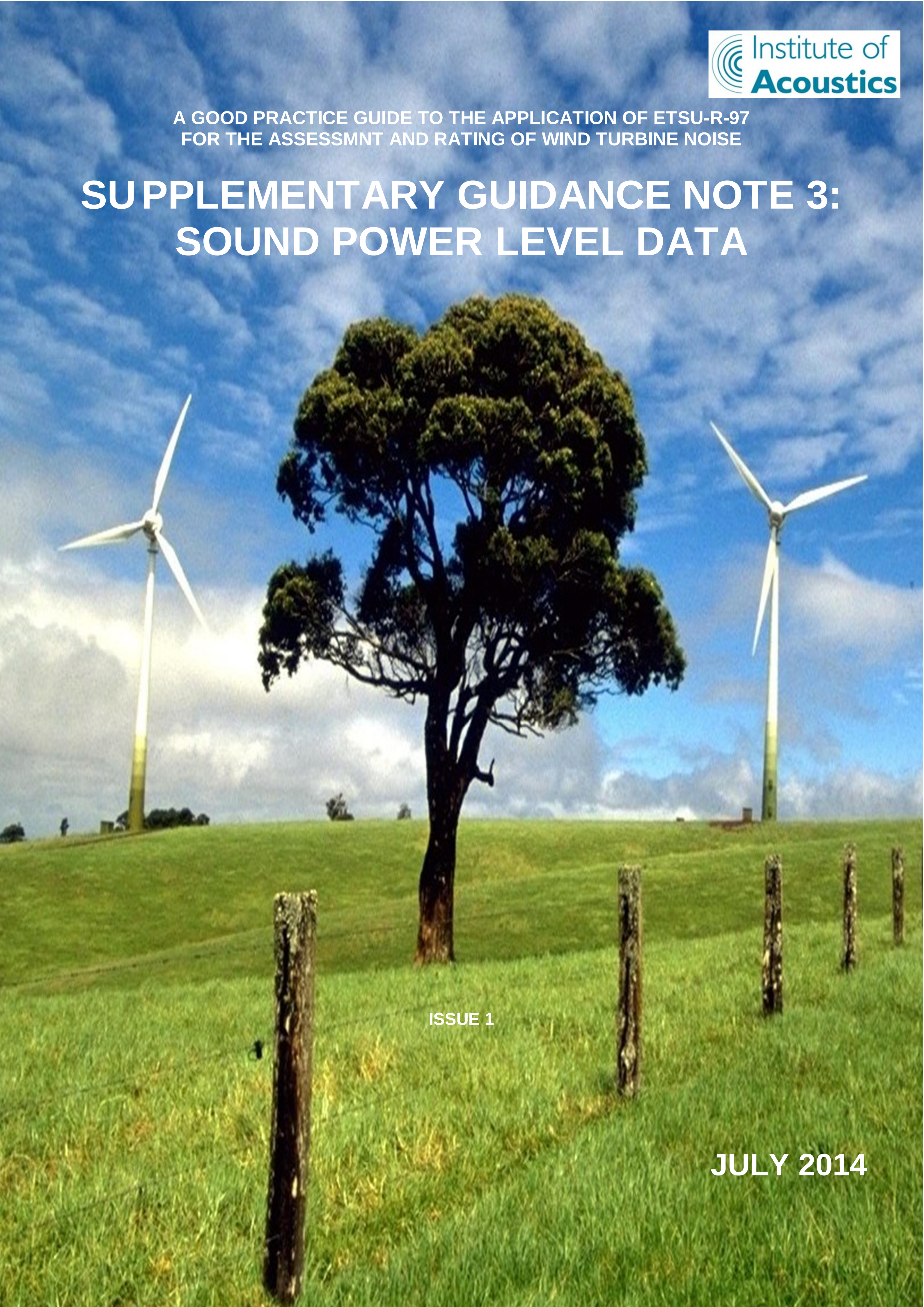
A GOOD PRACTICE GUIDE TO THE APPLICATION OF ETSU-R-97
FOR THE ASSESSMNT AND RATING OF WIND TURBINE NOISE

SUPPLEMENTARY GUIDANCE NOTE 3: SOUND POWER LEVEL DATA



ISSUE 1

JULY 2014

PREFACE

This document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

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The working group was also assisted in the drafting of this note by Jeremy Bass from Renewable Energy Systems Ltd.

This supplementary guidance note has been produced to supplement the IOA document 'A GOOD PRACTICE GUIDE TO THE APPLICATION OF ETSU-R-97 FOR THE ASSESSMENT AND RATING OF WIND TURBINE NOISE' which is available on the IOA website at the following link: http://www.ioa.org.uk/publications/good-practice-guide (checked 06.04.14).

Prior to publication of this note, a peer review was undertaken by a separate group.

Any comments on this document should be sent to ETSUCONSULT@IOA.ORG.UK. The IOA will keep the document under review, and consider updating when significant changes to current good practice have occurred.

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Supplementary Guidance Notes

Number	Title	Information
1	**Data Collection**	Equipment specifications; measurement surveys: Practical considerations and set-up guidance and examples.
2	**Data Processing & Derivation of ETSU-R-97 background curves**	Data filtering, processing and regression analysis for different types of noise environments.
3	**Sound Power Level Data**	Manufacturer's data and warranties analysis.
4	**Wind Shear**	Wind speed references and long-term data analysis.
5	**Post Completion measurements**	Examples, considerations and strategies.
6	**Noise Propagation over water for on-shore wind turbines**	Noise propagation over large bodies of water.

CONTENTS

1 Context

1.1 Background

1.1.1 The Institute of Acoustics (IOA) published ‘A GOOD PRACTICE GUIDE TO THE APPLICATION OF ETSU-R-97 FOR THE ASSESSMENT AND RATING OF WIND TURBINE NOISE’ (GPG) in May 2013 to provide technical assistance for the undertaking of wind turbine noise assessments using the ETSU-R-97 document. In order to keep the GPG to a reasonable length, but not to lose clarifications and case studies, it was decided to produce a number of supplementary guidance notes which would support the GPG.

1.1.2 This guidance note will be of relevance to:

i. Acoustics consultants;
ii. Local Planning Authority (LPA) Environmental Health and Planning departments;
iii. Developers;
iv. The Planning Inspectorate or equivalent regulating authority;
v. The general public.

1.2 Scope of the Document

1.2.1 A series of six Supplementary Guidance Notes have been produced. This Supplementary Guidance Note 3 supports Section 4.2 and 4.3 of the GPG. The main aim of this SGN is to ensure the adequacy of the input data for prediction of turbine noise immission. It provides additional information on the variety of source data for the sound power levels of turbines, and offers guidance on how to interpret the data for use in accordance with the method in the GPG.

1.3 Statutory Context

1.3.1 This Supplementary Guidance Note has been approved by the IOA Council for use by IOA Members and others involved in the assessment and rating of wind turbine noise using ETSU-R-97. It covers technical matters of an acoustic nature which the IOA-NWG believes represent current good practice.

2 Introduction and Types of data

2.1.1 Turbine Sound Power Level data can be acquired from a number of different sources. Section 4.2 of the GPG describes the different types of sound power data which can be available. At least one of these data types, assessed in line with the relevant standard stated, should be available from turbine manufacturers in order to allow undertaking predictions in line with the guidance set out in section 4.3 of the GPG. Obtaining either a larger number of, or more recent, data sources for a particular turbine model is generally useful as it can provide relevant or valuable information on sound power levels and uncertainty, but these should be compared with care.

2.1.2 There is no suggestion in the GPG that one type of source data is preferred to another; instead it is a requirement of the noise assessment report to demonstrate that, whatever the data source, an appropriate allowance has been made for the potential uncertainty in the data. Uncertainty can arise from measurement uncertainties, production tolerances and design differences, and must be clearly stated. Care must be taken when reviewing manufacturers' documentation as uncertainties will be stated in different ways and may not always be included in the stated data. Section 4.3.6 of the GPG provides guidance on the requirements for suitable data, when undertaking calculations in accordance with the prediction parameters specified in section 4 of the GPG. Paragraph 4.3.6 specifies the use of G=0.5 as a ground parameter, but 4.3.3/4.3.5 specifies conditions in which G=0.0 is recommended: for the avoidance of doubt, the same emission value requirements (4.3.6) apply in both cases.

2.1.3 It is acknowledged that different data sources or methods allowed by the guidance of 4.3.6 may lead to different results; the general introduction of 4.1.6 of the GPG should be borne in mind.

2.1.4 A turbine noise warranty document specifies noise levels which the manufacturer warrants would not be exceeded by undertaking a sound power test of the installed turbines on a specific site, subject to conditions. These conditions can include uncertainty considerations. Warranties can take the form of a general document which applies to the turbine in general or a site-specific warranty given to a customer purchasing a turbine for a particular site (but which are rarely available). If the document does not specify bounds on the emission noise levels, then it may be better described as a specification document.

2.1.5 In addition, the values stated in any such a document may not necessarily explicitly include an allowance for uncertainty (GPG 4.2.2). Therefore an evaluation of uncertainty allows scrutinising this data, for example using the test method proposed in GPG 4.3.6 which considers tested uncertainties with an “expanded” factor of 1.645 (as explained in footnote 5). This is stated as being between 1 and 2 dB(A) as typical of values obtained in most cases, but this may be above 2 dB(A) in some cases, and in the absence of any other data, the higher value should be used: see Example 3 below.

2.1.6 Alternatively, the method set out in TS IEC 61400-14 shows how to calculate a declared sound power level based on the results of (ideally) several test reports and incorporating directly an allowance for uncertainty. This may differ from values warranted by the manufacturer.

2.1.7 Practitioners should be mindful that an update to IEC 61400-11 has been approved in 2012: GPG 4.2.3, and that in particular test results may be reported as a function of hub height wind speed directly without the application of the standardisation factor.

2.1.8 Although data may not be available at all wind speeds, it is important to recognise that modern variable-speed pitch-regulated turbines will reach a maximum noise level of noise emissions at a certain wind speed (GPG 2.9.2): therefore if no data is available for the highest wind speeds (standardised wind speeds of 10 m/s and above), a constant value can be assumed. Similarly, noise emissions for these turbines tends to decrease strongly at lower wind speeds when approaching cut-in, and therefore calculations at the lowest end of the range may not be necessary to the assessment. For fixed-speed turbines, a more constant (linear) trend of noise emission versus wind speed is generally apparent and can be assumed at other wind speeds provided the turbine operation remains similar. For stall-regulated turbines, noise emissions can increase significantly at the higher wind speeds and data at these wind speeds should be sought if possible.

2.1.9 When considering information on tonality derived in sound power test reports using the IEC 61400-11 standard, it is important to recognise that this is evaluated using a different method than that in ETSU-R-97 and that the latter applies at residential properties rather than in proximity to the turbines.

3 Sound Power Data – Overall Levels – Examples

3.1 Overview

3.1.1 The following provides examples of the application of the guidance at section 4.3.6 of the GPG when considering the prediction parameters specified in section 4 of the GPG.

3.2 Example 1

3.2.1 The example represented in Figure 1 shows sound power data specified by the manufacturer. It is not fully clear from the document if or how the specified data (blue curve) is warranted, as this is likely to be agreed to specific terms in each commercial situation.

3.2.2 The specification states that an additional 1 dB should be added for all calculations. The tested sound power data is shown to be clearly below the specified data. The uncertainty specified in the test results (U_c or σ) is of σ =0.8 dB, therefore the "expanded" uncertainty is 1.645 σ = 1.32 dB and is shown in Figure 1 as error bars. This shows that the addition to the specification levels of an additional factor is required in this instance, as for half of the tested wind speeds, the upper bound of the error bars exceeds the specified levels. A further correction of at least +0.5 dB is required, and the addition of +1 dB recommended by the manufacturer therefore achieves this.

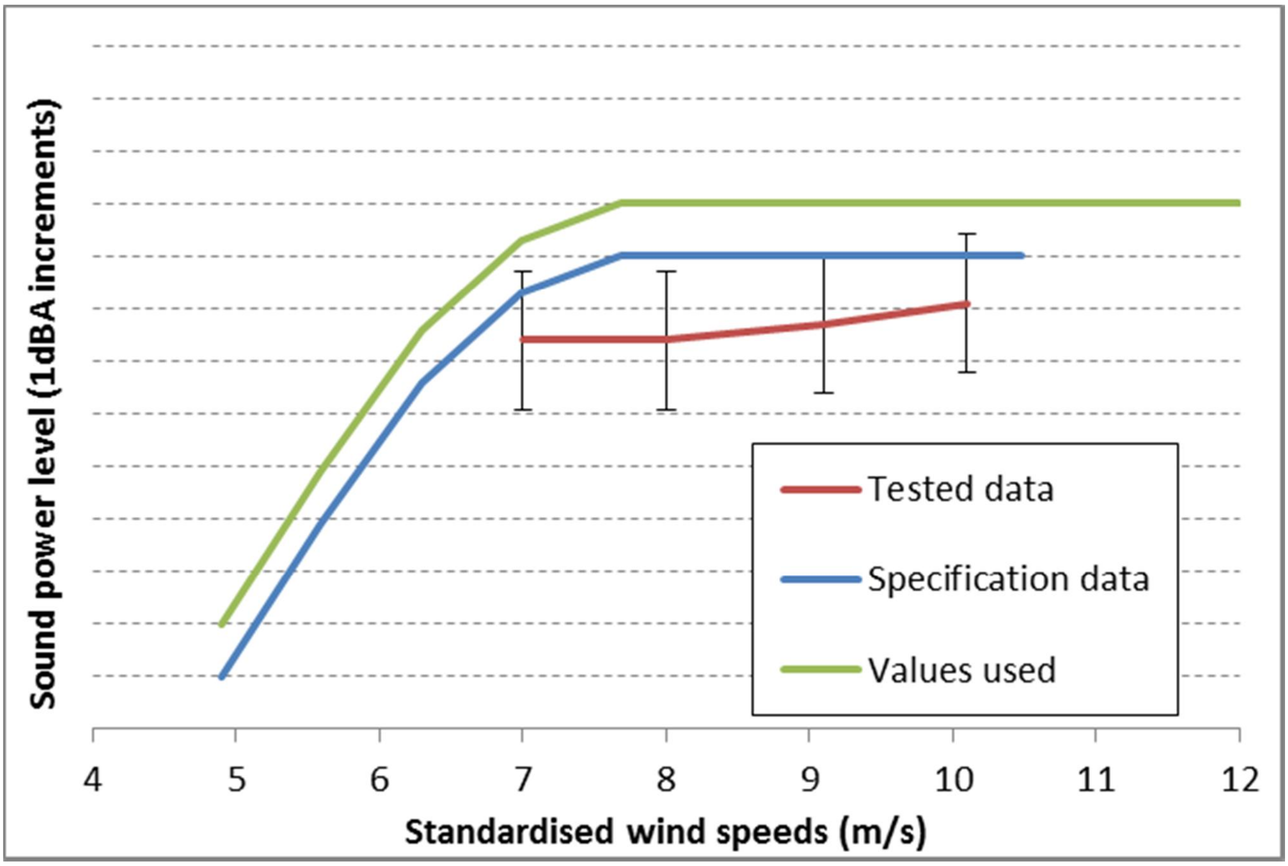

Figure 1 – example of specification data in relation to tested sound power with expanded uncertainty

3.3 Example 2

3.3.1 The example of Figure 2 shows a different set of manufacturer data (blue curve) contained within a generic warranty document. The document states that when evaluating any single test result in relation to the specified levels, they will be within the uncertainty values calculated in accordance with IEC 61400-14. This therefore means that although contained in warranty, the specified sound power *values* may not directly incorporate a margin of uncertainty, as the latter needs to be accounted for as part of the warranty test procedure: they would therefore not be used as stated.

3.3.2 This is confirmed by comparing these values to the results of a sound power test supplied by the manufacturer (only a single one available). The tested results are similar to the specified values, although marginally higher at some wind speeds. As little or no uncertainty was included in the manufacturer stated warranted values, and no information on uncertainty is specified in the test report extract available, a correction of + 2dB is added to these values, in accordance with the GPG guidance (4.3.6), to obtain suitable emission values (green curve).

3.3.3 A typical[1] expanded uncertainty of 1.5 dB is indicated on the chart of Figure 2 as error bars. It can be seen that the warranted data +2dB encompasses the test results and the expanded uncertainty for the large majority of the wind speed range.

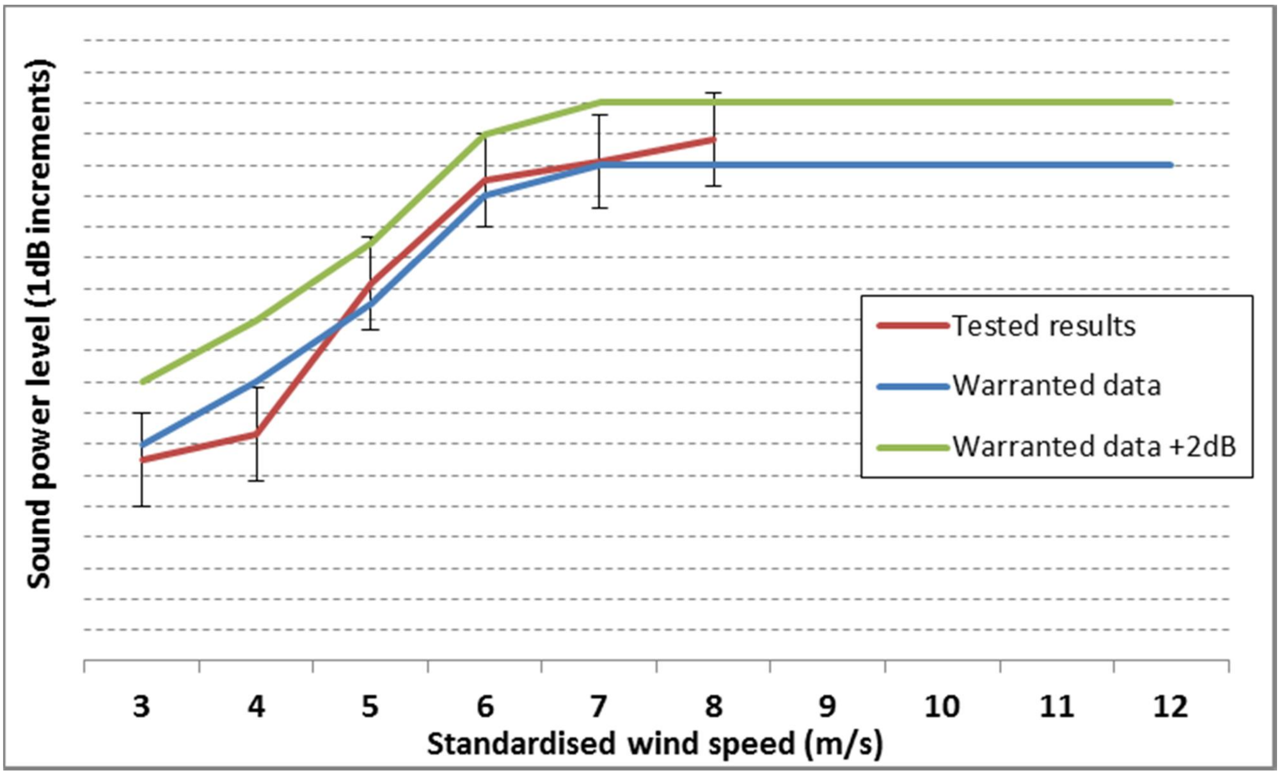

Figure 2 – Example of warranty data comparison with tested sound power with expanded uncertainty

[1] See GPG 4.3.6, footnote 6.

3.4 Example 3

3.4.1 In this example, no manufacturer warranty or specification is available, however the results of a test report undertaken in accordance with the IEC 61400-11 standard are available: see Table 1 below. These test report values can be used (in the absence of any other data) but, first, account needs to be taken of uncertainties in the data.

3.4.2 In addition to the sound power values (L_{WA}), the derived values of the test uncertainty $U_c = \sigma$ are stated: in this example they are relatively high, which may be due to the turbine having been tested in less than ideal conditions (such as with high background levels). In this case, an expanded uncertainty (1.645 σ) is higher than 2 dB in most cases; therefore, in this specific case, it is this expanded uncertainty value that is added to the sound power levels at all wind speeds to obtain the input to the predictions. If another test report with reduced uncertainty was available, it would be used in preference to this data.

Standardised Wind Speed (m/s)	**5**	**6**	**7**	**8**	**9**	**10**
Reported L_{WA}	98.2	100.8	101.4	103.0	104.5	106.7
Uncertainty $\sigma=U_c$	1.2	1.3	1.7	0.9	1.0	1.7
1.645.σ	2.0	2.1	2.8	1.5	1.6	2.8
L_{WA}+ 1.645σ	100.2	102.9	104.2	104.5	106.1	109.5
L_{WA}+2dB	100.2	102.8	103.4	105.0	106.5	108.7
ΔL_{WA}	0.0	0.1	0.8	-0.5	-0.4	0.8
L_{WA} for Predictions	100.2	102.9	104.2	104.5	106.1	109.5

Table 1 – Example of test data with relatively high uncertainty

3.5 Example 4

3.5.1 Table 2 provides an example of a calculation of a declared sound power level undertaken in accordance with the procedure used in TS IEC 61400-14, which should be referenced in full. In this example, three test results were used and a standard deviation of reproducibility σ_R=0.5 was assumed as this is considered realistic. This example set out in Table 2 is illustrated in Figure 3.

Standardised wind speed (m/s)	5	6	7	8	9	10
Test result 1 (dB(A))	n/a	103.6	104.8	105.2	105.3	106
Test result 2 (dB(A))	n/a	103.1	104.8	105.3	105.5	n/a
Test result 3 (dB(A))	101.5	102.4	104.1	104.7	104.2	n/a
Averaged sound power (Lw, dB(A))		103.0	104.6	105.1	105.0	
Standard deviation of production (s=σ_P)		0.6	0.4	0.3	0.7	
Total standard deviation (σ)		0.9	0.7	0.7	1.0	
Confidence Level (K = 1.645 σ)		1.5	1.2	1.1	1.6	
Declared sound power (Lw+K) (dB(A))		104.5	105.8	106.2	106.6	

Table 2 – Example of a calculation of a declared sound power level

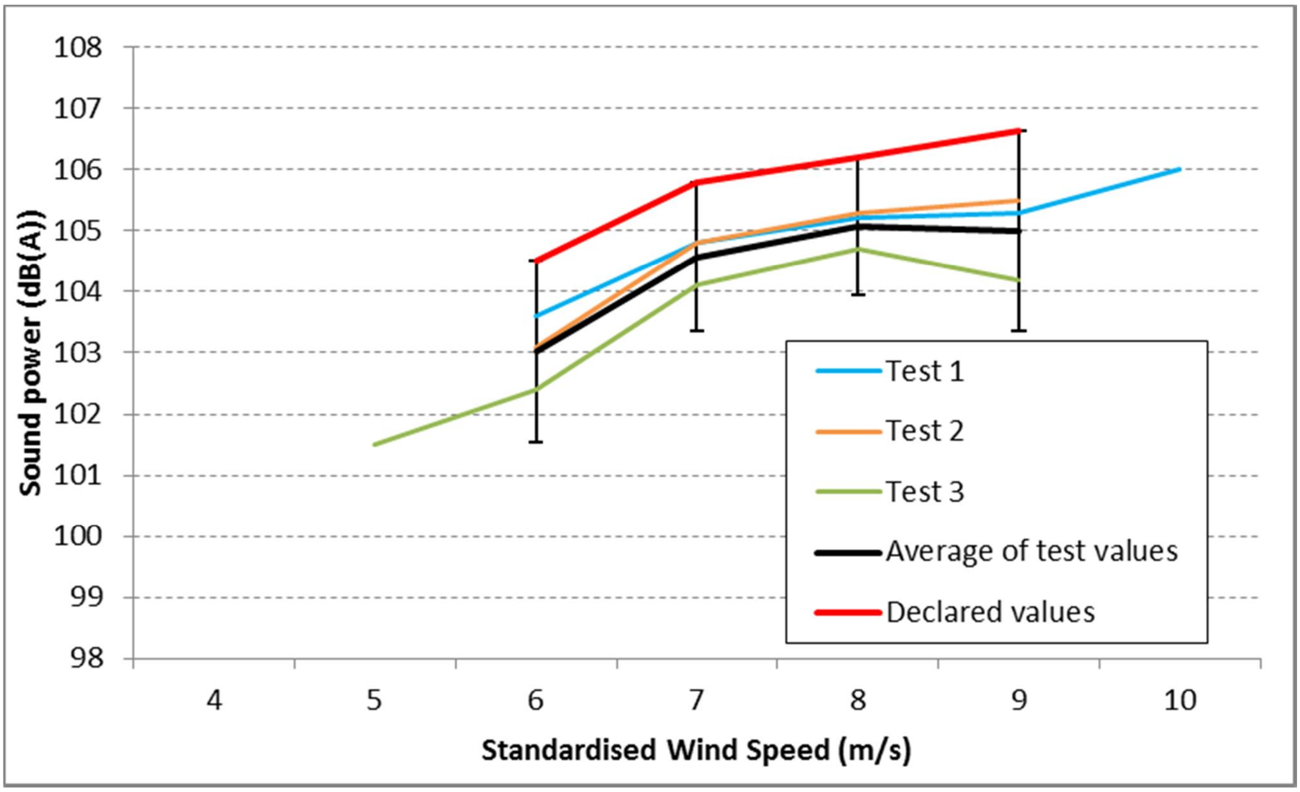

Figure 3 – Example of the calculation of a declared sound power value

4 Spectral data

4.1.1 Section 4.3.3 of the GPG recommends that predictions are made using a representative spectrum for the turbine. This can be obtained from an IEC 61400-11 test report which should state the tested 1/3 octave band spectrum at different key wind speeds in accordance with the standard. This can be reduced to octave band values, using logarithmic addition as in the example of Table 2, for input to the ISO 9613-2 calculations.

4.1.2 Please note that test spectra are reported A-weighted in accordance with the requirements of the standard and there is no need to apply A-weighting a second time. This should be clear from the profile of the spectrum.

4.1.3 Spectra may not be available for the full range of wind speeds considered, and it is standard practice to consider one or more spectra at (a) key wind speed(s) (8 m/s being commonly used as a reference wind speed), and scaling the results to the other wind speeds. As the overall levels used (see examples in Section 3 of this SGN) should include an allowance for uncertainty, they can differ from the A-weighted level derived from the test spectrum at a particular wind speed. The spectrum (or the results of the spectral propagation calculation) is then scaled for each wind speed in line the A-weighted sound power levels.

Frequency (Hz)	1/3 octave band spectrum (dB)	Octave Band spectrum (dB)
50	77.3	87.4
63	81.5	
80	85.5	
100	88.8	96.3
125	91.7	
160	93.1	
200	95.1	101.6
250	97.4	
315	97.5	
400	96.4	101.1
500	96.9	
630	95.6	
800	95.7	100.2
1000	95.3	
1250	95.2	
1600	93.5	97.2
2000	92.4	
2500	91.0	
3150	88.9	90.6
4000	84.0	
5000	80.4	
6300	76.2	78.2
8000	72.2	
10000	68.9	

Table 3 – Example of a tested sound power spectrum

5 Data for alternative hub heights

5.1.1 As it is standard practice to undertake predictions for wind speeds standardised to 10m height, the sound power level in relation to the standardised wind speed will vary for different turbine hub heights. It is possible to convert such data to different hub heights by relating the sound power results to hub height wind speed in the first instance, as the noise emission are related to this variable. This can then be converted to standardised wind speed for another hub height using the standard profile assumed in IEC 61400-11, and the resulting values interpolated to obtain integer wind speed values if required. An example is shown in Table 4 (and Figure 4) which shows how the apparent sound power is increased marginally, for a fixed standardised wind speed, if a higher hub is considered.

5.1.2 In the event that the turbine noise information states the sound power in relation to the hub height wind speeds directly, then the first step can be omitted and the standardised wind speeds can be calculated for the new height directly.

Wind Speed at 10m height (standardised from 69m)	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Tested sound power for 69m HH	101.5	103.4	103.9	103.6	103	102.5	102.1
Corresponding hub height wind speed (69m)	8.2	9.6	10.9	12.3	13.6	15.0	16.4
Wind Speed at 10m height (standardised from 100m)	5.7	6.7	7.6	8.6	9.5	10.5	11.4
Integer Wind Speeds at 10m height (standardised from 100m)	6	7	8	9	10	11	
New Sound Power Values for 100 m Hub (Standardised Wind Speeds)	102.1	103.6	103.8	103.3	102.7	102.3	

Table 4 – Conversion example of tested sound power (dB(A)) converted for standardised wind speeds (m/s) at a different hub height (HH)

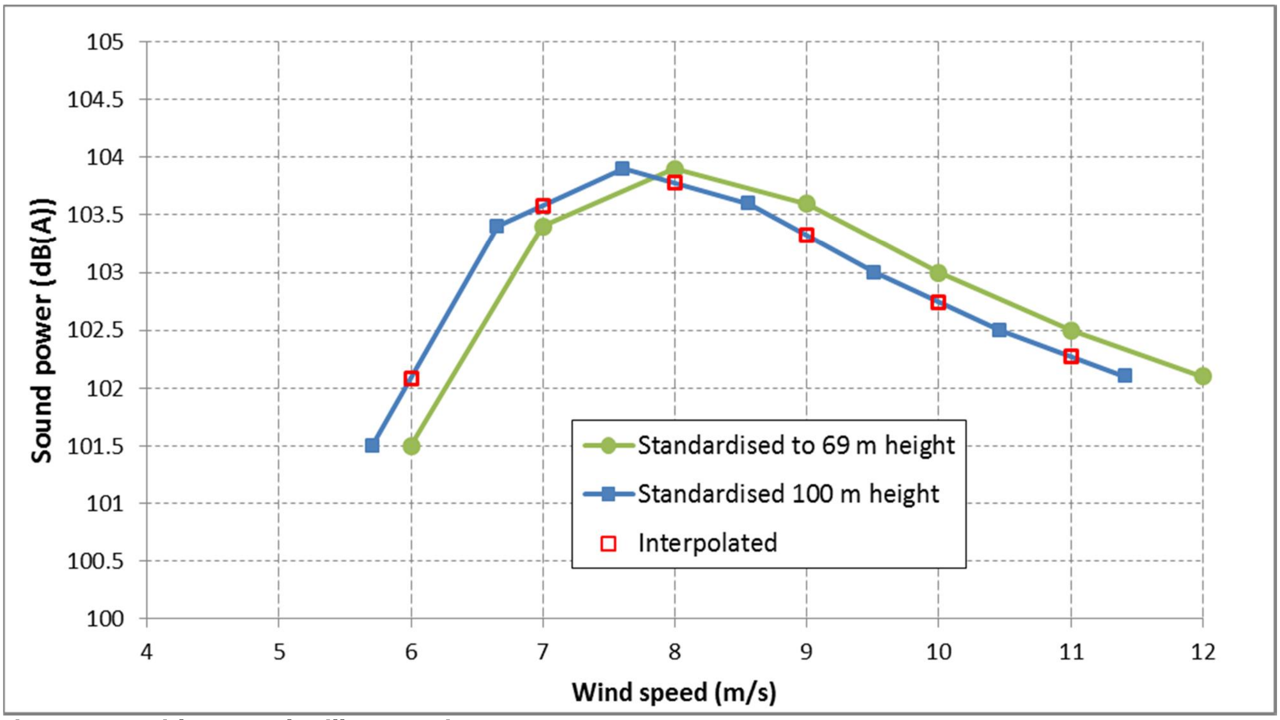

Figure 4 – Table 4 results illustrated

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