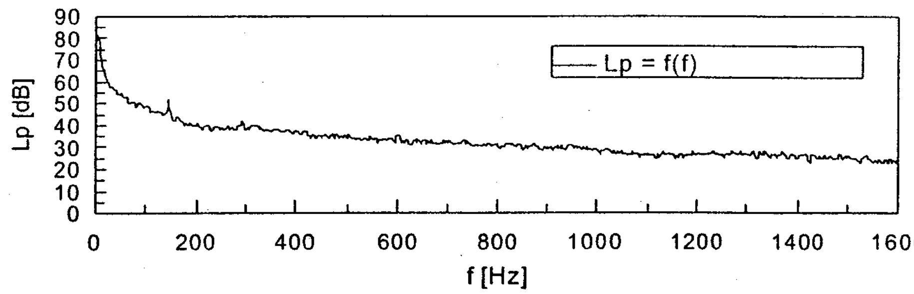


Table of results:

Bin range [m/s]	Bin average WS_{10m} [m/s]	Number of Spectra [-]	Frequency of tone f_T [Hz]	Sound pressure level diference ΔL [dB]	Tone penalty according to FGW – Standard [dB]
5,5 - 6,5	6	-	-	-	-
6,5 - 7,5	7	-	-	-	-
7,5 - 8,5	8	12	-	-	0
8,5 - 9,5	9	12	150	-4,88	0
9,5 - 10,5	10	12	146	-3,47	0

Bearbeiter:

Dipl.-Ing. J. Clausen

Geprüft:

Dipl.-Ing. V. Köhne
(Technischer Leiter)

Summary of Test Report

Page 1

Basic sheet "Geraeusche" (Noise), according to the *"Technische Richtlinien für Windenergieanlagen, Teil 1: Bestimmung der Schallemissionswerte" (technical guidelines for wind energy plants, Part 1: Determination of sound emission values)*

Rev. 13 of January 1, 2000 (Editor: Foerdergesellschaft Windenergie e.V., Flotowstrasse 41-43, D-22083 Hamburg, Germany)

Extract of Test Report No. 25597-1.001
on noise emission of wind energy plant of type Enercon E-66/18.70 in Hage

Manufacturer of plant:	Enercon GmbH	Rated power (generator):	1800 kW
		Diameter of rotor:	70m
Serial number:	70020	Hub height above ground:	65m
Location of plant:	26524 Hage	Type of tower:	conic tube + socle
		Power control:	blade adjustment
Complementary data to the rotor (manufacturer's specifications)		**Complementary data to gear unit and generator (manufacturer's specifications)**	
Manufacturer of rotor blade:	Enercon	Manufacturer of gear unit:	not applicable
Type of rotor blade:	Enercon	Type of gear unit:	not applicable
Blade setting angle:	Variable	Manufacturer of generator:	Enercon
Number of rotor blades:	3	Type of generator:	E-66/18.70, ring type
Rotor speed range:	8 to 22 r.p.m	Rated generator speed:	22 r.p.m

test report to power curve: Measurement of power curves DEWI-PV 0002-05-E, Deutsches Windenergie-Institut GmbH

	Reference Point		Observations	
	standardized wind speed in 10 m height	sound emission parameter		
sound power level $L_{WA,P}$	5 ms^{-1} 6 ms^{-1} 7 ms^{-1} — —	91,8 dB(A) 94,9 dB(A) 97,3 dB(A) — —		
tone adjustment in the near field K_{TN}	5 ms^{-1} 6 ms^{-1} 7 ms^{-1} — —	0 dB 0 dB 0 dB — —		
impulse adjustment in the near field K_{IN}	5 ms^{-1} 6 ms^{-1} 7 ms^{-1} — —	0 dB 0 dB 0 dB — —		

sound power level in third-octave bands for reference point v_{10} = 6,0 ms^{-1} in dB(A)

frequency	16	20	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500
$L_{WA,P}$	--	--	30,7,	37,4	44,4	49,65	56,1	60,0	65,0	70,4	73,8	78,3	81,9	83,1	83,4	84,6
frequency	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000	12500	16000	20000
$L_{WA,P}$	86,8	85,3	85,6	84,7	83,1	80,9	79,5	78,4	77,1	74,3	72,0	69,8	68,7	66,5	63,3	58,3

sound power level in third-octave bands for reference point v_{10} = 7,0 ms^{-1} in dB(A)

frequency	16	20	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500
$L_{WA,P}$	--	--	33,1	39,8	46,8	51,9	58,5	62,4	67,4	72,8	76,2	80,7	84,3	85,5	85,8	87,0
frequency	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000	12500	16000	20000
$L_{WA,P}$	89,2	87,8	88,0	87,1	85,5	83,3	81,9	80,8	79,5	76,7	74,4	72,2	71,1	59,9	65,6	60,7

This summary of the test report is valid only in connection with manufacturer's certification. These specifications do not replace the test report mentioned above (particularly for noise immission predictions).

Note: The sound power levels should be determined for the range of wind speeds v_{10} from 5 to 7 m/s.

Measured by: KÖTTER Consulting Engineers
- Rheine -

KÖTTER CONSULTING ENGINEERS
Bonifatiusstraße 400 · 48432 Rheine
Tel. 0 59 71 - 97 10.0 · Fax 0 59 71 - 97 10.43

Date: 2001-07-20

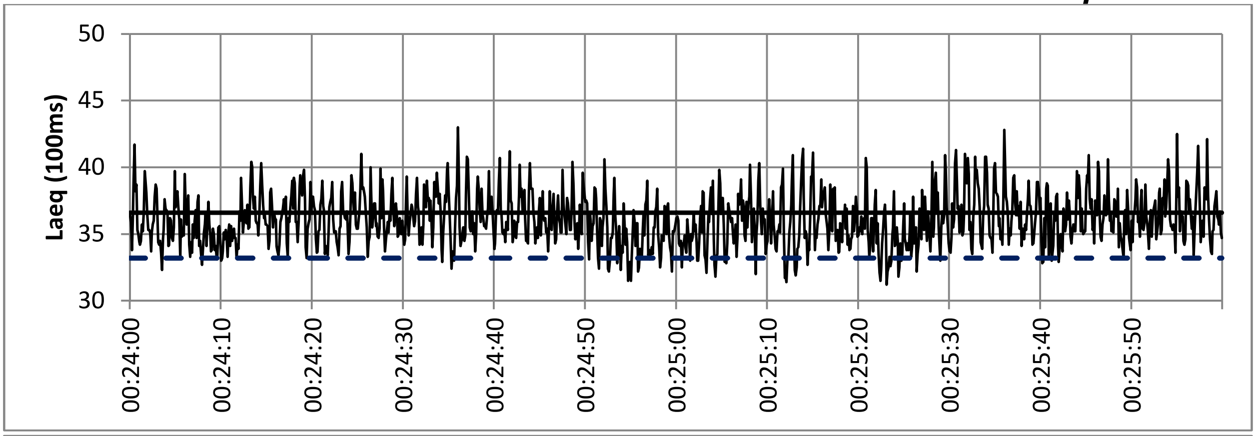
i. V. Arno Schälly

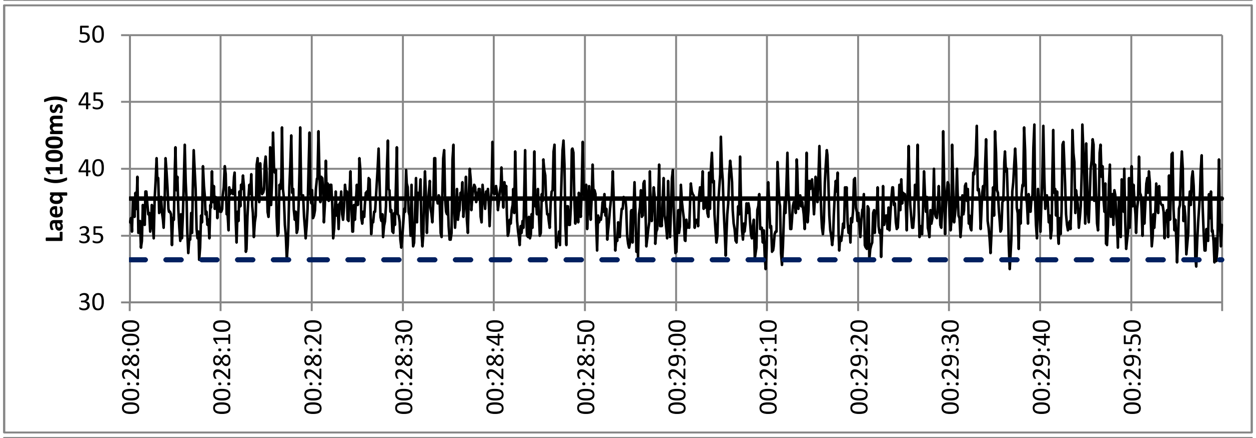
Signature

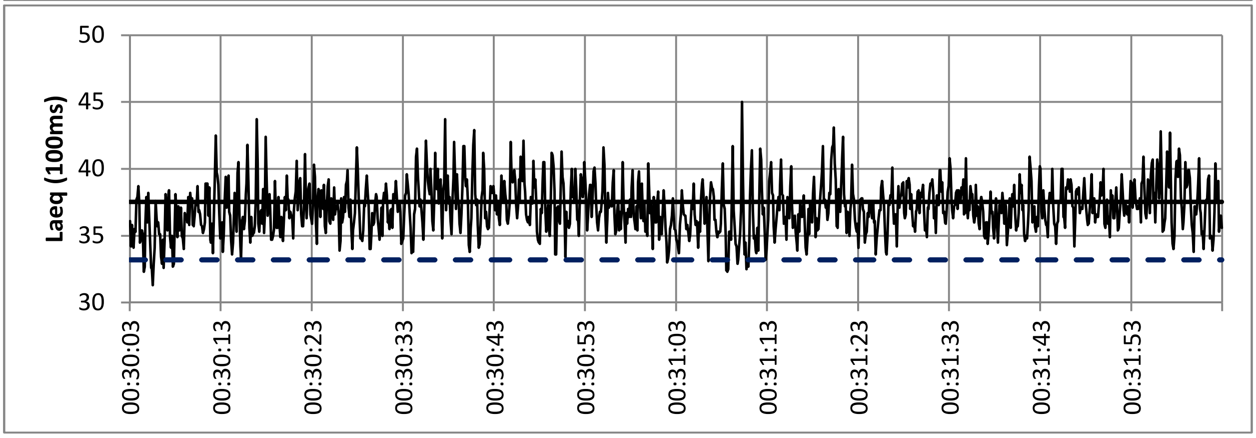
This summary of the test report covers 1 page.

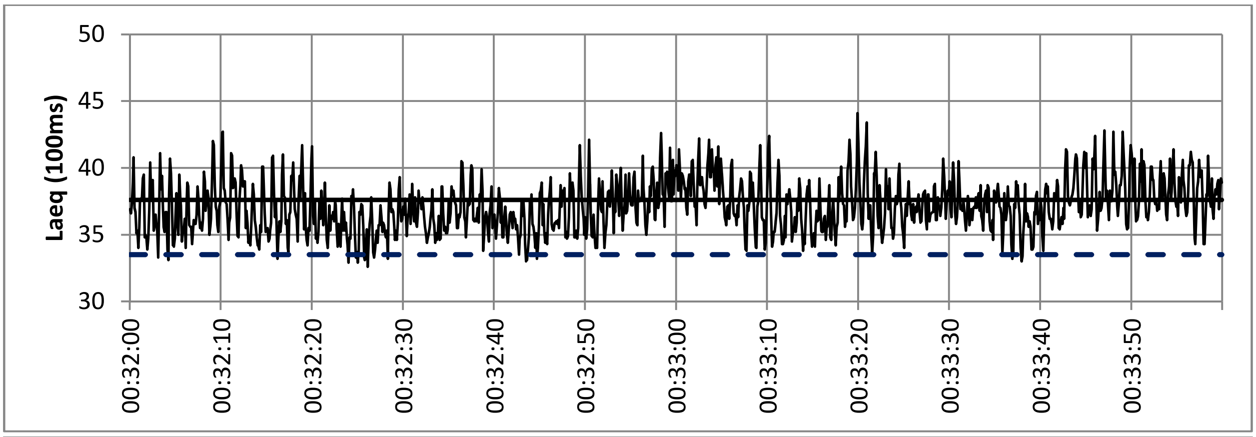
Appendix 2

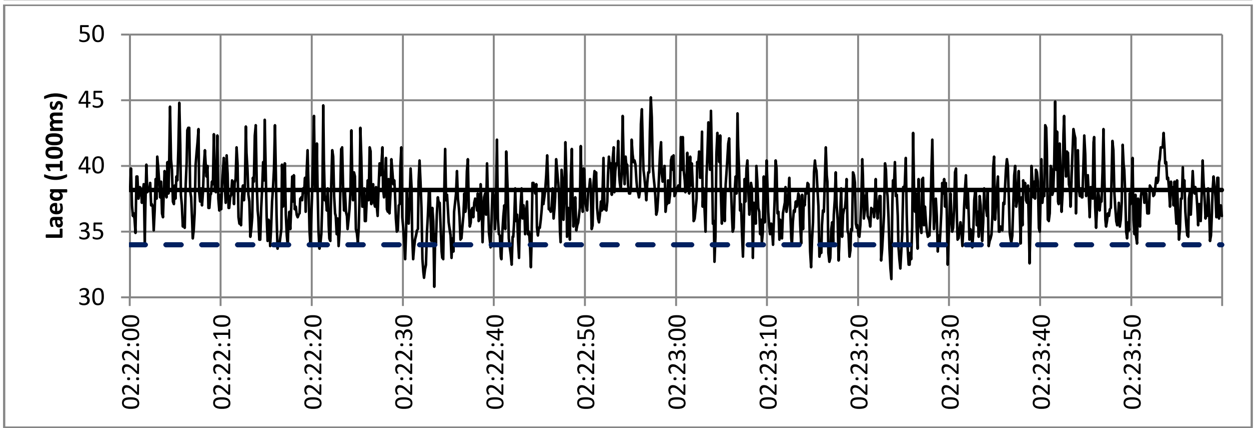
Figures showing 2 minute samples of wind turbine noise measured xxxm from the Sporle Road turbine at Swaffham. The blue dotted line shows the predicted noise (LAeq) using the IoA GPG recommended parameter of G=0.5 and warranted levels + 2dB. The black line shows the actual measured LAeq.

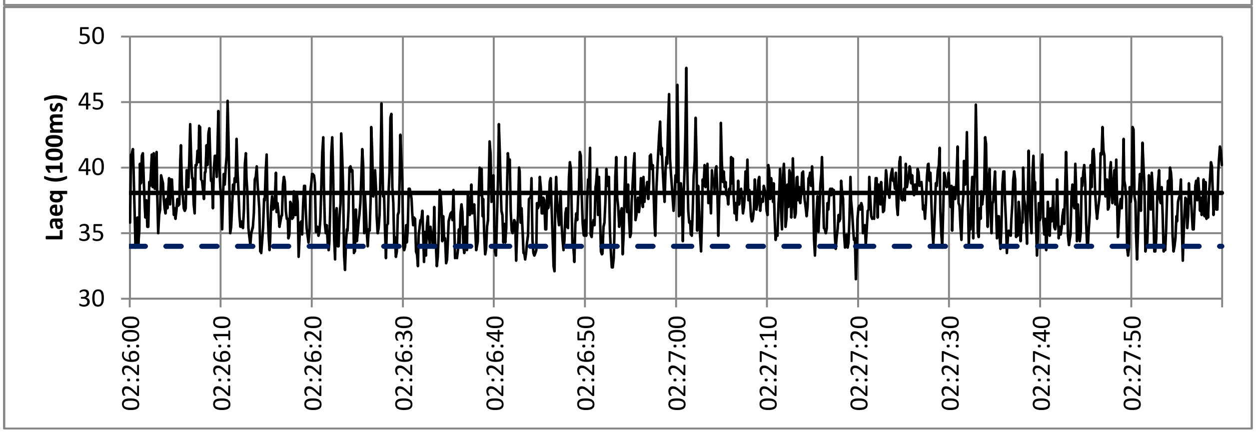


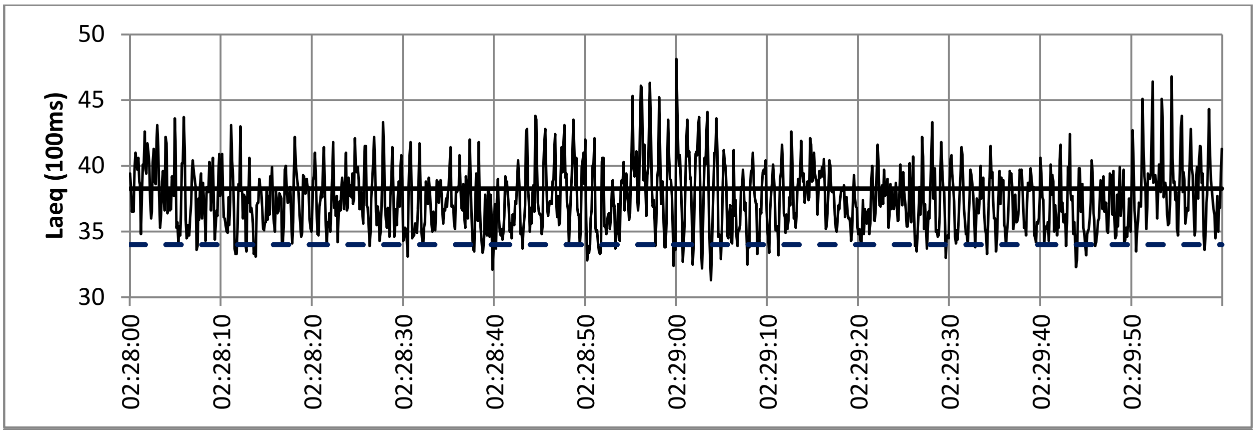


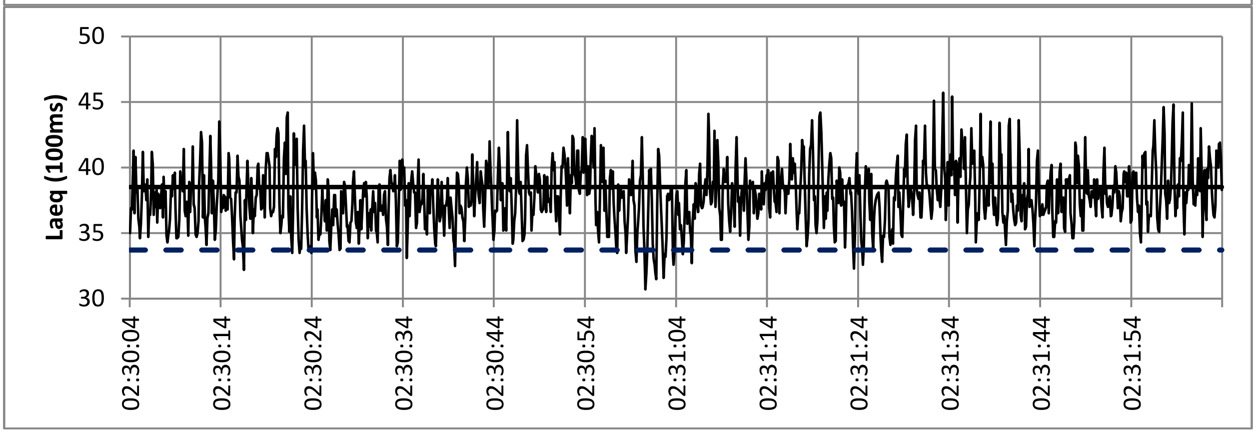



Laeq (100ms)
50
45
40
35
30
00:32:00
00:32:10
00:32:20
00:32:30
00:32:40
00:32:50
00:33:00
00:33:10
00:33:20
00:33:30
00:33:40
00:33:50


Laeq (100ms)
50
45
40
35
30
02:22:00
02:22:10
02:22:20
02:22:30
02:22:40
02:22:50
02:23:00
02:23:10
02:23:20
02:23:30
02:23:40
02:23:50


Laeq (100ms)
50
45
40
35
30
02:26:00
02:26:10
02:26:20
02:26:30
02:26:40
02:26:50
02:27:00
02:27:10
02:27:20
02:27:30
02:27:40
02:27:50


Laeq (100ms)
50
45
40
35
30
02:28:00
02:28:10
02:28:20
02:28:30
02:28:40
02:28:50
02:29:00
02:29:10
02:29:20
02:29:30
02:29:40
02:29:50


Laeq (100ms)
50
45
40
35
30
02:30:04
02:30:14
02:30:24
02:30:34
02:30:44
02:30:54
02:31:04
02:31:14
02:31:24
02:31:34
02:31:44
02:31:54

Appendix 1.

Manufacturer’s warranty and test data for the Enercon E66

Guaranteed sound power level and tonality for the ENERCON E-66/20.70 with 2.000kW rated power, 70m rotor diameter and 65m hub height based on measurements of the ENERCON E-66/18.70 with 1.800kW and 70m rotor diameter.

	Measured Sound power level and tonality of the ENERCON E-66/18.70 with 70m rotor diameter and 65m hub height for reference wind speed of 6, 7, 8, 9 and 10m/s in 10m height			**Guarantee for ENERCON E-66/20.70 with 65m hub height**
Number	1. Measurement	2. Measurement	3. Measurement	**Guaranteed sound power level and tonality**
Institute	WINDTEST KWK	KÖTTER Consulting Engineers	KÖTTER Consulting Engineers	
Report	WT1618/00 dated 2000-12-21	KÖTTER 25716 -1.001 dated 2001-11-30	KÖTTER 26207 -1.001 dated 2002-05-28	
6m/s	-	**96,3 dB(A)** 0 dB	-	**96,5 dB(A)** 0-1 dB
7m/s	-	**98,9 dB(A)** 0 dB	-	**99,0 dB(A)** 0-1 dB
8m/s	**100,5 dB(A)** 0 dB	**100,9 dB(A)** 0 dB	**100,9 dB(A)** 0 dB	**101,0 dB(A)** 0-1 dB
9m/s	**102,1dB(A)** 0 dB	**102,4dB(A)** 0 dB	**102,7dB(A)** 0 dB	**102,5 dB(A)** 0-1 dB
10m/s	**102,7 dB(A)** 0 dB	**103,0 dB(A)** 0 dB	**103,0 dB(A)** 0 dB	**103,0 dB(A)** 0-1 dB

1. The values of the sound power level for 65m hub height based on calculations on the measurements of the sound power level of the E-66/18.70 with 1.800kW rated power and 70m rotor diameter, carried out by WINDTEST Kaiser-Willhelm-Koog-GmbH and KÖTTER Consulting Engineers according to their measurement reports WT1618/00 dated December 21st 2000, KCE 25716-1.001 dated November 30th 2001 and KCE 26207-1.001 dated May 28th 2002.
2. The measurement of the sound power level as well as the determination of the tonality and the impulsivity were carried out according to the FGW-guidelines (technical guidelines to determine the power curve, sound power levels and electrical characeristics of wind energy converters, Rev. 13, dated 01.01.2000, Brunsbüttel, Fördergesellschaft Windenergie e.V.), based on DIN EN61400-11 (wind energy converters, part 11: sound emissions) dated February 2000. The determination of the impulsivity is according to DIN 45645 (T1, „Uniform determination of performance levels for sound emissions“, dated July 1996). The determination of the tonality followed the technical guidelines according to DIN 45681 (draft, „Determination of tonality from sounds“, dated January 1992).
3. ENERCON turbines with their wear-resistant concept and the variable operational control guarantee that the given sound power level is being kept over the entire lifetime.
4.

5. Basically and essentially the sound power level of a wind turbine is determined by the aeorydynamic sound caused by the air flow around the rotor blades. Since the noise emission is depending on the blade tip speed to the power of five, the noise emission increases with rotational speed. ENERCONs E-66/20.70 wind turbines with 2000 kW rated power and 70 m rotor diameter represent a further development based on ENERCONs E-66/18.70 wind turbines with 1800 kW and also 70 m rotor diameter. In this case only the rated power has been increased, not the rotor diameter and not the rotational speed. Therefore the sound power level remains unchanged in comparison to the 1800 kW model.

   Taking the same rotational speed for the ENERCON E-66/18.70 and E-66/20.70 ENERCON into consideration, the same measured sound power levels of the ENERCON E-66/18.70 (cp. measurement reports mentioned on the top of page 1) can be guaranteed accordingly for the ENERCON E-66/20.70.

6. Official measurements of the sound power level for E-66/20.70 with 2.000kW and 70m rotor diameter will be carried out according to the latest guidelines (e.g. DIN/IEC guidelines 88/48/CDV Draft, March 1996, Wind energy converters, part 10: sound measurements) and DIN 45681 for the evaluation of tonality). According to the guidelines a measurement accuracy of 1 dB(A) will be assumed.

The sound power level of the ENERCON E-66 with 1,800kW rated power output and a rotor diameter of 70m is as follows:

Hub Height	Measured Sound Power Level, Tonality and Impulsivity for 6 m/s in 10 m Height, KÖTTER Consulting Engineers	ENERCON Guarantee
65 m	**94,9 dB(A)** Tonality K_{TN} = 0 dB Impulsivity K_{IN} = 0 dB	**95,0 dB(A)** Tonality K_{TN} = 0 - 1 dB Impulsivity K_{IN} = 0 dB
85 m	**95,4 dB(A)** Tonality K_{TN} = 0 dB Impulshaltigkeit K_{IN} = 0 dB	**95,5 dB(A)** Tonality K_{TN} = 0 - 1 dB Impulsivity K_{IN} = 0 dB
98 m	**95,7 dB(A)** Tonality K_{TN} = 0 dB Impulsivity K_{IN} = 0 dB	**96,0 dB(A)** Tonality K_{TN} = 0 - 1 dB Impulsivity K_{IN} = 0 dB

1. These data are based on the measurements of the E-66/18.70 sound power level carried out by KÖTTER Consulting Engineers, Rheine, according to their latest measurement report 25597-1.001 dated July 20, 2001 and is valid for a reference wind speed of 6 m/s in 10 m height. According to the guidelines a measurements accuracy of ± 1 dB is being confirmed in the measurement report.
2. The measurements of the sound power level have been carried out generally according to the German FGW-Richtlinien (Technischer Richtlinie zur Bestimmung der Leistungskurve, des Schalleistungspegels und der elektrischen Eigenschaften von Windenergieanlagen, Rev. 13, Stand 01.01.2000, Brunsbüttel, Fördergesellschaft Windenergie e.V.), which is based on the DIN EN61400-11 (Windenergieanlagen, Teil 11: Geräuschimmissionen) dated February 2000.
3. ENERCON guarantees that there is not Tonality or Impulsivity over the complete measured reference wind speed 5 m/s < v_{10} < 7m/s for all hub heights.
4. Zero (0 - 1 dB(A)) tonality corresponds to $\Delta L_{tn} = L_{pt} - L_{pn} \leq -2$ dB according to IEC standard 88/48/CDV (page 21/22).
5. ENERCON turbines with their variable operational control guarantee that a given sound power level is being kept over the entire life of the turbine.
6. The mechanical concept of the ENERCON turbines (no fast rotating parts - therefore no mechanical wear) guarantees that no increase of machinery noise will occur during the entire lifetime of the turbines.
7. Sound power levels for the hub height of 85m and 98m Nabenhöhe are calculated by measured values of the hub height of 65m according to the German FGW-Richtlinie.

Summary of measurement results from the noise emmission measurement on the wind turbine

Enercon E66/18.70

Report WT 1630/01 dated 2001-01-05

WINDTEST
Kaiser-Wilhelm-Koog GmbH

Wind turbine technical data:

Type: E66/18.70
Manufacturer: .... Enercon GmbH, Aurich
Rated power: .... 1800 kW
Hub height above ground: .... 65,7 m
Hub height above top of foundation: .... 65 m
Power limiting: .... pitch
Tower type: .... steel circular section
Rotor diameter: .... 70 m
Number of rotor blades: 3
Rotor blade manufacturer: .... Enercon
Rotor blade type: .... Enercon
Rotor speed (range): .... 8 - 22 min^{-1}
Gearbox manufacturer: .... n/a
Gearbox type: .... n/a
Generator type: .... ring form, synchronous

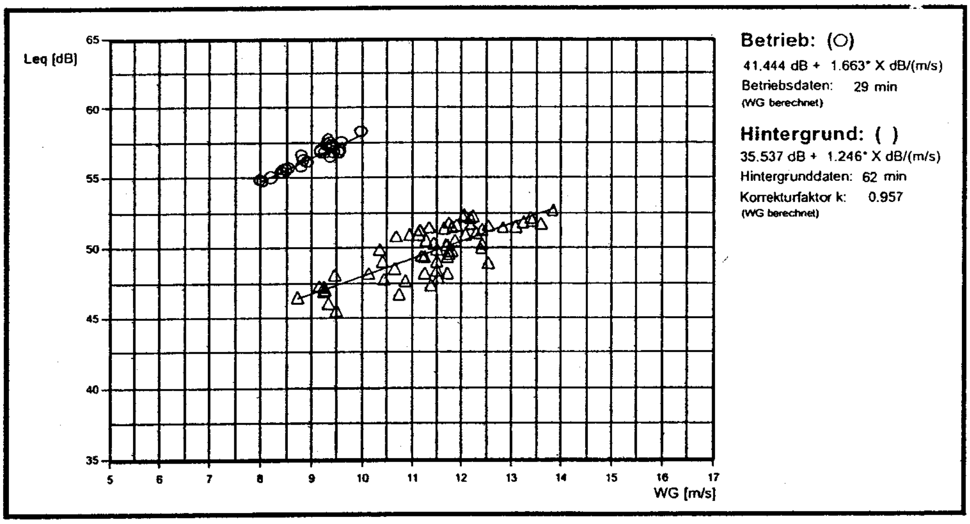
Measurement geometry:

Measurement distance R_0: .... 85 m
Height of foundation h_F: .... 0,7 m
Height of microphone h_A: .... 0 m
Plane of rotation ⇒ centre of tower d: .... 4,3 m

Measurement conditions:

Wind speed at a height of 10m,
1-min-averages, WS_{10m}: .... 6,9 – 13,1 m/s
Wind direction WD: .... WSW
Real electrical power $P_{e\ real}$: .... 103 - 1875 kW
Atmospheric air pressure p_{atmos}: .... 1001 hPa
Atmospheric air temperature T_{atmos}: .... 13,8 °C
Atmospheric air humidity: .... 80 %rel.

Determination of the sound power level according to the FGW-Standard:



Wind speed bin [m/s]	Bin range [m/s]	Bin average value [m/s]	No. of values [-]	Background noise corrected sound pressure level $L_{Aeq,c}$ at the bin average [dB]	Background noise corrected sound power level $L_{WA,c}$ [dB]
6	5,5 - 6,5	-	-	-	-
7	6,5 - 7,5	-	-	-	-
8	7,5 - 8,5	8,3	6	54,6	100,5
9	8,5 - 9,5	9,1	18	56,2	102,1
10	9,5 - 10,5	9,6	5	56,8	102,7

Bemerkungen:

- There is no data available in the lower bins.
- The 95 %-value of the rated power is 1710 kW which corresponds to 9,62 m/s at a height of 10 m.

Impulsivity according to FGW-Guideline/DIN 45645 T1 for reference conditions:

Wind speed bin [m/s]	Bin range [m/s]	Bin average [m/s]	Number of values [-]	Sound press. L_{Aeq} [dB]	Periodic max. L_{AFTm} [dB]	Impulsivity penalty K_{IN} [dB]
6	5,5 - 6,5	-	-	-	-	
7	6,5 - 7,5	7,4	2	55,1	56,3	1,2
8	7,5 - 8,5	8,2	90	55,3	56,3	1,0
9	8,5 - 9,5	9,0	180	56,4	57,4	1,0
10	9,5 - 10,5	10,2	1261	57,9	58,9	1,0

Third octave analysis for reference conditions (for 9,62 m/s at a height of 10 m):

25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630
65,7	68,2	71,9	75,4	78,1	80,9	83,1	85,3	88,0	86,3	88,6	91,2	92,2	92,6	93,2

800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
93,4	92,7	92,5	91,7	89,4	87,3	85,4	83,2	78,6	74,6	70,8	65,6

Octave analysis for reference conditions (for 9,62 m/s at a height of 10 m):

31,5	63	125	250	500	1000	2000	4000	8000
74,1	83,4	90,6	93,9	97,4	97,6	94,5	87,9	76,4

Determination of tonality according to FGW-Standard / EDIN 45681 for reference conditions:

Representative FFT - Spectrum for reference conditions (9,62 m/s at a height of 10 m):

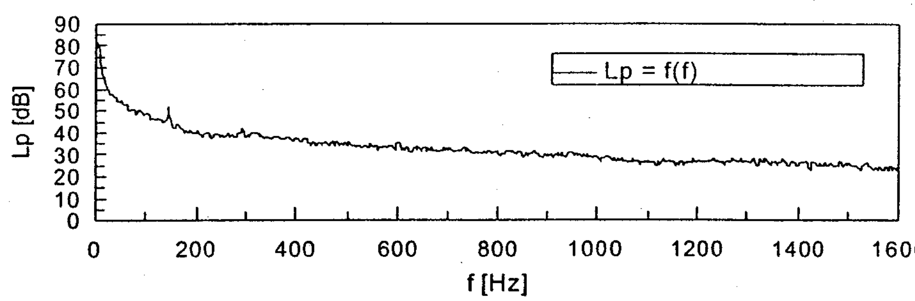


Table of results:

Bin range [m/s]	Bin average WS_{10m} [m/s]	Number of Spectra [-]	Frequency of tone f_T [Hz]	Sound pressure level diference ΔL [dB]	Tone penalty according to FGW – Standard [dB]
5,5 - 6,5	6	-	-	-	-
6,5 - 7,5	7	-	-	-	-
7,5 - 8,5	8	12	-	-	0
8,5 - 9,5	9	12	150	-4,88	0
9,5 - 10,5	10	12	146	-3,47	0

Bearbeiter:

Dipl.-Ing. J. Clausen

Geprüft:

Dipl.-Ing. V. Köhne
(Technischer Leiter)

Summary of Test Report

Basic sheet "Geraeusche" (Noise), according to the *"Technische Richtlinien für Windenergieanlagen, Teil 1: Bestimmung der Schallemissionswerte" (technical guidelines for wind energy plants, Part 1: Determination of sound emission values)*

Rev. 13 of January 1, 2000 (Editor: Foerdergesellschaft Windenergie e.V., Flotowstrasse 41-43, D-22083 Hamburg, Germany)

Extract of Test Report No. 25597-1.001
on noise emission of wind energy plant of type Enercon E-66/18.70 in Hage

Manufacturer of plant:	Enercon GmbH	Rated power (generator):	1800 kW
		Diameter of rotor:	70m
Serial number:	70020	Hub height above ground:	65m
Location of plant:	26524 Hage	Type of tower:	conic tube + socle
		Power control:	blade adjustment
Complementary data to the rotor (manufacturer's specifications)		**Complementary data to gear unit and generator (manufacturer's specifications)**	
Manufacturer of rotor blade:	Enercon	Manufacturer of gear unit:	not applicable
Type of rotor blade:	Enercon	Type of gear unit:	not applicable
Blade setting angle:	Variable	Manufacturer of generator:	Enercon
Number of rotor blades:	3	Type of generator:	E-66/18.70, ring type
Rotor speed range:	8 to 22 r.p.m	Rated generator speed:	22 r.p.m

test report to power curve: Measurement of power curves DEWI-PV 0002-05-E, Deutsches Windenergie-Institut GmbH

	Reference Point		Observations	
	standardized wind speed in 10 m height	sound emission parameter		
sound power level $L_{WA,P}$	5 ms^{-1} 6 ms^{-1} 7 ms^{-1} — —	91,8 dB(A) 94,9 dB(A) 97,3 dB(A) — —		
tone adjustment in the near field K_{TN}	5 ms^{-1} 6 ms^{-1} 7 ms^{-1} — —	0 dB 0 dB 0 dB — —		
impulse adjustment in the near field K_{IN}	5 ms^{-1} 6 ms^{-1} 7 ms^{-1} — —	0 dB 0 dB 0 dB — —		

sound power level in third-octave bands for reference point v_{10} = 6,0 ms^{-1} in dB(A)

frequency	16	20	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500
$L_{WA,P}$	--	--	30,7,	37,4	44,4	49,65	56,1	60,0	65,0	70,4	73,8	78,3	81,9	83,1	83,4	84,6
frequency	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000	12500	16000	20000
$L_{WA,P}$	86,8	85,3	85,6	84,7	83,1	80,9	79,5	78,4	77,1	74,3	72,0	69,8	68,7	66,5	63,3	58,3

sound power level in third-octave bands for reference point v_{10} = 7,0 ms^{-1} in dB(A)

frequency	16	20	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500
$L_{WA,P}$	--	--	33,1	39,8	46,8	51,9	58,5	62,4	67,4	72,8	76,2	80,7	84,3	85,5	85,8	87,0
frequency	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000	12500	16000	20000
$L_{WA,P}$	89,2	87,8	88,0	87,1	85,5	83,3	81,9	80,8	79,5	76,7	74,4	72,2	71,1	59,9	65,6	60,7

This summary of the test report is valid only in connection with manufacturer's certification. These specifications do not replace the test report mentioned above (particularly for noise immission predictions).

Note: The sound power levels should be determined for the range of wind speeds v_{10} from 5 to 7 m/s.

Measured by: KÖTTER Consulting Engineers
- Rheine -

KÖTTER CONSULTING ENGINEERS
Bonifatiusstraße 400 · 48432 Rheine
Tel. 0 59 71 - 97 10.0 · Fax 0 59 71 - 97 10.43

Date: 2001-07-20

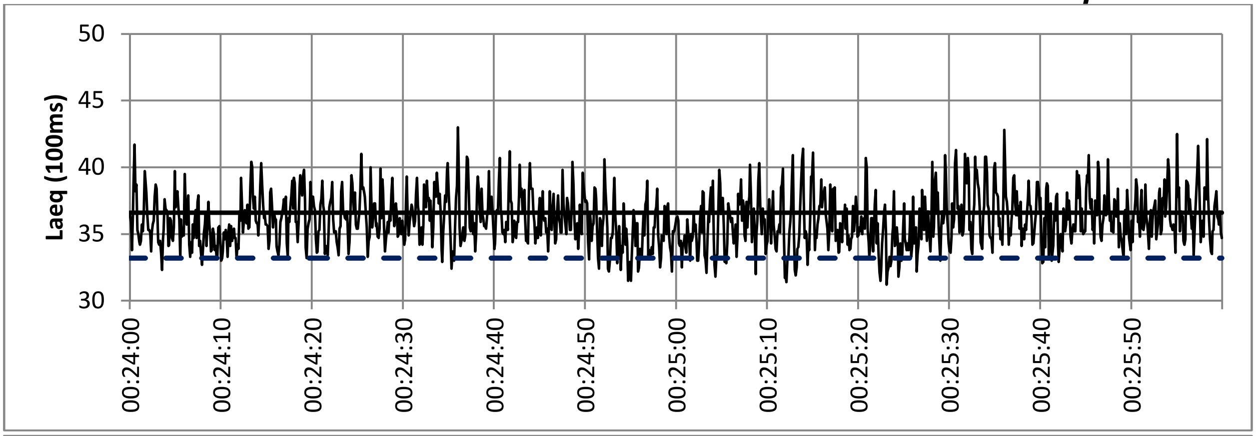
i. V. Arno Schälly

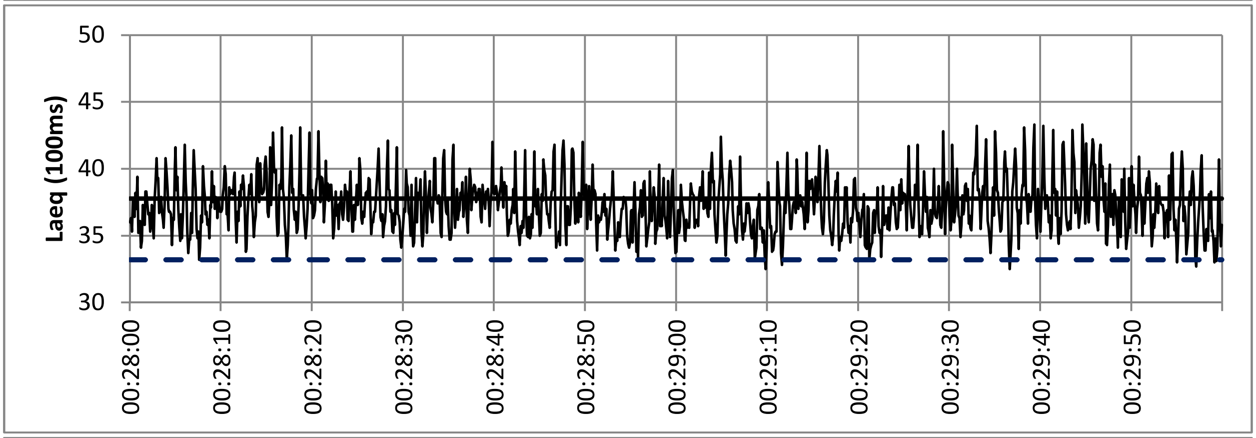
Signature

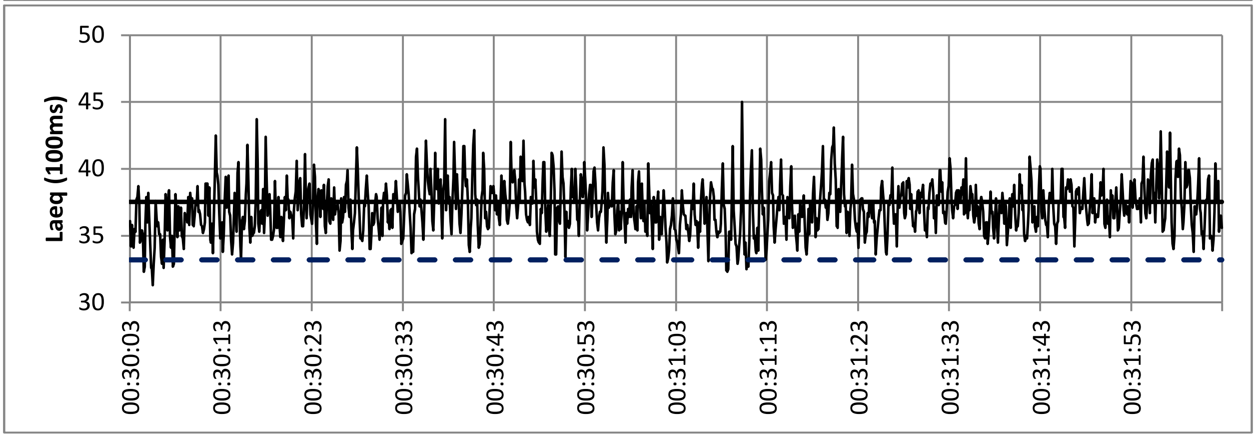
This summary of the test report covers 1 page.

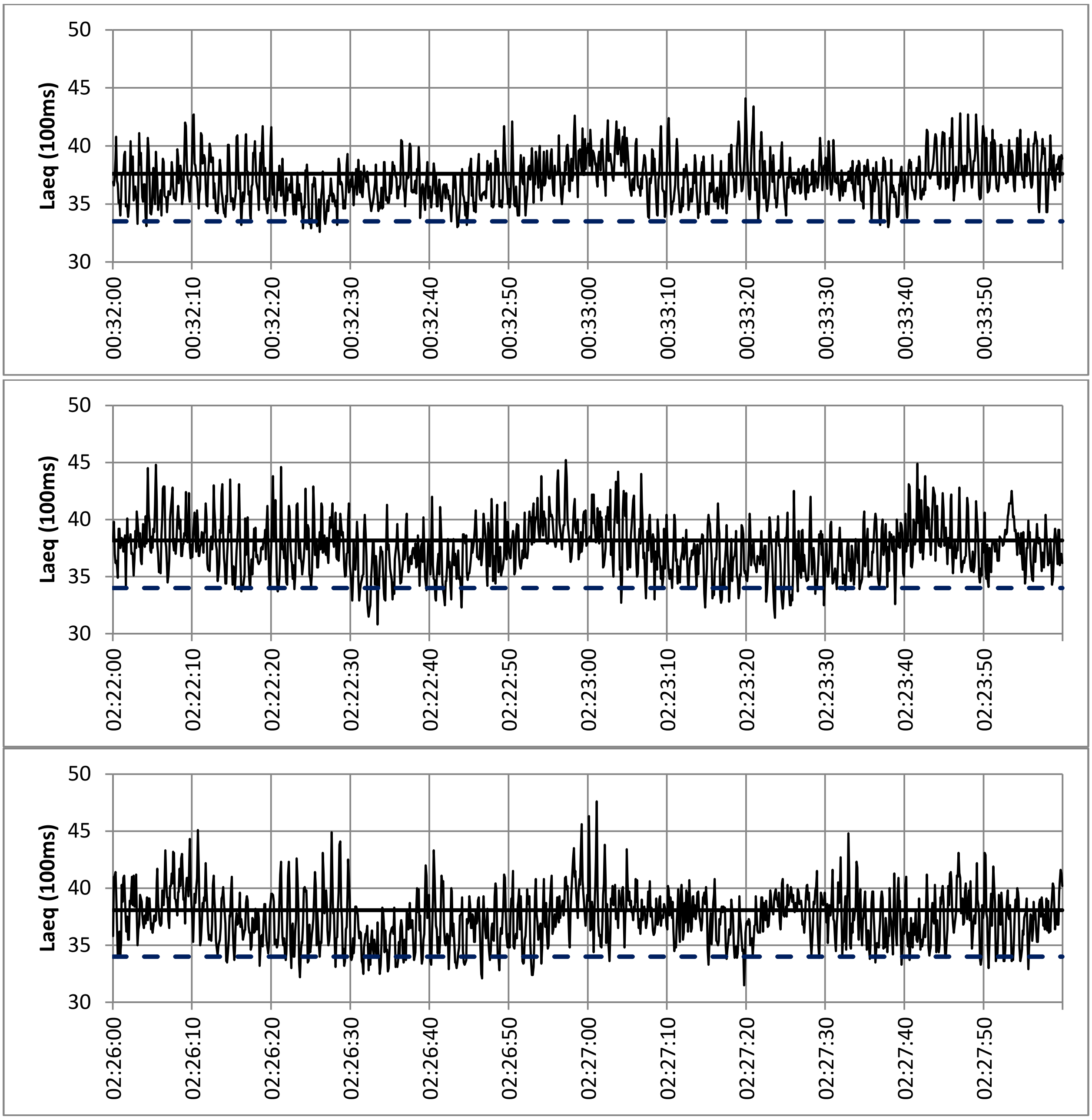
Appendix 2

Figures showing 2 minute samples of wind turbine noise measured 487m from the Sporle Road turbine at Swaffham. The blue dotted line shows the predicted noise (LAeq) using the IoA GPG recommended parameter of G=0.5 and warranted levels + 2dB. The black line shows the actual measured LAeq.

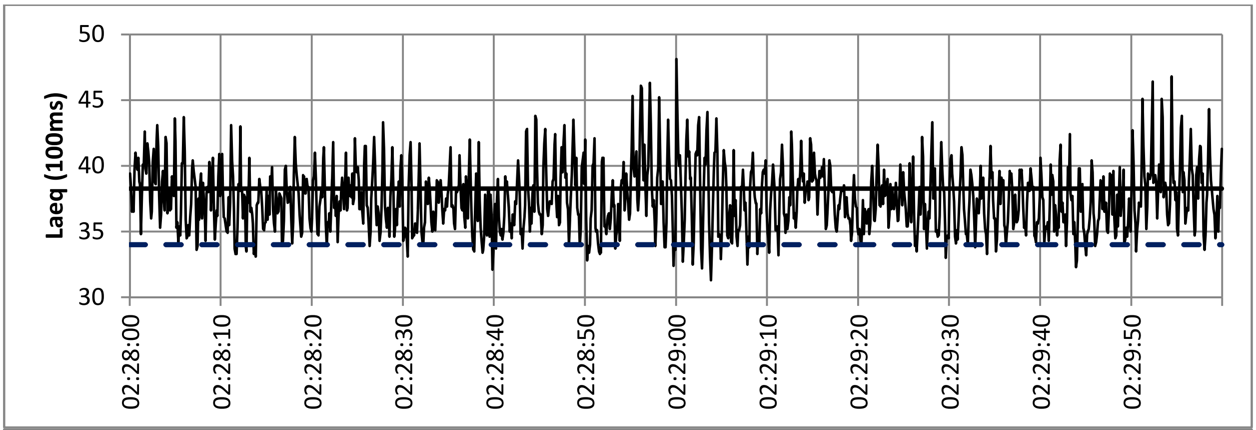


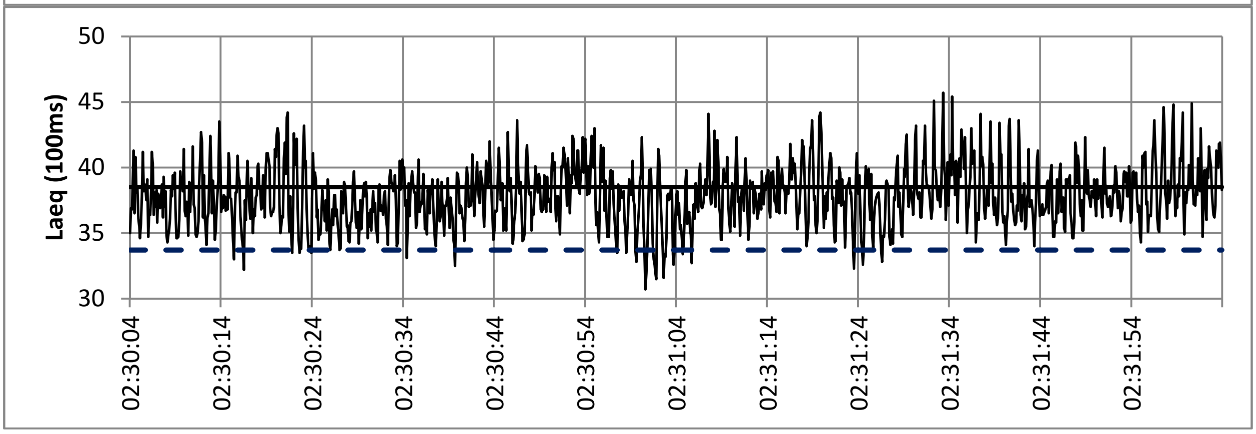






Laeq (100ms)
50
45
40
35
30
00:32:00
00:32:10
00:32:20
00:32:30
00:32:40
00:32:50
00:33:00
00:33:10
00:33:20
00:33:30
00:33:40
00:33:50
02:22:00
02:22:10
02:22:20
02:22:30
02:22:40
02:22:50
02:23:00
02:23:10
02:23:20
02:23:30
02:23:40
02:23:50
02:26:00
02:26:10
02:26:20
02:26:30
02:26:40
02:26:50
02:27:00
02:27:10
02:27:20
02:27:30
02:27:40
02:27:50


Laeq (100ms)
50
45
40
35
30
02:28:00
02:28:10
02:28:20
02:28:30
02:28:40
02:28:50
02:29:00
02:29:10
02:29:20
02:29:30
02:29:40
02:29:50


Laeq (100ms)
50
45
40
35
30
02:30:04
02:30:14
02:30:24
02:30:34
02:30:44
02:30:54
02:31:04
02:31:14
02:31:24
02:31:34
02:31:44
02:31:54