British Wind Energy Association Small Wind Turbine Performance and Safety Standard (March 2007)

1 General Information

1.1 Purpose

This standard was created by the small wind turbine industry, scientists, state officials, and consumers to provide consumers with realistic and comparable performance ratings and an assurance the small wind turbine products certified to this standard have been engineered to meet carefully considered standards for safety and operation. The goal of the standard is to provide consumers with a measure of confidence in the quality of small wind turbine products meeting this standard and an improved basis for comparing the performance of competing products.

1.2 Overview

1.2.1 This performance and safety standard provides a method for evaluation of wind turbine systems in terms of safety, reliability, power performance, and acoustic characteristics. This standard for small wind turbines is derived largely from existing international wind turbine standards developed under the auspices of the International Electrotechnical Commission (IEC). Specific departures from the IEC standards are provided to account for technical differences between large and small wind turbines, to streamline their use, and to present their results in a more consumer-friendly manner. The equivalent BS (British Standard) are quoted for ease of use.

1.2.2 No indirect or secondary standards references are intended. Only standards directly referenced in this standard are embodied.

1.3 Scope

1.3.1 This standard generally applies to small wind turbines for both on-grid and off-grid applications.

1.3.2 This standard applies to wind turbines having a rotor swept area of 200 m2 or less. In a horizontal-axis wind turbine this equates to a rotor diameter of ~ 16 m (~ 52 ft)

1.3.3 A turbine system includes the wind turbine itself, the turbine controller, the inverter, if required, wiring and disconnects, and the installation and operation manual(s).

1.3.4 In cases where several variations of a turbine system are available, it is expected that a full evaluation would be performed on one of the most representative arrangements. Other variations, such as different power output forms, need only be evaluated or tested in the ways in which they are different from the base configuration. For example, a wind turbine available in both grid-intertie and battery charging versions would need separate performance tests if both versions were to be certified, but would

not need a separate safety evaluation in most cases.

1.3.5 Except as noted in Sections 2.1.1, 4.2, 5.2.6, 5.2.7, and 6.1.4.1, towers and foundations are not part of the scope of this standard because it is assumed that conformance of the tower structure to the International Building Code, Uniform Building Code or their local equivalent will be required for a building permit.

1.4 Compliance

1.4.1 Compliance with this standard must be certified by an independent certification body itself accredited to the requirements of EN 45011 by UKAS or an equivalent accreditation body (for example, a member of EA: European Co-operation for Accreditation).

1.4.2 Test data may be taken, analyses may be performed, and test reports may be submitted by any party, including the manufacturer, but they must be provided in a manner acceptable to an accredited certifying body[1].

1.4.3 As an interim measure to 1.4.1 self-certification may be undertaken by the manufacturer subject to the ongoing consent of the British Wind Energy Association (BWEA).

1.5 Definitions

1.5.1 Per BS EN 61400-12-1:2006 (Performance); BS EN 61400-11:2003 (Acoustic Noise); and BS EN 61400-2:2006 (Design Requirements).

1.5.2 Additional Definitions

1.5.2.1 BWEA Reference Power: The wind turbine's power output at 11.0 m/s (24.6 mph) per the power curve from BS EN 61400-12-1.

1.5.2.2 BWEA Reference Annual Energy: The calculated total energy that would be produced during a one-year period at an average wind speed of 5.0 m/s (11.2 mph), assuming a Rayleigh wind speed distribution, 100% availability, and the power curve derived from BS EN 61400-12-1 (sea level normalized).

1.5.2.3 BWEA Reference Sound Level: The sound level that will not be exceeded 95% of the time, assuming an average wind speed of 5.0 m/s (11.2 mph), a Rayleigh wind speed distribution, 100% availability, and an observer location 60 m (~ 200 ft.) from the rotor center[2], calculated from BS EN 61400-11:2003 test results, except as modified in Section III of this Standard.

1.5.2.4 Cut-in Wind Speed: The lowest wind speed at which a wind

1 Unless conducted by an accredited and independent test laboratory, this will normally require that the certification authority be involved well before the commencement of data gathering, and the certification authority are likely to require intense scrutiny of the entire process.

[2] Appendix A contains guidance on obtaining sound levels for different observer locations and background sound levels.

turbine will begin to have power output[3].

1.5.2.5 Cut-out Wind Speed: The wind speed above which, due to control function, the wind turbine will have no power output.

1.5.2.6 Maximum Power: The maximum one-minute average power output a wind turbine in normal steady-state operation will produce (peak instantaneous power output can be higher).

1.5.2.7 Maximum Voltage: The maximum voltage the wind turbine will produce in operation including open circuit conditions.

1.5.2.8 Maximum Current(s): The maximum current(s) the wind turbine will produce on each side of the systems control or power conversion electronics.

1.5.2.9 Overspeed Control: The action of a control system, or part of such system, which prevents excessive rotor speed.

1.5.2.10 Power Form: Physical characteristics which describe the form in which power produced by the turbine is made deliverable to the load.

1.5.2.11 Rotor Swept Area: Projected area perpendicular to the wind direction swept by the wind turbine rotor in normal operation (un-furled position). If the rotor is ducted, the area inscribed by the ducting shall be included.

1.5.2.12 Turbulence Intensity: The standard deviation of 1-second wind speed data divided by the mean of 1-second wind speed data averaged over a period of 1-minute.

1.6 Units

1.6.1 The primary units will be SI (metric). The inclusion of secondary units in the English system is recommended [e.g., 10 m/s (22.4 mph)].

1.7 Test Turbine and Electronics

1.7.1 Tested wind turbines and their associated electronics shall conform to the specific requirements of the governing IEC / BS EN wind generator standard for each test, but incorporating any amendments contained in this standard.

2 Performance Testing

2.1 Wind turbine performance shall be tested and documented in a test report per the latest edition of BS EN 61400-12-1, but incorporating the additional guidance provided in this section.

2.1.1 In Section 5.1, Wind Turbine and Electrical Connection: When characterizing performance, the wind turbine generator system shall

[3] As determined per Section 2.1.6

include the following components, as appropriate: the turbine; turbine tower; turbine controller, regulator, or inverter; wiring between the turbine and the load; transformer; and dump load. Power shall be measured at the connection to the load such that the losses in the complete wind turbine system are included[4].

2.1.2 Battery banks are not considered to be part of the wind turbine system for battery-charging wind turbines, but they are considered to be part of the system for grid-connected wind turbines that incorporate a battery bank.

2.1.3 Also in Section 5.1, Wind Turbine and Electrical Connection: The wind turbine shall be connected to an electrical load that is representative of the load for which the turbine is designed.

2.1.4 Also in Section 5.1, Wind Turbine and Electrical Connection: The wind turbine shall be installed using the manufacturer's specified mounting system. If a wind turbine is not supplied with a specific mounting system, the generator should be mounted at a hub height of at least 10 meters.

2.1.5 The total wire run length, measured from the base of the tower, must be at least 8 rotor diameters and the wiring is to be sized per the manufacturer's installation instructions.

2.1.6 The cut-in wind speed is the first wind speed bin in the averaged power curve that is positive.

2.1.7 Also in Section 5.1, Wind Turbine and Electrical Connection: The voltage regulator in a battery-charging system shall be capable of maintaining voltage at the connection of the turbine to the batteries within 10% of 2.1 volts per cell for lead acid batteries over the full range of power output of the turbine. The 1-minute average of the load voltage must be within 5% of 2.1 volts per cell for lead acid batteries to be included in the usable data set.

2.1.8 In Section 5.2.1, Location of meteorological mast: If it is more practical to mount the anemometer on a long boom that is connected to the turbine tower, a separate meteorological mast is not required. To minimize the potential for the wake from the anemometer, the wind vane and their mounting hardware to influence flow into a small rotor, all such components shall be located at least 3 meters away from any part of the rotor provided that the measurement anemometer is placed between 2-4 rotor diameters from the turbine (as per section 5.2.1 of BS EN 61400-12-1: 2006). In addition, the anemometer mounting should be configured to minimize its cross-sectional area above the level that is 1.5 rotor diameters below hub height.

2.1.9 In Section 6.1, Electric power: Turbine output power shall be measured at the connection to the load.

[4] For the avoidance of doubt the inverter is considered to be a system component, i.e. power shall therefore be power delivered after the inverter (power injected into the grid for grid-connected wind turbines; similarly power delivered to the batteries for battery-charging wind turbines).

2.1.10 In Section 6: In addition to electric power, voltage at the connection to the load shall be measured to ensure compliance with the requirements listed below.

2.1.11 In Section 6.4, Air density: The air temperature sensor and the air pressure sensor shall be mounted such that they are at least 1.5 rotor diameters below hub height even if such mounting results in a location less than 10 m above ground level.

2.1.12 In Section 6.6, Wind turbine generator status: Monitoring of small wind turbine status is required only when the turbine controller provides an indication of turbine faults.

2.1.13 In Section 7.3, Data collection: Preprocessed data shall be of 1-minute duration. In Section 7.4, Data rejection: Select data sets shall be based on 1-minute periods.

2.1.14 In Section 7.6, Database: The database shall be considered complete when it has met the following criteria:

2.1.14.1 Each wind speed bin between 1 m/s below cut-in and 14 m/s shall contain a minimum of 10 minutes of sampled data.

2.1.14.2 The total database contains at least 60 hours of data with the small wind turbine operating within the wind speed range.

2.1.14.3 The database shall include 10 minutes of data for all wind speeds at least 5 m/s beyond the lowest wind speed at which power is within 95% of Maximum Power (or when sustained output is attained).

2.1.15 In Section 8.1, Data normalization: For turbines with passive power control such as furling or blade fluttering, the power curve shall be normalized using Equation 3 (wind speed adjustment), Equation 2 (power adjustment), or an alternate method. Documentation must be provided to justify the use of an alternate method.

2.1.16 In Section 8.3, Annual energy production (AEP): In cases where the small wind turbine does not shut down in high winds, AEP measured and AEP projected shall be calculated as though cut-out wind speed were the highest, filled wind speed bin or 25 m/s, whichever is greater.

2.1.17 In Section 9, Reporting format: In addition to the information listed in clause 9, the description of the wind turbine and the test set-up shall include:

2.1.17.1 wiring sizes, conductor material, types, lengths and connectors used to connect the wind turbine to the load;

2.1.17.2 measured resistance of wiring between the inverter and the load or between the turbine and the load if no inverter is used;

2.1.17.3 voltage setting(s) for any over or under-voltage protection devices that are part of the small wind turbine generator system;

2.1.17.4 nominal battery bank voltage (e.g., 12, 24, 48 volts);

2.1.17.5 battery bank size (i.e., amp-hour capacity), battery type and age; and

2.1.17.6 description including make, model, and specifications of the voltage regulation device used to maintain the battery bank voltage within specified limits.

2.2 The Performance Test Report shall include the turbulence intensity for each data set (sequential, unbroken, time series) so that the reviewers can pass judgment on the appropriateness of the test site.

3 Acoustic Sound Testing

3.1 Wind turbine sound levels shall be measured and reported in accordance with the latest edition of BS EN 61400-11:2003, but incorporating the additional guidance provided in this section.

3.1.1 The averaging period shall be 10 second instead of 1 minute.

3.1.2 Measuring wind speed directly instead of deriving wind speed through power is the preferred method.

3.1.3 The method of bins shall be used to determine the sound pressure levels at integer wind speeds.

3.1.4 It shall be attempted to cover an as wide a wind speed range as possible, as long as the wind screen remains effective.

3.1.5 A description shall be provided of any obvious changes in sound at high wind speeds where overspeed protection becomes active (like furling, pitching or fluttering).

3.1.6 A tonality analysis is not required, but the presence of prominent tones shall be observed and reported.

4 Strength and Safety

4.1 Except as noted below, mechanical strength of the turbine system will be assessed using either the simple equations in Section 7.4 of BS EN 61400-2:2006 in combination with the safety factors in Section 7.8, or the aeroelastic modeling methods in Section 7.9. Evaluation of, as a minimum, the blade root, main shaft and the yaw axis (for HAWT's) will be performed using the outcome of these equations. A quick check of the rest of the structure for obvious flaws or hazards will be done and if judged needed, additional analysis may be required.

4.2 Variable speed wind turbines are generally known to avoid harmful dynamic interactions with towers. Single/dual speed wind turbines are generally known to have potentially harmful dynamic interactions with their towers. Therefore, in the case of single/dual speed wind turbines, such as those using either one or two induction generators, the wind turbine and tower(s) must be shown to avoid

potentially harmful dynamic interactions. A variable speed wind turbine with dynamic interactions, arising for example from control functions, must also show that potentially harmful interactions are likewise avoided.

4.3 Other safety aspects of the turbine system will be evaluated including:

4.3.1 procedures to be used to operate the turbine;

4.3.2 provisions to prevent dangerous operation in high wind;

4.3.3 methods available to slow or stop the turbine in an emergency or for maintenance; and

4.3.4 adequacy of maintenance and component replacement provisions.

4.4 A Safety and Function Test shall be performed in accordance with Section 9.6 of BS EN 61400-2:2006.

5 Duration Test

5.1 To establish a minimum threshold of reliability, a duration test shall be performed in accordance with the BS EN 61400-2:2006 Section 9.4.

5.2 Changes and additional clarifications to this standard include:

5.2.1 The test shall continue for 2500 hours of power production.

5.2.2 The test must include at least 25 hours in wind speeds of 15 m/s (33.6 mph) and above.

5.2.3 Downtime and availability shall be reported and an availability of 90% is required.

5.2.4 Minor repairs are allowed, but must be reported.

5.2.5 If any major component such as blades, main shaft, generator, tower, controller, or inverter is replaced during the test, the test must be restarted.

5.2.6 The turbine and tower shall be observed for any tower dynamics problems during the duration test and the test report shall include a statement of the presence or absence of any observable problems

6 Reporting and Certification

6.1 For each model to be certified the manufacturer shall submit to an accredited certifying body for review and certification:

6.1.1 Summary Report, containing a power curve, an AEP curve, and the measured sound pressure levels (Section 9.4 of BS EN 61400-11:2003). This report, once approved by an accredited certifying body, is to be made publicly available

6.1.2 Performance Test Report

6.1.3 Acoustic Test Report

6.1.4 BWEA Reference Annual Energy

6.1.5 BWEA Reference Sound Level

6.1.6 BWEA Reference Power, at 11.0 m/s (24.6 mph)

6.1.7 Wind Turbine Strength and Safety Report

6.1.7.1 The tower top design loads shall be reported

6.1.8 Duration Test Report

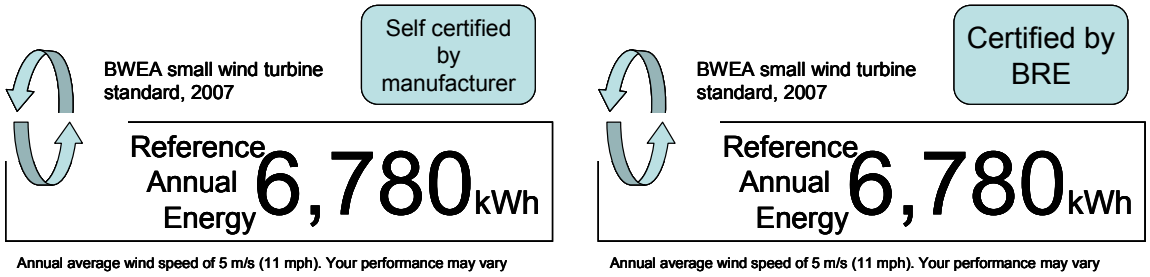
6.2 The manufacturers of certified wind turbines must also abide by the labeling requirements of Section 7.

7 Labeling

7.1 BWEA Reference Annual Energy (BWEA RAE) shall be provided in any product literature or advertising in which product specifications are provided.

7.1.1 The BWEA RAE shall be rounded to no more than 3 significant figures.

7.1.2 The form of presentation can be in plain text, but the preferred form is (example of self certified form on left; externally certified form on right[5]):



7.2 The manufacturer shall use BWEA Reference Power if a rated power is specified.

7.3 The manufacturer shall provide the BWEA Reference Sound Level.

7.4 Other recommended performance specifications are:

7.4.1 Cut-in Wind Speed

7.4.2 Cut-out Wind Speed

7.4.3 Maximum Power

7.4.4 Maximum Voltage

7.4.5 Maximum Current(s)

7.4.6 Overspeed Control

7.4.7 Power Form

[5] Insert name of manufacturer, or alter the example of BRE to any other certification authority as appropriate.

7.5 The use of more detailed performance characterizations, such as power curves or estimated energy output graphs or tables, is allowed so long as this material was included in the certification.

8 Changes to Certified Products

8.1 It is anticipated that certified wind turbines will occasionally be changed to provide one form of improvement or another. In some cases such changes will require review by an accredited certifying body and possible changes to the certified product parameters. The following guidance is provided concerning when product changes will require review by an accredited certifying body:

8.1.1 Any changes to a certified wind turbine that will have the cumulative effect of reducing BWEA Reference Power or BWEA Reference Annual Energy by more than 10%, or that will raise the BWEA Reference Sound Level by more than 1 dBA will require retesting and recertification by an accredited certifying body. Only those characteristics of the wind turbine affected by the design change(s) would be reviewed again.

8.1.2 Any changes to a certified wind turbine that could reduce the strength and safety margins by 10%, or increase operating voltages or currents by 10%, will require resubmission of the Wind Turbine Strength and Safety Report and recertification by an accredited certifying body.

8.1.3 Any changes to a certified wind turbine that could materially affect the results of the Duration Test will require retesting, submission of a new Duration Test Report, and recertification by an accredited certifying body.

8.2 For the first two years after turbine certification the manufacturer is required to notify the accredited certifying body of all changes to the product, including hardware and software. The accredited certifying body will determine whether the need for retesting and additional review under the guidelines provided in Section 8.1.

8.3 The use of Engineering Change Orders or their equivalent is recommended.

9 References and Appendices

9.1 References[6].

9.1.1 BS EN 61400-12-1: 2006, Wind Turbines: Power performance measurement of grid connected wind turbines.

9.1.2 BS EN 61400-11:2003, Wind turbine generator systems: Acoustic noise measurement techniques.

9.1.3 BS EN 61400-2:2006 , Wind turbine generator systems: Design requirements of small wind systems.

[6] The British Standards (BS) are the official English Language versions of the respective European Standards (EN) which in turn correspond to the International Standards published by the IEC.

Appendix A

Sound Levels for Different Observer Locations and Background Sound Levels

The BWEA Reference Sound Level is calculated at a distance of 60 meter from the rotor hub and excludes any contribution of background sound. As the distance from the turbine increases, the background sound becomes more dominant in determining the overall sound level (turbine plus background).

Background sound levels depend greatly on the location and presence of roads, trees, and other sound sources. Typical background sound levels range from 35dBA (quiet) to 50dB(A) (urban setting)

Equation 1 can be used to calculate the contribution of the turbine to the overall sound level using the BWEA Reference Sound Level. Equation 2 can be used to add the turbine sound level to the background sound level to obtain the overall sound level.

$$turbine\ sound\ level = L_{BWEA} + 10\log(4\pi 60^2) - 10\log\left(4\pi R^2\right) \quad (1)$$

Where:
L_{BWEA} is the Reference Sound Level [dBA].
R is the observer distance from the turbine rotor center [m]

$$overall\ sound\ level = 10\log(10^{\frac{turbine\ level}{10}} + 10^{\frac{background\ level}{10}}) \quad (2)$$

Table 1 Overall Sound Levels at Different Locations for a Reference Sound Level of 40 dBA

Distance from rotor center [m]	L_{BWEA}: 40dBA				
	background noise level (dBA):				
	30	35	40	45	50
10	55.6	55.6	55.7	55.9	56.6
20	49.6	49.7	50.0	50.9	52.8
30	46.1	46.4	47.0	48.6	51.5
40	43.7	44.1	45.1	47.3	50.9
50	41.9	42.4	43.9	46.6	50.6
60	40.4	41.2	43.0	46.2	50.4
70	39.2	40.2	42.4	45.9	50.3
80	38.2	39.4	41.9	45.7	50.2
100	36.6	38.3	41.3	45.5	50.2
150	34.1	36.8	40.6	45.2	50.1
200	32.8	36.1	40.4	45.1	50.0

Table 2 Overall Sound Levels at Different Locations for a Reference Sound Level of 45 dBA

Distance from rotor center [m]	L_{BWEA}: 45dBA				
	background noise level (dBA):				
	30	35	40	45	50
10	60.6	60.6	60.6	60.7	60.9
20	54.6	54.6	54.7	55.0	55.9
30	51.1	51.1	51.4	52.0	53.6
40	48.6	48.7	49.1	50.1	52.3
50	46.7	46.9	47.4	48.9	51.6
60	45.1	45.4	46.2	48.0	51.2
70	43.8	44.2	45.2	47.4	50.9
80	42.7	43.2	44.4	46.9	50.7
100	40.9	41.6	43.3	46.3	50.5
150	37.8	39.1	41.8	45.6	50.2
200	35.9	37.8	41.1	45.4	50.1

Table 3 Overall Sound Levels at Different Locations for a Reference Sound Level of 50 dBA

Distance from rotor center [m]	L_{BWEA}: 50dBA				
	background noise level (dBA):				
	30	35	40	45	50
10	65.6	65.6	65.6	65.6	65.7
20	59.5	59.6	59.6	59.7	60.0
30	56.0	56.1	56.1	56.4	57.0
40	53.5	53.6	53.7	54.1	55.1
50	51.6	51.7	51.9	52.4	53.9
60	50.0	50.1	50.4	51.2	53.0
70	48.7	48.8	49.2	50.2	52.4
80	47.6	47.7	48.2	49.4	51.9
100	45.7	45.9	46.6	48.3	51.3
150	42.3	42.8	44.1	46.8	50.6
200	40.0	40.9	42.8	46.1	50.4

Table 4 Overall Sound Levels at Different Locations for a Reference Sound Level of 55 dBA

Distance from rotor center [m]	L_{BWEA}: 55dBA				
	background noise level (dBA):				
	30	35	40	45	50
10	70.6	70.6	70.6	70.6	70.6
20	64.5	64.5	64.6	64.6	64.7
30	61.0	61.0	61.1	61.1	61.4
40	58.5	58.5	58.6	58.7	59.1
50	56.6	56.6	56.7	56.9	57.4
60	55.0	55.0	55.1	55.4	56.2
70	53.7	53.7	53.8	54.2	55.2
80	52.5	52.6	52.7	53.2	54.4
100	50.6	50.7	50.9	51.6	53.3
150	47.1	47.3	47.8	49.1	51.8
200	44.7	45.0	45.9	47.8	51.1

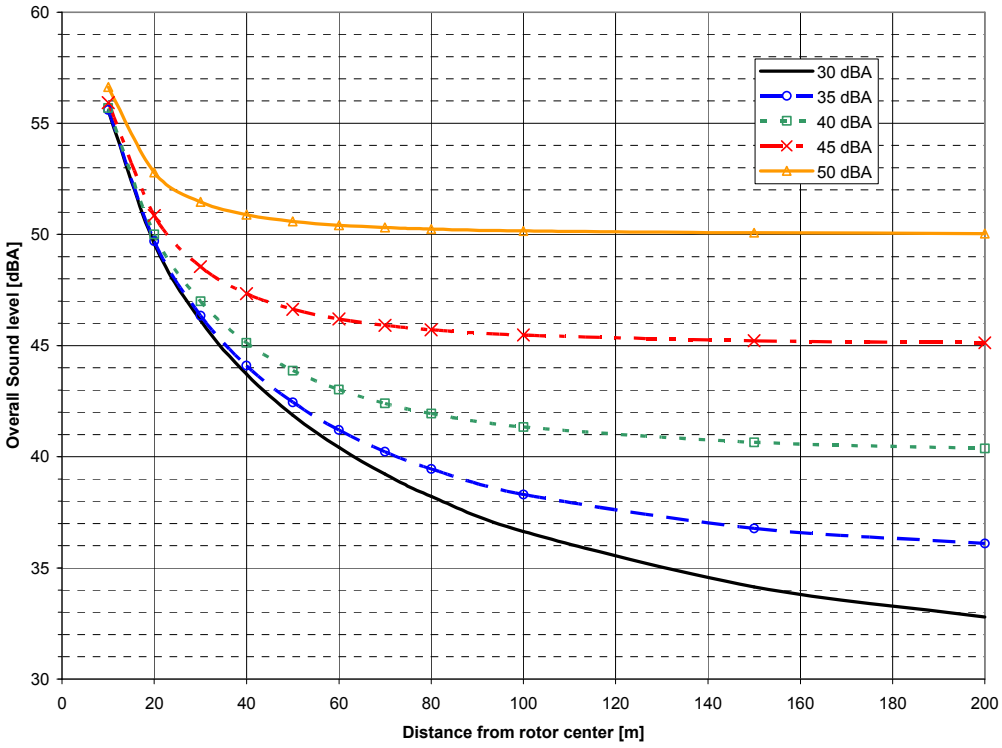


Figure 1. Sound levels as a function of distance and background noise levels for Reference Sound Level of 40dB(A)

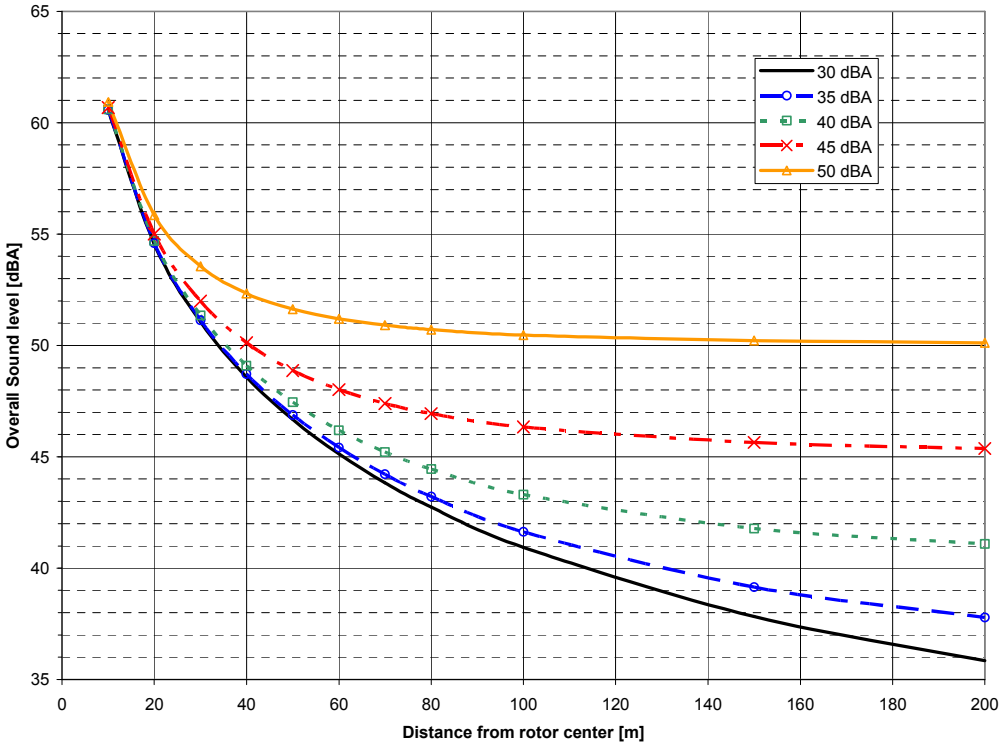


Figure 2 Sound levels as a function of distance and background noise levels for Reference Sound Level of 45dB(A)

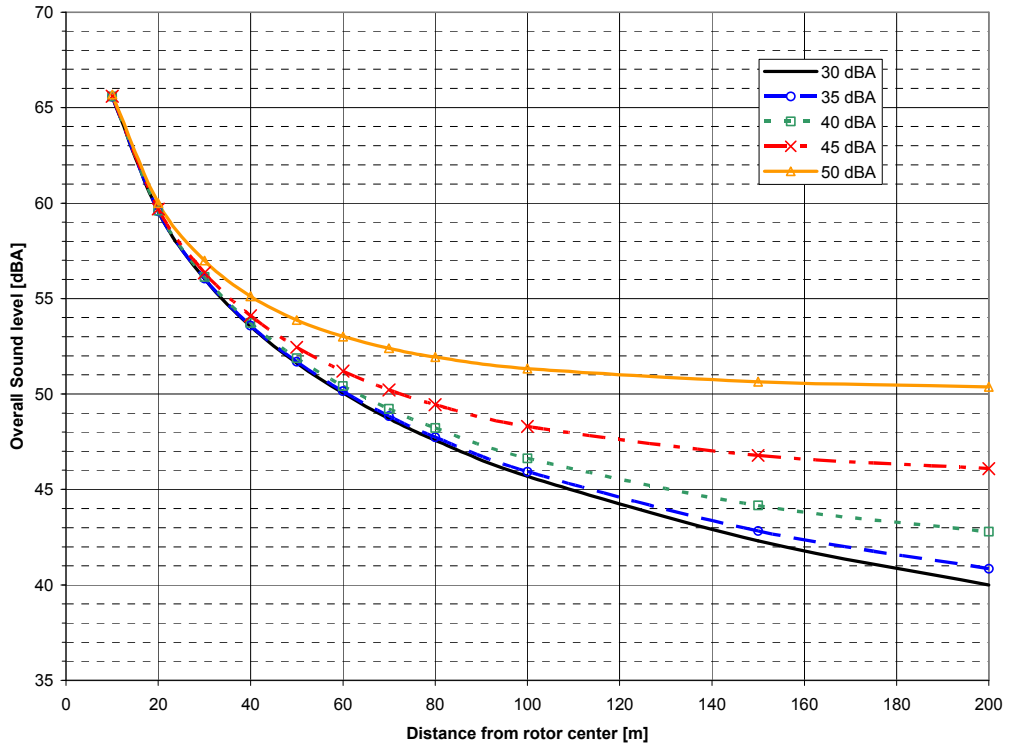


Figure 3 Sound levels as a function of distance and background noise levels for Reference Sound Level of 50dB(A)

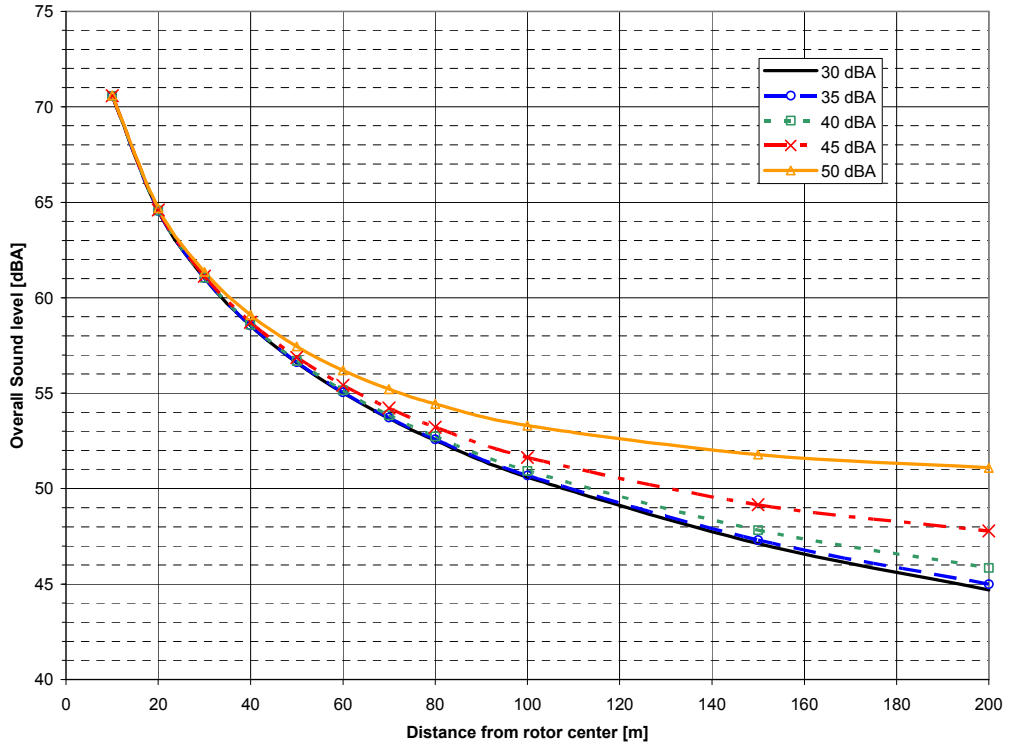


Figure 4 Sound levels as a function of distance and background noise levels for Reference Sound Level of 55dB(A)