June 2003 NREL/EL-500-33833

ACCREDITED
Certificate No. 1239-01

Wind Turbine Generator System

Acoustic Noise Test Report

for the

Bergey Excel Wind Turbine

By

National Wind Technology Center
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401

A. Huskey, M. Meadors

January 8, 2003

Approval By: Arlinda Huskey — 14 April 2003
Arlinda Huskey, NREL Certification Test Engineer — Date

Approval By: Harold F. Link — 14 April 03
Harold F. Link, NREL Certification Senior Test Engineer — Date

Approval By: Trudy Forsyth — 4/15/03
Trudy Forsyth, NREL Project Engineer — Date

1.0 Table of Contents

2.0 Table of Tables

3.0 Table of Figures

4.0 Disclaimer

This report was prepared as an account of work sponsored by an agency of the United States government. The test results documented in this report define the characteristics of the test article as configured and under the conditions tested.

The U.S. Government, nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Nor do they assume legal liability or responsibility for the performance of the test article or any similarly named article when tested under other conditions or using different test procedures.

Neither Midwest Research Institute nor the U. S. government shall be liable for special, consequential, or incidental damages. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government or any agency thereof. The views and opinions of the authors expressed herein do not necessarily state or reflect those of the U.S. Government or any agency thereof.

The National Renewable Energy Laboratory (NREL) is a National Laboratory of the U. S. Department of Energy (DOE), and as an adjunct of the U.S. government, cannot certify wind turbines. The information in this report is limited to NREL's knowledge and understanding as of this date.

5.0 Background

This test is being conducted as part of the U.S. DOE's Small Wind Turbine Field Verification Program. The primary purpose of this program is to provide consumers, manufacturers, and host site organizations with an independent assessment of the performance, reliability, safety, and acoustics of small U.S. wind turbines.

The test equipment, which is located at the National Wind Technology Center (NWTC), included a Bergey Excel wind turbine mounted on a 36.6-ft lattice tower and a Trace Gridtek-10 inverter. Bergey WindPower Company in Oklahoma manufactured the turbine. AWS Scientific installed the system with support from Bergey WindPower.

6.0 Test Objective

The objective of the test is to characterize the noise emissions of the Bergey Excel wind turbine using two sets of blades: BW3 and SH3052. To meet this objective, the measurements were collected and analyzed in accordance with the International Electrotechnical Commission standard for acoustic noise measurement techniques, IEC 61400-11 (Ref. 1). This report documents the measurement techniques, test equipment, analysis procedures, results, and uncertainty for the following quantities:

- Apparent sound power level
- Dependence on wind speed
- Directivity.

7.0 Results Using Measured Wind Speed

7.1 Bergey Excel-S with BW3 Blades

Turbine and background data were collected on the Bergey Excel with the first set of blades (identified as BW3) on 19 April 2001, 08 February 2002, and 14 February 2002. The following sections show the results of the analysis. The results used the measured, standardized wind speed. The measured wind speed was obtained from an anemometer located 292^{o} from the turbine at hub height (37 meters) then standardized to the reference height of 10 m and roughness length 0.05 m. Noise measurements were averaged over 10 seconds, instead of 1 minute as the Standard specifies, to better characterize the noise at higher wind speed (specifically, when the turbine employs overspeed control).

Figure 1 through Figure 4 show the data used for analysis for microphone positions 1 through 4, respectively. For the sound power, directivity, wind speed dependence, and tonality analysis and figures, the inverter is 100% online and connected to the grid. Section 7.1.5 includes data from when the inverter is partially or fully offline.

7.1.1 A-Weighted Sound Power Level

The apparent sound power level for all microphone positions was determined using turbine and background data between the measured standardized wind speeds of 6 to 10 m/s. Table 1 gives the calculated apparent sound power level for four microphone positions around the turbine using the measured reference wind speed. As shown in Figure 19, reference microphone position 1 is downwind, microphone position 3 is upwind, and microphone positions 2 and 4 are on each side of the turbine.

Table 1. BW3 Configuration: Apparent Sound Power Levels Using the Measured Reference Wind Speed

Microphone Position	Unit	1	2	3	4
Apparent sound power level at 8 m/s	dBA	98.4	95.9	97.1	94.9
Uncertainty ¥	dBA	2.8	2.8	2.8	2.8
Turbine sound pressure level at 8 m/s	dBA	58.9	56.5	57.8	56.2
Background sound pressure level at 8 m/s	dBA	46.0	45.1	47.4	49.4
Difference between background and turbine	dBA	12.9	11.3	10.4	6.8
Number of turbine points	--	399	399	399	399
Number of background points	--	320	320	320	320

¥ - The uncertainty reported is the worst case.

7.1.2 Wind Speed Dependence

All standardized wind speeds above 4 m/s from reference microphone position 1 were used in this analysis. Higher wind speeds were included to characterize the noise when the turbine employs overspeed control; in this case, furling. However, for the lower wind speed bins, the difference between the turbine and background noise was less than 3 dBA, and the Standard requires it be reported the turbine noise was less than the background noise. For bins in which the difference between turbine and background noise is between 3 and 6 dBA, a standard background correction of 1.3 dBA was applied and noted. The results are shown in Table 2 and Figure 5 for all bins with at least 3 data points.

Table 2. BW3 Configuration: Wind Speed Dependence for Measured Wind Speed

Bin m/s	Wind Speed Average m/s	Position 1 Corrected Sound Pressure Level dBA	Uncertainty[¥] dBA
4	4.2	-- **	--
5	5.0	47.5 *	3.0
6	6.0	51.3	3.7
7	7.0	56.4	3.2
8	8.0	59.7	3.0
9	8.9	62.5	2.9
10	10.0	65.6	2.1
11	11.0	67.8	2.6
12	11.9	70.1	1.8
13	13.0	72.5	1.9

¥ The uncertainty reported is the worst case.

* The difference between the turbine and background noise was greater than 3 dB and less than 6 dB, so a standard background correction of 1.3 dB was applied.

** The difference between the turbine and background noise was less than 3 dB, so the turbine noise was less than the background noise.

7.1.3 Directivity

In calculating the directivity, the measurements from the four microphone positions were measured simultaneously. The directivity was calculated for positions 2, 3, and 4 in reference to position 1 at a wind speed of 8 m/s. The results are shown in Table 3.

Table 3. BW3 Configuration: Directivity at 8 m/s

Position	Units	2	3	4
Directivity	dB	-2.5	-1.3	-3.4
Uncertainty[¥]	dB	3.7	3.8	3.8

[¥] The uncertainty reported is the worst case.

7.1.4 Tonal Analysis

A tone inspection was completed for frequencies from 20 to 5000 Hz for the reference microphone position 1 at a wind speed of approximately 8 m/s. The sets of unweighted spectra were obtained using the settings shown in Table 4.

Table 4. Data Created for Tone Inspection

Microphone Position	Bandwidth	Frequency Resolution	Number of Spectra
1	0 - 3200	6	480
1	3000 - 6200	6	480

An inspection for tones was completed for the frequency range 20 to 5000 Hz with an effective bandwidth of 6 Hz using a Hanning window. Figure 6 shows an averaged 2-minute unweighted spectrum for turbine noise for reference microphone position 1 at an averaged wind speed of 8 m/s. Table 5 shows the results of the tonality analysis.

Table 5. BW3 Configuration: Tonality Results

Frequency of Tone [Hz]	Critical Band [Hz]	L_{pn} Masking Noise Level [dB]	L_{pt} Overall Tone Level [dB]	$\Delta L_{tn,}$ Tonality [dB]	U_C Combined Uncertainty [dB]
78 - 82	30 - 130	44.6	64.6	20.0	7.0

7.1.5 Other Results

The data used in the analysis for sound power level, wind speed dependence, and tonality were collected when the inverter was 100% online during the 10-second average. Data were also collected when the inverter was partially or fully offline during the average (shown in Figure 7). No analysis was performed on this data.

7.2 Bergey Excel-S with SH3052 Blades

Turbine and background data were collected on the Bergey Excel with the second set of blades (identified as SH3052) on 27 March 2002. The following sections show the results of the analysis using the measured, standardized wind speed. The measured wind speed was obtained from an anemometer located 292^{o} from the turbine at hub height (37 meters) then standardized to the reference height of 10 m and roughness length of 0.05 m. Noise measurements were averaged over 10 seconds, instead of 1 minute as the Standard specifies, to better characterize the noise at higher wind speeds (specifically when the turbine employs overspeed control).

Figure 8 through Figure 11 show the data used for analysis for microphone positions 1 through 4, respectively. For these figures, the inverter is 100% online and connected to the grid. Section 7.2.5 includes data from when the inverter is partially or fully offline.

7.2.1 A-Weighted Sound Power Level

The apparent sound power level for all microphone positions was determined using turbine and background data between the standardized wind speeds of 6 to 10 m/s. Table 1 gives the calculated apparent sound power level for four microphone positions around the turbine. As shown in Figure 19, reference microphone position 1 is downwind, microphone position 3 is upwind, and microphone positions 2 and 4 are on each side of the turbine. The Standard states that if the difference between the turbine and background noise is between 3 and 6 dBA, turbine noise can be corrected for background noise but cannot be used to determine the sound power level or directivity. Therefore, the apparent sound power level is not reported for any microphone positions.

Table 6. SH3052 Configuration: Apparent Sound Power Levels for the Acoustic Reference Wind Speed

Microphone Position	Unit	1	2	3	4
Apparent sound power level at 8 m/s	dBA	*	*	*	*
Uncertainty ¥	dBA	--	--	--	--
Turbine sound pressure level at 8 m/s	dBA	52.2	50.9	52.2	53.2
Background sound pressure level at 8 m/s	dBA	47.9	47.3	48.1	49.0
Difference between background and turbine	dBA	4.3	3.6	4.1	4.2
Number of turbine points	--	292	292	292	292
Number of background points	--	126	126	126	119

¥ - The uncertainty reported is the worst case.

* - The difference between the turbine and background noise was less than 6 dBA, so the apparent sound power level cannot be determined.

7.2.2 Wind Speed Dependence

All standardized wind speeds above 4 m/s from reference microphone position 1 were used in this analysis. Higher wind speeds were included to characterize the noise when the turbine employs

overspeed control (in this case, furling). For bins in which the difference between turbine and background noise is between 3 and 6 dBA, a standard background correction of 1.3 dBA was applied and noted. The results are shown in Table 2 and Figure 12 for all bins with at least 3 data points.

Table 7. SH3052 Configuration: Wind Speed Dependence for Measured Wind Speed

Bin m/s	Wind Speed Average m/s	Position 1 Corrected Sound Pressure Level dBA		Uncertainty[¥] dBA
7	7.1	51.0	*	2.2
8	8.0	51.0	*	2.3
9	9.1	52.6	*	2.0
10	10.0	53.7	*	1.9
11	11.0	55.3	*	2.2
12	12.0	57.2	*	2.2
13	12.9	59.2	*	2.9
14	14.0	60.6	*	2.5
15	15.0	61.8	*	2.1

¥ The uncertainty reported is the worst case.

* The difference between the turbine and background noise was greater than 3 dB and less than 6 dB, so a standard background correction of 1.3 dB was applied.

7.2.3 Directivity

Directivity is determined from sound power levels for each microphone position. Because the sound power level could not be calculated for microphones 1, 2, 3, and 4, the directivity could not be determined.

7.2.4 Tonal Analysis

A tone inspection was completed for frequencies from 20 to 5000 Hz for the reference microphone position 1. The sets of unweighted spectra were obtained using the settings shown in Table 4.

Table 8. Data Created for Tone Inspection

Microphone Position	Bandwidth	Frequency Resolution	Number of Spectra
1	0 - 3200	6	480
1	3000 - 6200	6	480

An inspection for tones was completed for the frequency range 20 to 5000 Hz with an effective bandwidth of 6 Hz using a Hanning window. Figure 13 shows an averaged 2-minute unweighted spectrum for turbine noise for reference microphone position 1 at an averaged wind speed of 8 m/s. Although there are tones in the turbine and background spectra, no tones originate from the turbine at a wind speed of 8 m/s.

7.2.5 Other Results

The data used in the analysis for sound power level, wind speed dependence, and tonality were collected when the inverter was 100% online during the 10-second average. Data were also collected when the inverter was partially or fully offline during the average (shown in Figure 14). No analysis was performed on this data.

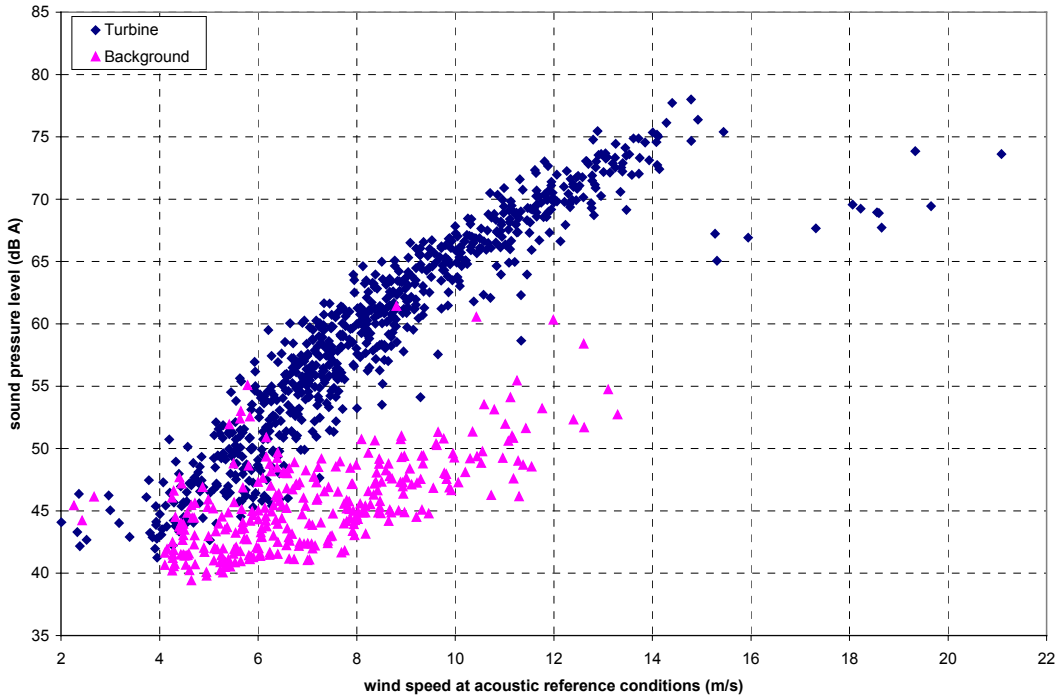


Figure 1. BW3 configuration turbine plus background and background data for microphone position 1.

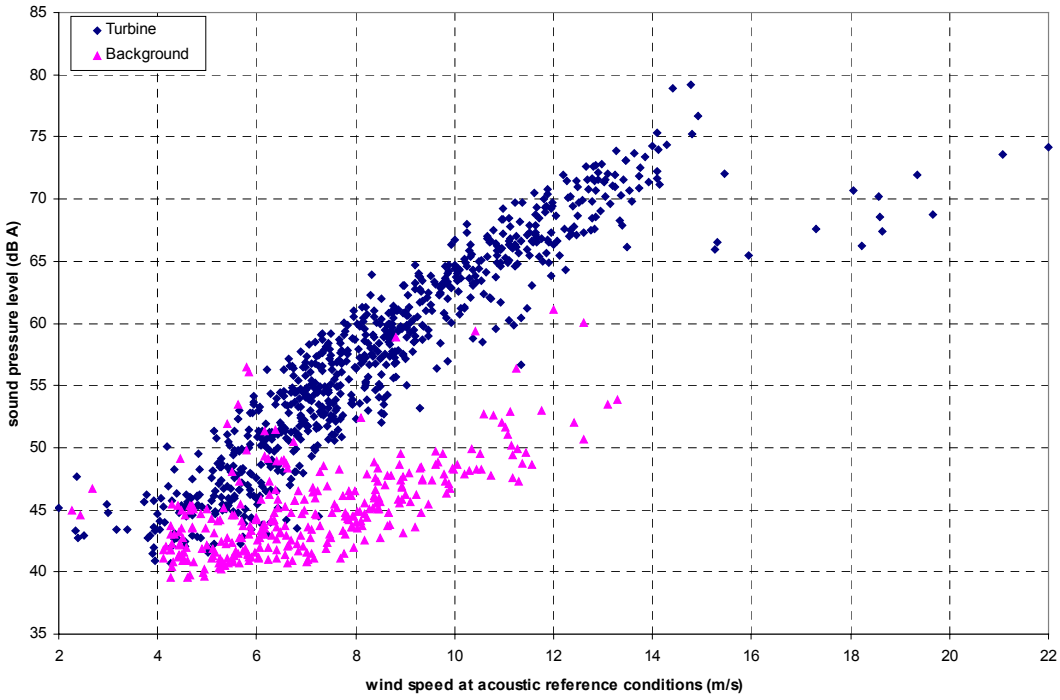


Figure 2. BW3 configuration turbine plus background and background data for microphone position 2.

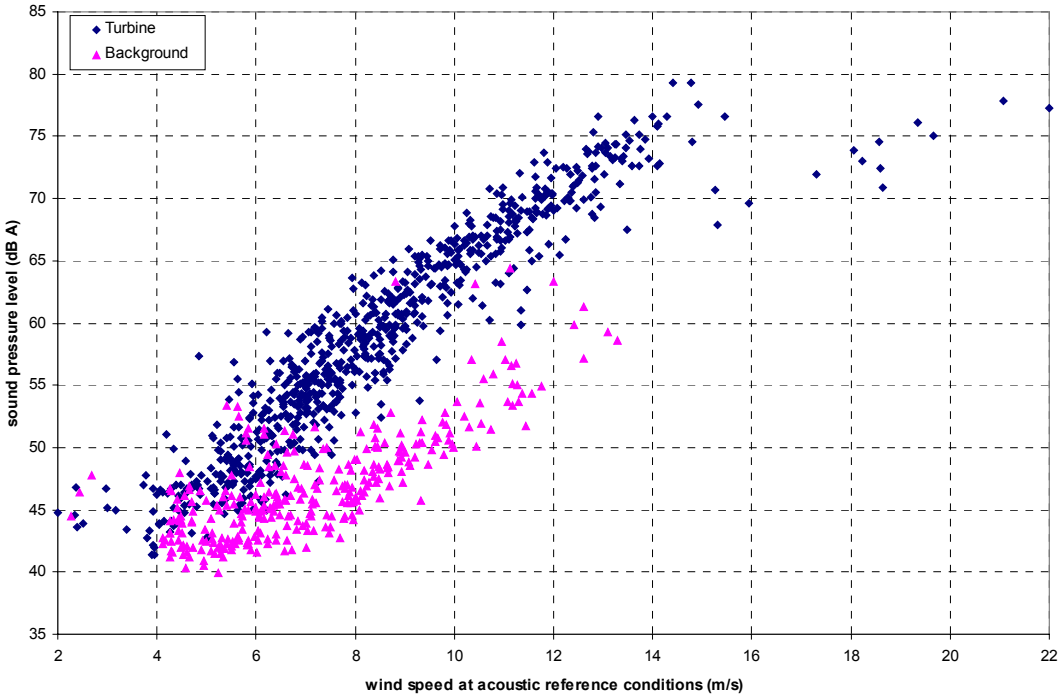


Figure 3. BW3 configuration turbine plus background and background data for microphone position 3.

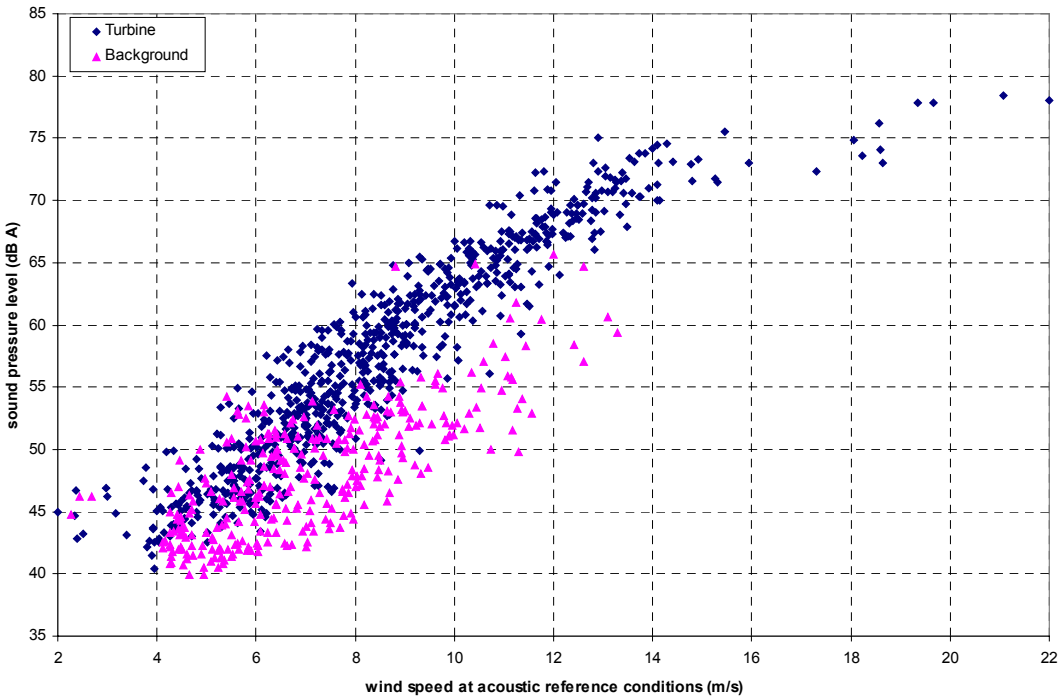


Figure 4. BW3 configuration turbine plus background and background data for microphone position 4.

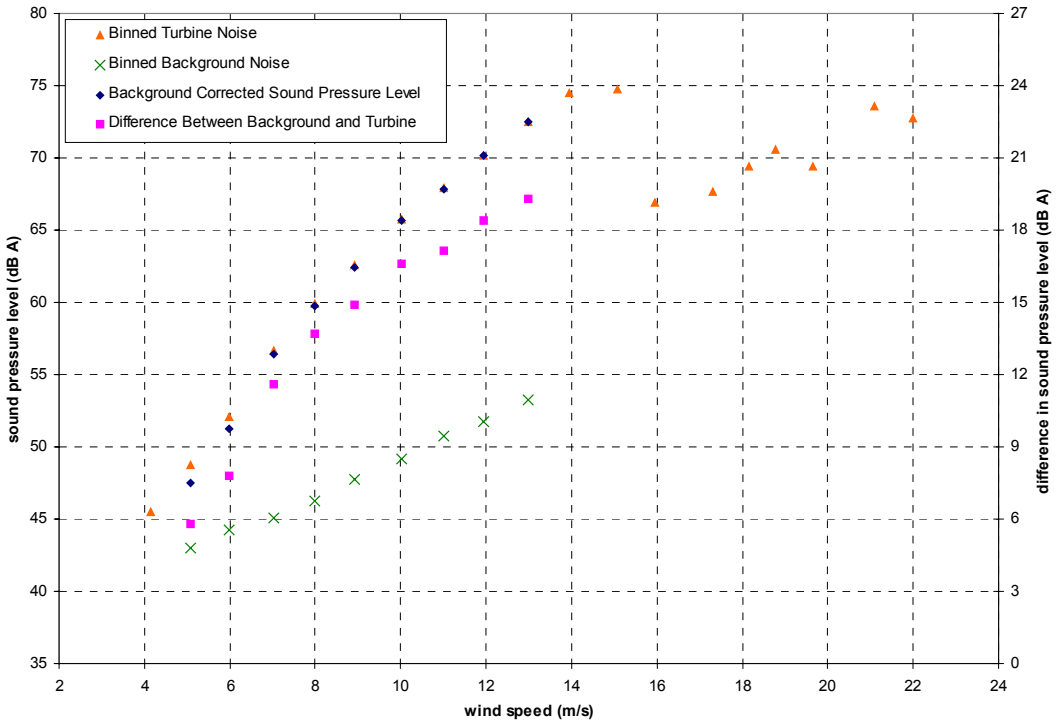


Figure 5. BW3 configuration: wind speed dependence at microphone position 1.

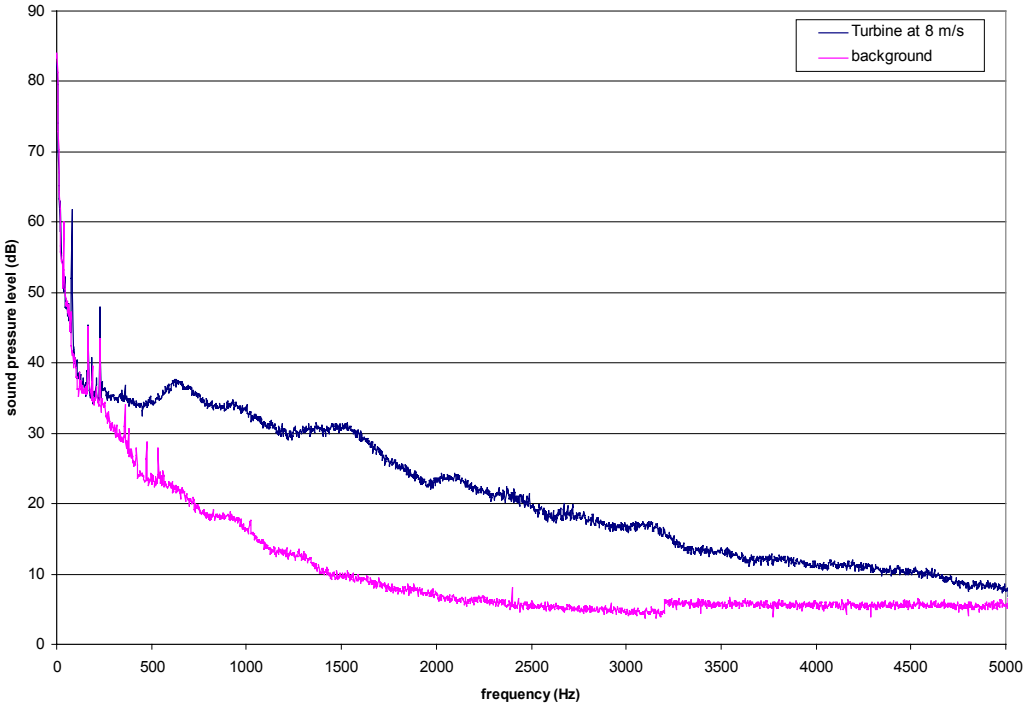


Figure 6. BW3 configuration: turbine plus background and background spectrum for microphone position 1.

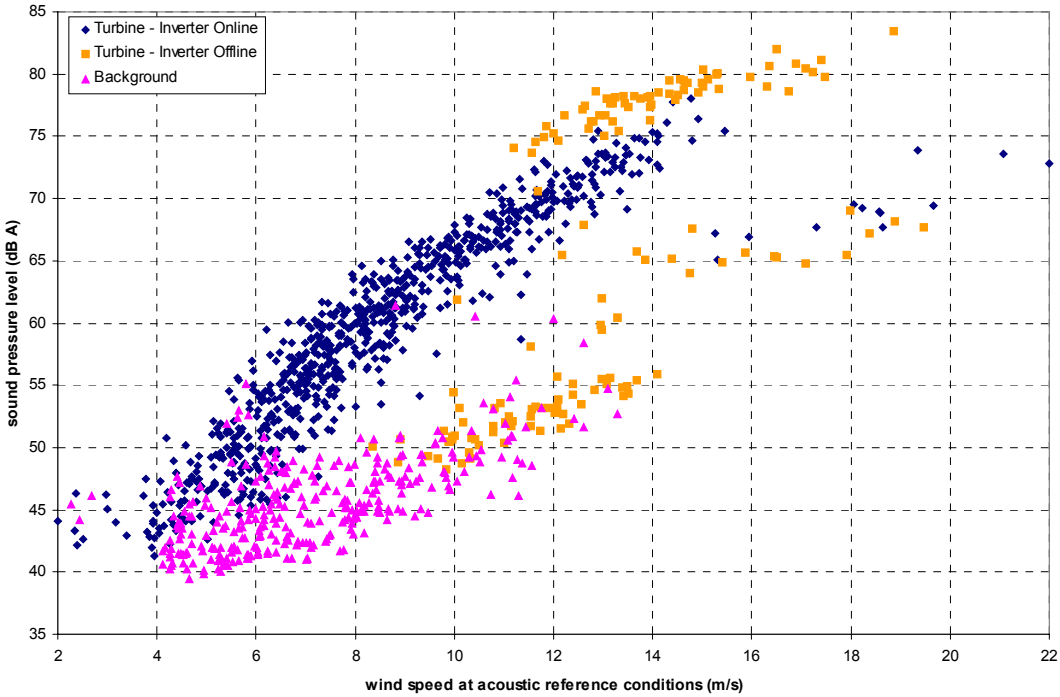


Figure 7. BW3 configuration: inverter online and offline sound pressure levels.

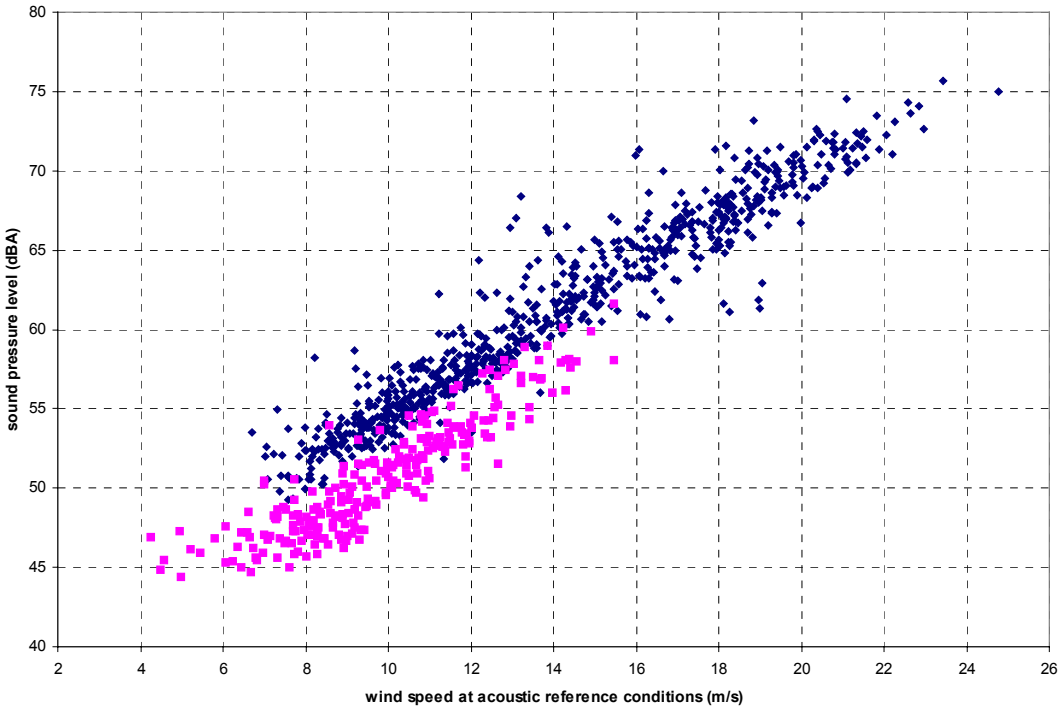


Figure 8. SH3052 configuration: turbine plus background and background data for microphone position 1.

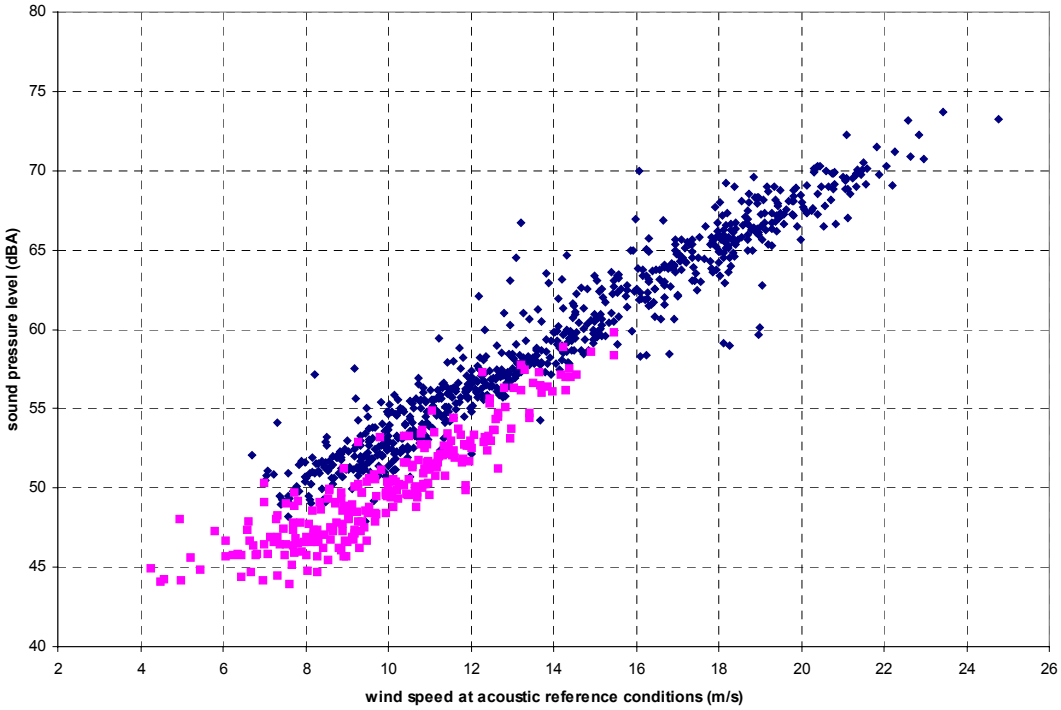


Figure 9. SH3052 configuration: turbine plus background and background data for microphone position 2.

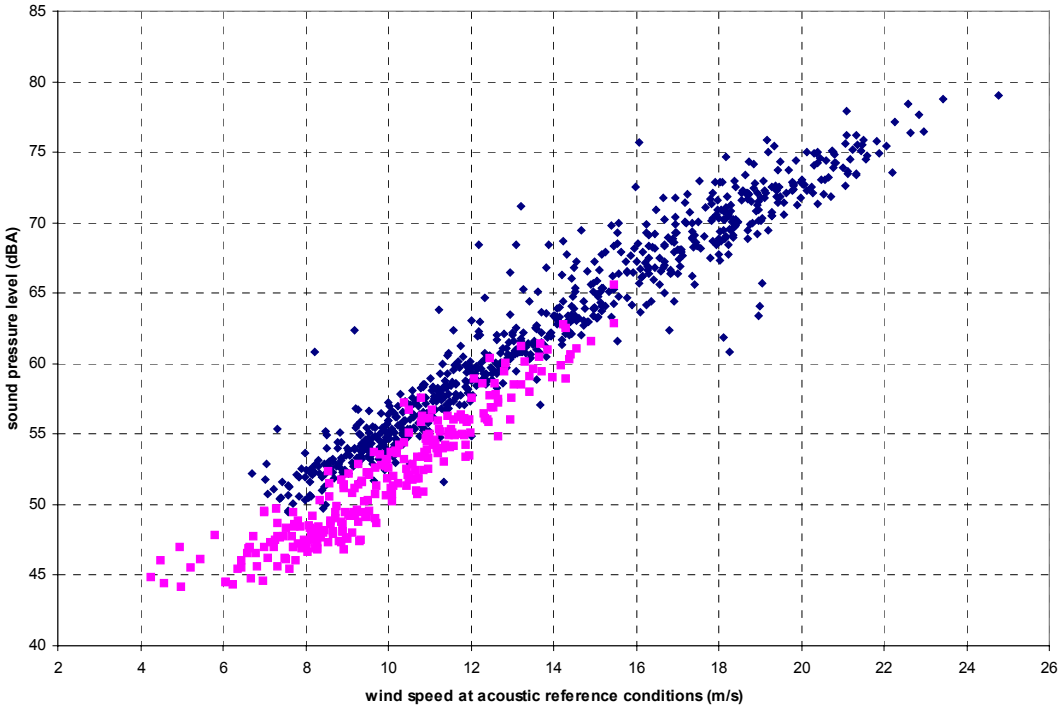


Figure 10. SH3052 configuration: turbine plus background and background data for microphone position 3.

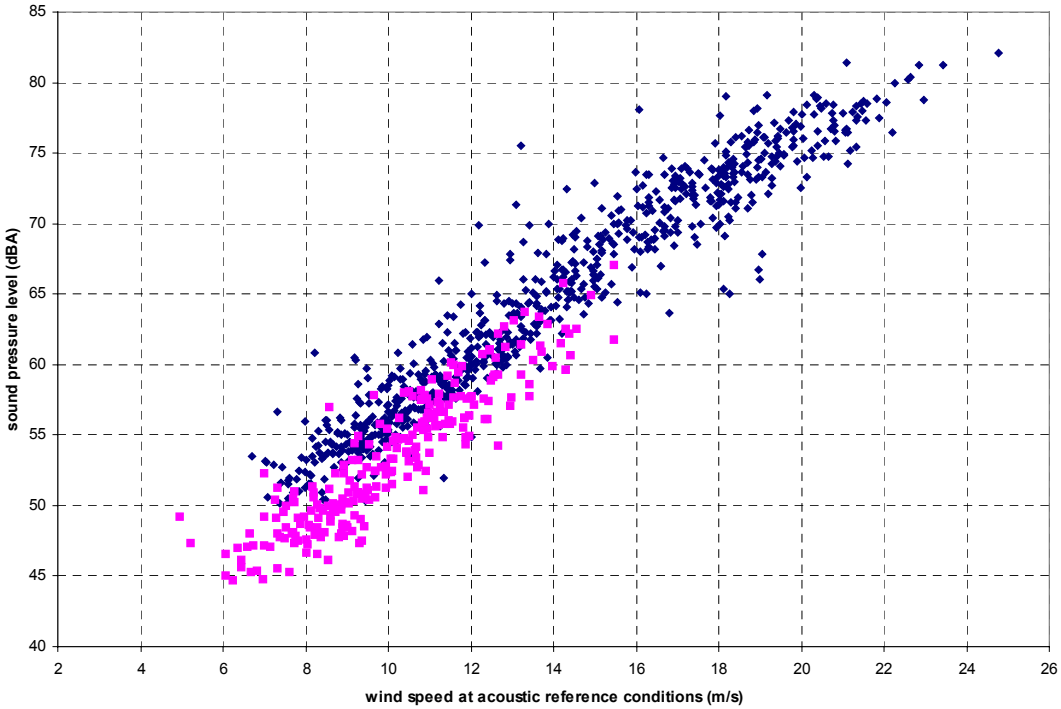


Figure 11. SH3052 configuration: turbine plus background and background data for microphone position 4.

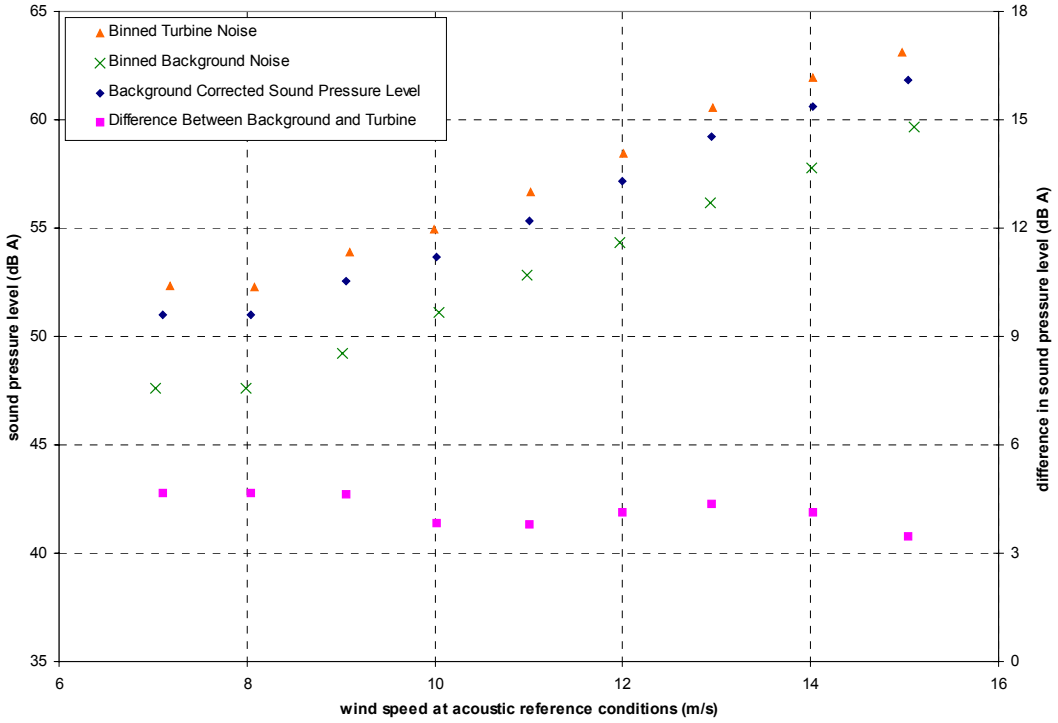


Figure 12. SH3052 configuration: wind speed dependence at microphone position 1.

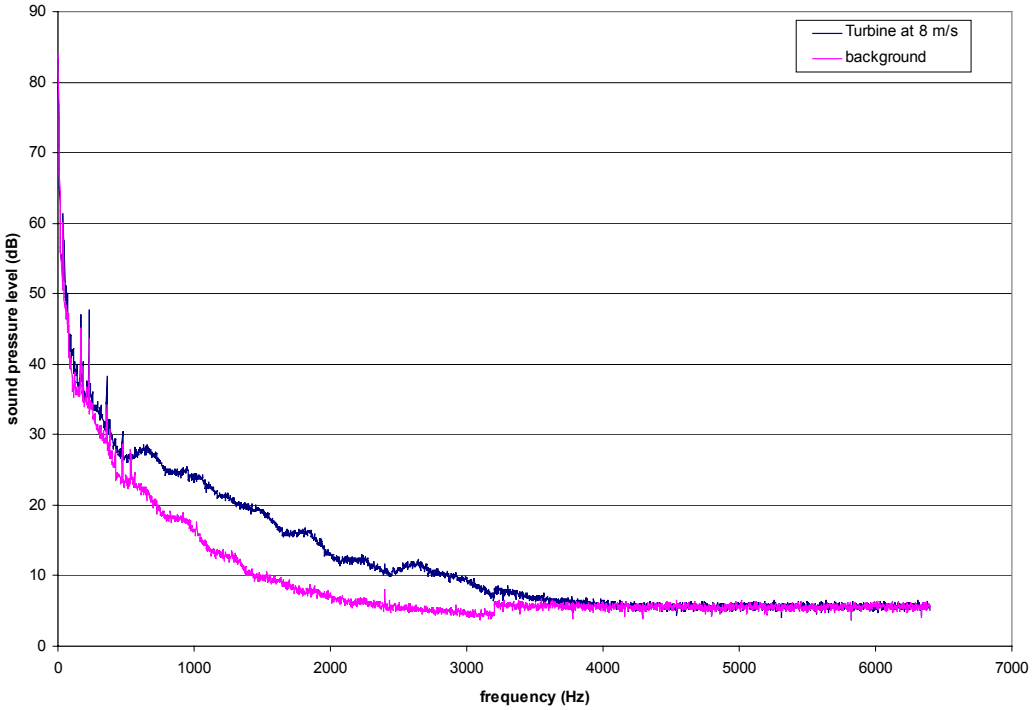


Figure 13. SH3052 configuration: turbine plus background and background spectrum for microphone position 1.

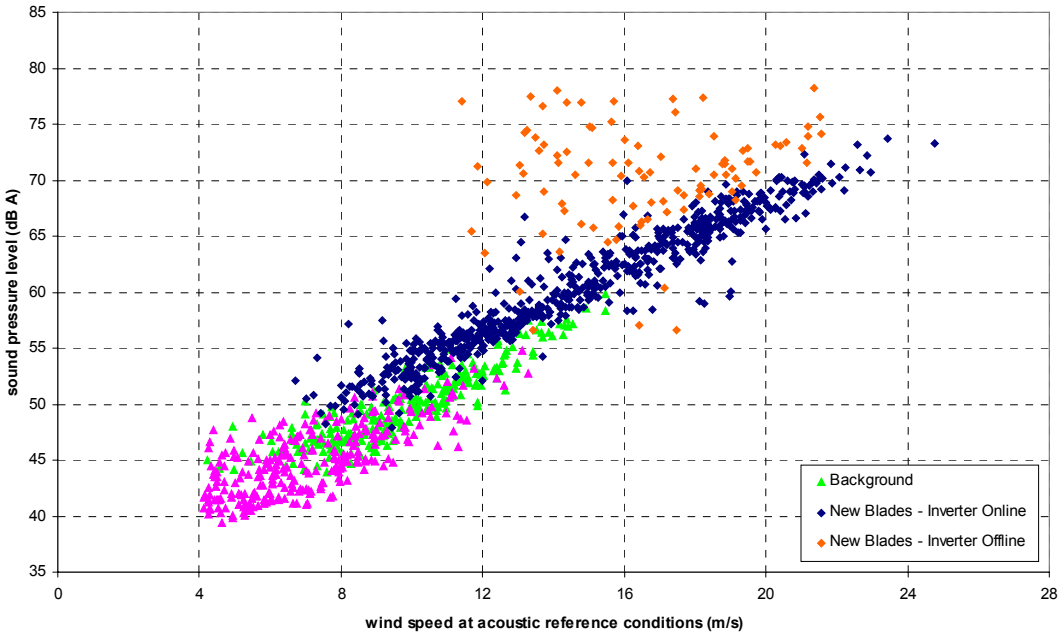


Figure 14. SH3052 configuration: inverter online and offline sound pressure levels.

8.0 Results Using Wind Speed Derived from Power

The Standard states that the preferred method of determining the wind speed is through measured power. Section 13.2 explains how wind speed is derived from measured power.

Figure 15 and Figure 16 show the results obtained when this method was applied to the acoustic noise data. Although Figure 15 shows a good correlation between sound pressure level and derived wind speed, Figure 16 shows that there is a large scatter of data and poor correlation of noise level to wind speed derived from power measurements.

8.1 Apparent Sound Power Level for the Bergey Excel-S with BW3 Blades

The apparent sound power level for all microphone positions was determined using turbine and background data between the derived standardized wind speeds of 6 to 10 m/s. Table 9 gives the calculated apparent sound power level for four microphone positions around the turbine using wind speed.

Table 9. BW3 Configuration: Apparent Sound Power Levels for the Acoustic Reference Wind Speed from Power

Microphone Position	Unit	1	2	3	4
Apparent sound power level at 8 m/s	dBA	98.0	95.5	96.6	94.4
Uncertainty ¥	dBA	3.0	3.0	3.0	3.3
Turbine sound pressure level at 8 m/s	dBA	58.5	56.2	57.4	55.8
Background sound pressure level at 8 m/s	dBA	46.0	45.1	47.4	49.4
Difference between background and turbine	dBA	12.6	11.0	10.0	6.4
Number of turbine points	--	373	373	373	373
Number of background points	--	320	320	320	320

¥ - The uncertainty reported is the worst case.

8.2 Apparent Sound Power Level for the Bergey Excel-S with SH3052 Blades

For most wind turbines, the output power correlates well to wind speed up to the point of maximum power. This was true for the Bergey Excel using the BW3 blades but not true for the Bergey Excel using the SH3052 blades. There was a large scatter of data and poor correlation of noise level to wind speed derived from power measurements. Therefore, the results obtained through this method were not reported. Section 13.2 describes the correlation between the power and sound pressure levels. NREL has not determined why this method did not show a better correlation than the method that uses the measured wind speed.

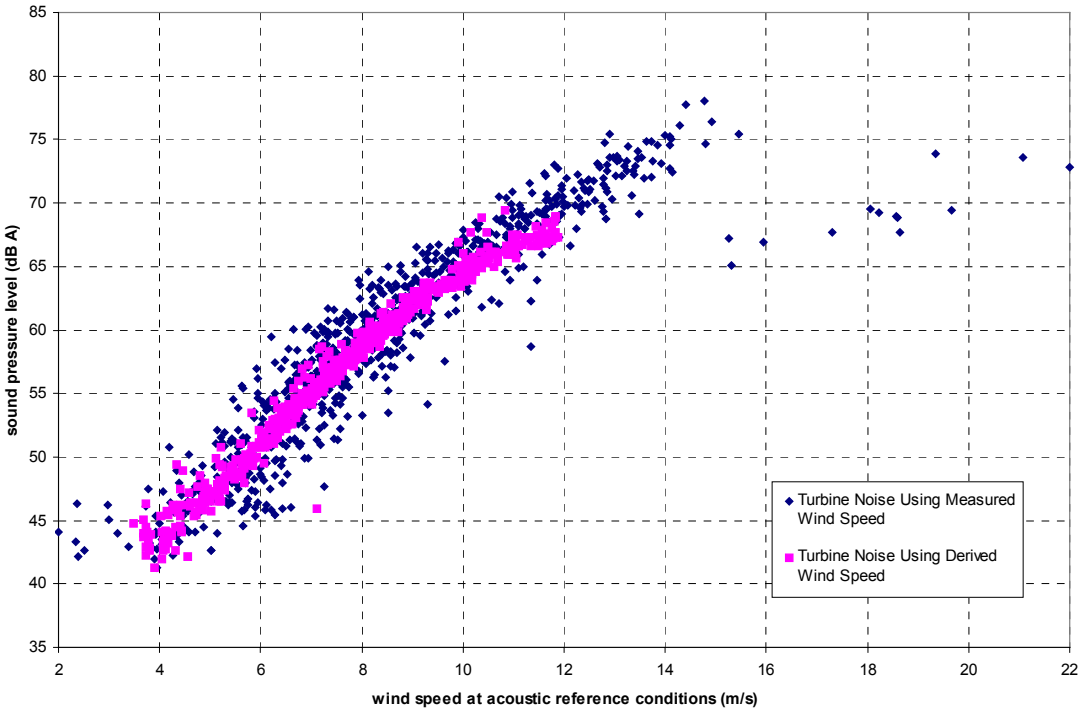


Figure 15. Bergey with BW3 blades: reference microphone position 1 data using measured and derived wind speed.

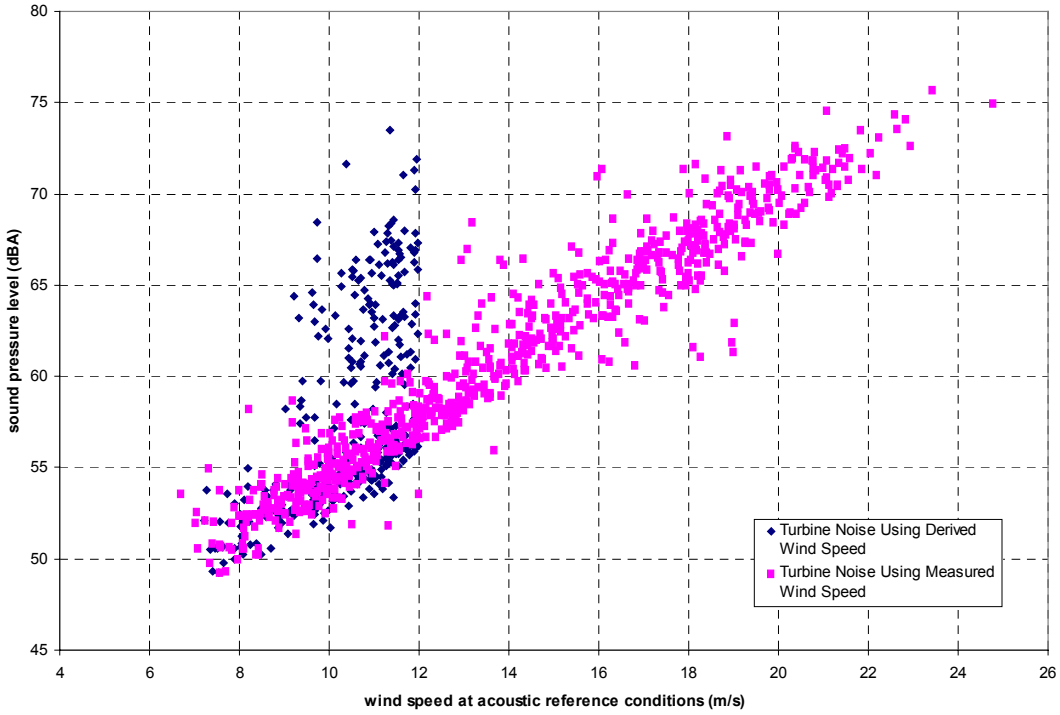


Figure 16. Bergey with SH3052 blades: reference microphone position 1 data using measured and derived wind speed.

9.0 Test Turbine

Figure 17 shows the Bergey Excel-S wind turbine. The Bergey Excel-S is a three-bladed upwind wind turbine rated at 10 kW output at 13.0 m/s. It is connected to a Bergey Gridtek inverter, which provides power to the NWTC public service electrical grid.

The Excel uses a permanent magnet alternator to produce three-phase variable frequency output at a nominal 240 volts. The three-phase output is rectified to DC power and then converted to single-phase 240-volt 60-Hz AC power in the Gridtek inverter.

In high wind speeds (greater than about 15.6 m/s), the turbine will turn out of the wind (known as furling) to protect the turbine from overspeeding. Table 10 lists basic turbine configuration and operational data.

The Bergey Excel was tested with two blade configurations: BW3 blades and SH3052 blades. The BW3 turbine blades are made from pultruded fiberglass. The SH3052 turbine blades have no pitch weights and are shorter. Further, using SH3052 blades changes the rotational direction of the rotor.

Table 10 lists configuration and operational data for the Bergey Excel-S for both configurations.

Figure 17. Test turbine.

Table 10. Test Turbine Configuration and Operational Data

General Configuration:	
Make, Model, Serial Number	Bergey Wind Power Company, Bergey Excel
Rotation Axis	Horizontal
Orientation	Upwind
Number of Blades	3
Rotor Hub Type	Rigid
Rotor Diameter (m)	BW3 configuration: 7 SH3052 configuration: 6.2
Hub Height (m)	37.0
Performance:	
Rated Electrical Power (kW)	10
Rated Wind Speed (m/s)	13.0
Cut-In Wind Speed (m/s)	3.1
Cut-Out Wind Speed (m/s)	None
Rotor:	
Swept Area (m^2)	38.4
Rotational Speed (rpm)	0 to 350
Tilt Angle (deg)	
Blade Pitch Angle (deg)	
Direction of Rotation	BW3 configuration: clockwise SH3052 configuration: counterclockwise
Overspeed Control/Protection	AutoFurl
Power Regulation (active/passive)	Passive
Yaw System:	
Wind Direction Sensor	Tail vane
Yaw Control Method	Free yaw
Tower:	
Type	Bergey guyed lattice
Height (m)	36.5
Control / Electrical System:	
Controller: Make, Type	Bergey Gridtek inverter
Electrical Output Voltage, Number of Phases	Nominal 240-volt single phase

10.0 Test Site

The Bergey Excel wind turbine was located at Site 1.4 of the NWTC (hereafter referred to as the test site), approximately 8 km south of Boulder, Colorado. The test site is located in somewhat complex terrain at an approximate elevation of 1850 m above sea level. Figure 18 shows a plot plan of the test site with topography lines listed in feet above sea level. During the acoustic noise test, there was little vegetation,

and neighboring turbines were shut off during testing. However, a concrete plant was located approximately 900 meters west of the test turbine.

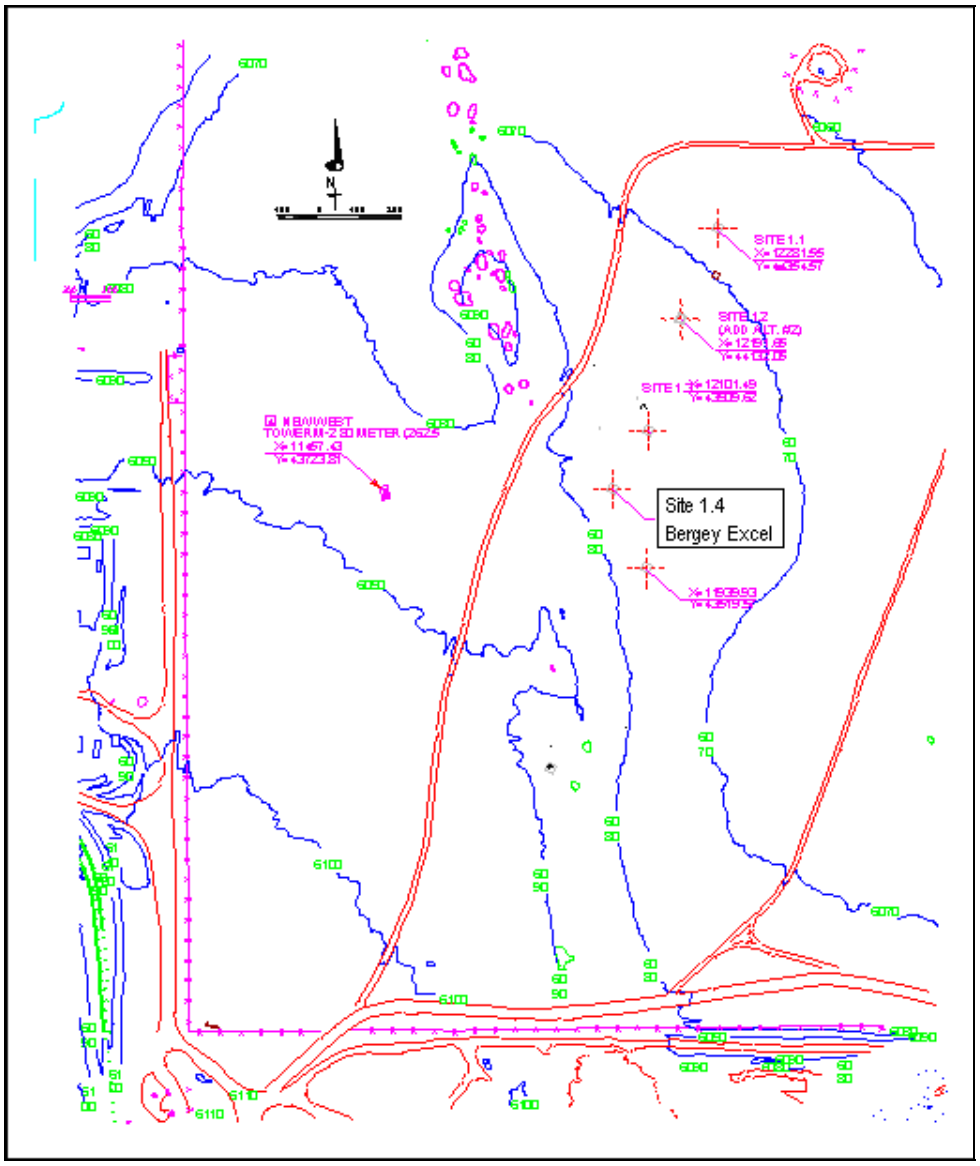


Figure 18. Test turbine location.

11.0 Test Equipment

11.1 Equipment Description

Table 11 shows the list of equipment used for the test.

Table 11. Equipment List for Acoustic Test

Date Used	Instrument	Manufacturer	Model Number	Serial Number	Calibration Due Date
19 Apr 2001	Signal Analyzer	Hewlett Packard	35670A	3431A01613	8/14/2001
	Microphone	ACO Japan	7012	17508	5/10/2002
	Microphone	ACO Japan	7012	17509	5/10/2002
	Microphone	ACO Japan	7012	17510	5/10/2002
	Microphone	ACO Japan	7012	19037	5/10/2002
	Preamplifier	ACO Pacific	4012	9903	5/17/2002
	Preamplifier	ACO Pacific	4012	960032	5/17/2002
	Preamplifier	ACO Pacific	4012	96050	5/17/2002
	Preamplifier	ACO Pacific	4012	9900503	5/17/2002
	Calibrator	Bruel & Kjaer	4230	830235	5/15/2001
	Digital Recorder	Sony	PC208AX	U3538	8/25/2000 Post-test calibrated on 2/22/2002
	Anemometer	Met One	010C	Y4397	2/20/2002
	Wind Vane	Met One	020C	U1477	2/20/2002
	Pressure Sensor	Omega	HHP-102F	T3330002	12/19/2001
	Temperature Sensor	Omega	869	0653393	12/12/2001
	Data Logger	Campbell Scientific	23X	1214	1/31/2002
8-14 Feb 2002	Signal Analyzer	Hewlett Packard	35670A	3431A01613	8/8/2004
	Microphone	ACO Japan	7012	17561	6/17/2003
	Microphone	ACO Japan	7012	17509	6/16/2003
	Microphone	ACO Japan	7012	17508	5/10/2002
	Microphone	ACO Japan	7012	19037	6/16/2003
	Preamplifier	ACO Pacific	4012	6009	6/18/2003
	Preamplifier	ACO Pacific	4012	960032	6/18/2003
	Preamplifier	ACO Pacific	4012	9900504	6/18/2003
	Preamplifier	ACO Pacific	4012	9900503	5/17/2002
	Calibrator	Bruel & Kjaer	4230	861619	10/22/2002
	Digital Recorder	Sony	PC208AX	U3538	8/25/2000 Post-test calibrated on 2/22/2002
	Anemometer	Met One	010C	Y4397	2/20/2002
	Wind Vane	Met One	020C	U1477	2/20/2002
	Pressure Sensor	Omega	HHP-102F	S2830007	11/19/2002

	Temperature Sensor	Omega	869	0464507	11/19/2002
	Data Logger	Campbell Scientific	23X	3101	10/30/2002
27 Mar 2002	Signal Analyzer	Hewlett Packard	35670A	3431A01613	8/8/2004
	Microphone	ACO Japan	7012	17561	6/17/2003
	Microphone	ACO Japan	7012	17510	5/10/2002
	Microphone	ACO Japan	7012	17509	6/16/2003
	Microphone	ACO Japan	7012	17508	5/10/2002
	Preamplifier	ACO Pacific	4012	9900503	5/17/2002
	Preamplifier	ACO Pacific	4012	960032	6/18/2003
	Preamplifier	ACO Pacific	4012	9900504	6/18/2003
	Preamplifier	ACO Pacific	4012	6009	6/18/2003
	Calibrator	Bruel & Kjaer	4230	861619	10/22/2002
	Digital Recorder	Sony	PC208AX	U3538	2/22/2004
	Anemometer	Met One	010C	T2345	2/21/2003
	Wind Vane	Met One	020C	T1010	2/21/2003
	Pressure Sensor	Omega	HHP-102F	S2830007	11/19/2002
	Temperature Sensor	Omega	869	0464507	11/19/2002
	Data Logger	Campbell Scientific	23X	3101	10/30/2002

The power and meteorological measurements (wind speed, wind direction, pressure, and temperature) were averaged and recorded by the Campbell data logger. The digital audio tape recorder recorded the acoustic measurements. Acoustic measurements were synchronized with power and meteorological measurements in the post-processing stage.

11.2 Meteorological Tower Location

The meteorological tower was located 22.7 meters from the test turbine at a bearing of 292^{o} true. This distance is more than 3.0 rotor diameters from the test turbine and within the range specified in the Standard (between 2 and 4 rotor diameters).

11.3 Instrumentation Locations

Figure 19 shows the layout of the microphones. The radius, R_o is determined by Equation 1.

$$R_o = H + \frac{D}{2}$$ **Equation 1**

Table 12. Variables for Determining the Distance between the Turbine Base and Microphones

Parameter	Description	Value	Units
R_o	Reference distance	40.5	m
H	Vertical distance from the ground to the rotor center	37.0	m
D	Diameter of the rotor (BW3 blades)	7.0	m

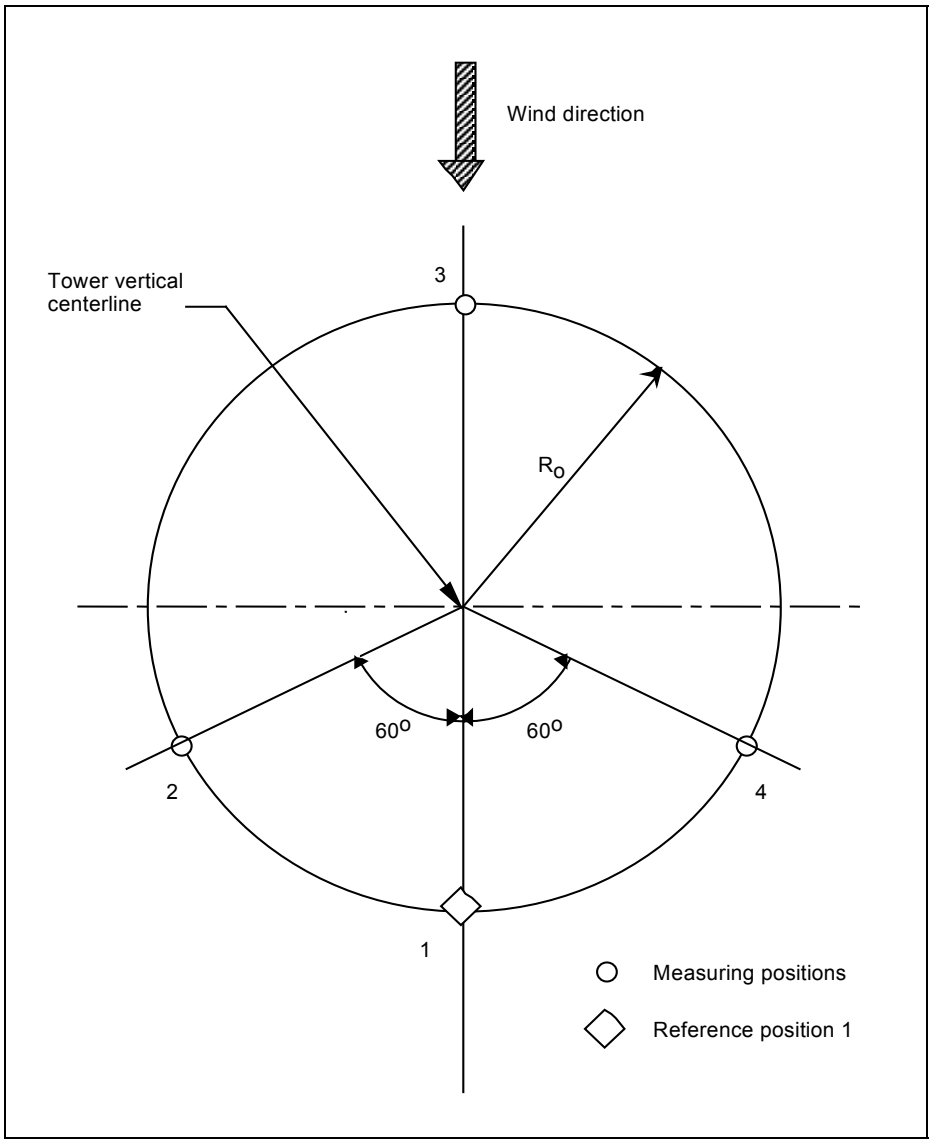


Figure 19. Microphone positions.

For both turbine configurations, microphones were located 40.0 m from the center of the tower with relative positions, as shown in Figure 19. Small adjustments from the nominal microphone positions may be required to avoid reflecting surfaces or to obtain allowable grazing angles. This distance meets the requirements of the Standard for both turbine configurations.

The anemometer will be located on a permanent meteorological tower at 37.0 m height at a bearing of 292^{o} true. The meteorological tower will be located upwind from reference microphone position 1 during testing.

12.0 Measurement Procedures

12.1 Test Conduct

The acoustic noise test consists of two types of noise measurements: turbine and background. Turbine noise measurements are taken when the turbine is operating, and background noise measurements are taken when the turbine is stopped.

The operator begins a measurement session by starting the digital tape recording to record noise from the four microphones. Simultaneously, the data logger acquires wind speed, wind direction, and turbine power. The data logger averages each of these readings over 10-second periods. Noise data is processed into 10-second averages and synchronized with the data logger averages in post-processing.

Because the Bergey Excel uses furling for overspeed control, 10-second averages were used instead of 1-minute averages (as the Standard recommends) so that the noise from turbine response to changes in wind speed could be better characterized.

12.2 Test Completion

The test is complete when all requirements listed in Table 13 are fulfilled for turbine and background measurements.

Table 13. Data Requirements

Measurement Type	Requirements
A-weighted sound pressure level: (turbine and background measurements)	At least 10 measurements taken during a wind speed not differing more than 2 m/s from the acoustic reference wind speed (8 m/s)
	At least 25% of the measurements below the acoustic reference wind speed
	At least 25% of the measurements above the acoustic reference wind speed
	Data at or above the point at which the turbine employs overspeed control
Narrowband measurements	Twelve 10-second measurements close to the acoustic reference wind speed (8 m/s)

13.0 Analysis Methods

13.1 Data Selection

All data were collected in three measurement series. Conditions are listed in Table 14.

Table 14. Measurement Conditions

Date	Measurement Time HH:MM	Reference Microphone Position degrees	Wind Direction Range degrees	Pressure kPa	Temperature K
BW3 Configuration					
19 April 2001	08:42 to 15:13	110 ^{o}	286^{o} to 316 ^{o}	80.0 – 80.1	292.3 – 293.6
08 February 2002	17:49 to 20:23	112 ^{o}	277^{o} to 307 ^{o}	79.8 – 80.5	270.3 – 271.6
14 February 2002	10:30 to 13:55	112 ^{o}	277^{o} to 307 ^{o}	80.3 – 80.8	271.2 – 278.6
SH3052 Configuration					
27 March 2002	09:25 to 17:27	92 ^{o}	257^{o} to 287 ^{o}	79.9 – 80.4	282.1 – 288.8

The first step in the data analysis procedure is to reject all data obtained during the following circumstances:

- Interruption from noise sources such as a passing vehicle or airplane
- Failure of test equipment
- Wind direction outside of allowable range
- Wind speed below cut-in
- Turbine failure
- Adverse weather conditions.

13.2 Determination of Wind Speed

The Standard's preferred method of determining the wind speed is to use the measured power output and derive the wind speed through the power curve. The power curve relates the power to the wind speed averaged over the rotor swept area. The turbine is used as a large anemometer and usually gives a better determination of wind speed at the rotor than using a cup anemometer located on a meteorological tower a distance from the turbine.

For most wind turbines, the output power correlates well with turbine sound pressure level up to the point of maximum power. This was true for the Bergey Excel using the BW3 blades but not true using the SH3052 blades. Figure 20 displays less scatter in the power-versus-wind speed relationship for the Bergey using BW3 blades. Figure 21 displays the large scatter in the power-versus-wind speed relationship for the Bergey using SH3052 blades. Ten-second averaged power measurements collected during the noise test were used to derive the wind speed from the 1-minute averaged power curve. The results shown in Section 8.0 use the wind speed derived from power.

The Standard's optional method of determining the wind speed is to directly measure the wind speed and standardize this wind speed to acoustic reference conditions (roughness length of 0.5 meters and height of 10 m). The results shown in Section 7.0 use this method for determining the wind speed.

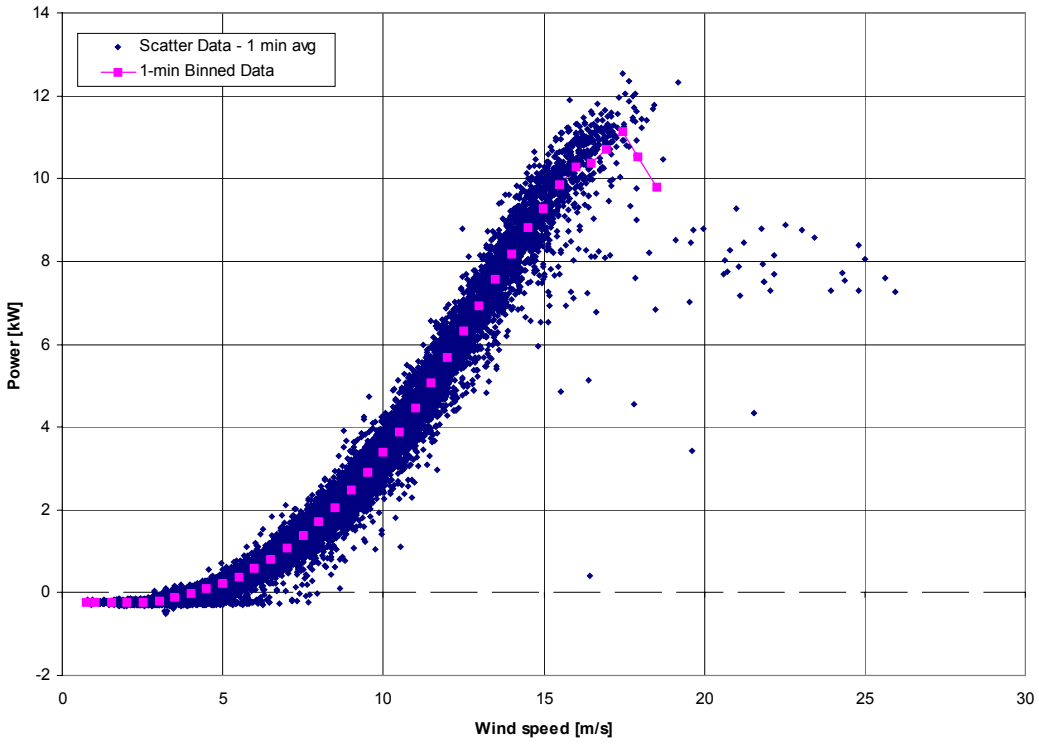


Figure 20. Bergey with BW3 blades: measured power curve using 1-minute averages.

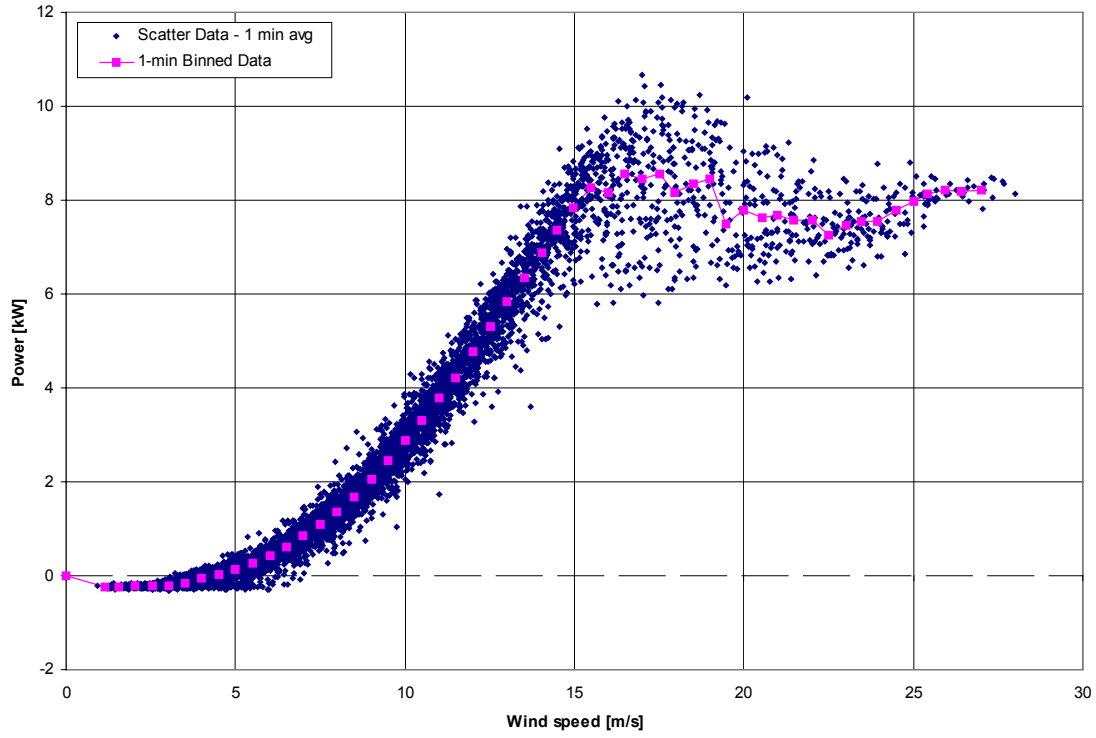


Figure 21. Bergey with SH3052 blades: measured power curve using 1-minute averages.

13.3 Wind Speed Correction

Wind speed, derived or measured, is corrected to the reference condition of an anemometer height of 10 meters using Equation 2.

$$V_s = V_z \left[\frac{\ln \frac{z_{ref}}{z_{oref}} \ln \frac{H}{z_o}}{\ln \frac{H}{z_{oref}} \ln \frac{z}{z_o}} \right] \qquad \textbf{Equation 2}$$

Table 15. Variables for Standardizing Wind Speed

Parameter	Description	Value	Units
V_s	Corrected wind speed		m/s
V_z	Wind speed measured at anemometer height z		m/s
z_{oref}	Reference roughness length	0.05	m
z_o	Roughness length	0.05	m
H	Rotor center height	37.0	m
z_{ref}	Reference height	10.0	m
z	Anemometer height	37.0	m

13.4 A-Weighted Sound Power Level

A linear regression analysis is done with at least 10 pairs of equivalent continuous sound pressure levels from the microphone at the reference position and the corrected wind speed. These pairs are selected to cover wind speeds between 6 and 10 m/s. The reference position sound pressure level, L_{Aeq}, is the value of the regression line at the acoustic reference wind speed. A similar analysis yields the background noise level at the acoustic reference wind speed. If the difference between the turbine and background noise is greater than 6 dB, Equation 3 is used to correct the turbine noise level for background noise and provides the corrected sound pressure level at the reference position, $L_{Aeq,c}$. If the difference is less than 6 dB and greater than 3 dB, then the turbine noise level is corrected by subtracting 1.3 dB from the turbine noise. However, these corrected sound pressure levels may not be used in any other calculations, including sound power level. If the difference is less than 3 dB, then it must be reported that the turbine noise was less than the background noise, and it cannot be used in any calculations.

$$L_{Aeq,c} = 10 * \log\left[10^{(0.1L_{s+n})} - 10^{(0.1L_n)}\right] \qquad \textbf{Equation 3}$$

Table 16. Variables for Determining Equivalent Sound Pressure Level

Parameter	Description	Units
$L_{Aeq,c}$	Sound pressure level of the turbine operating alone	dB
L_{s+n}	Sound pressure level of the turbine	dB
L_n	Sound pressure level of the background	dB

Finally, we calculate the apparent sound power level, L_{WA}, from the corrected sound pressure level using Equation 4.

$$L_{WA} = L_{Aeq,c} - 6 + 10 * \log\left(\frac{4\pi R_1^2}{S_o}\right) \qquad \textbf{Equation 4}$$

Table 17. Variables in Calculating the Apparent Sound Power Level

Parameter	Description	Value	Units
$L_{Aeq,c}$	Background-corrected, A-weighted, sound pressure level at the acoustic reference wind speed under reference conditions		dB
R_1	Slant distance from the rotor center to the microphone	13.6	m
S_o	Reference area	1.0	m^2

13.5 Wind Speed Dependence

The Standard requires that wind speed dependence be defined by binning the reference microphone data into integer values of standardized wind speed. For each bin, the sound pressure level at the reference microphone position is corrected for that bin's background noise.

13.6 Directivity

Directivity, Δ_i, is the difference in A-weighted sound pressure levels at Positions 2, 3, and 4 compared to the A-weighted sound pressure levels at the reference position. In addition, corrections are made for differences in slant distances. (Slant distance is the distance from the microphone to the center of the turbine's rotor.) The directivity at each position is calculated by Equation 5.

$$\Delta_i = L_{Aeq,i} - L_{Aeq,1} + 20 * \log\left(\frac{R_i}{R_1}\right). \qquad \textbf{Equation 5}$$

Table 18. Variables in Determining the Directivity

Parameter	Description	Units
$L_{Aeq,i}$	A-weighted sound pressure level at positions 2, 3, or 4, corrected for background noise in the same position	dB
$L_{Aeq,1}$	A-weighted sound pressure level at the reference position, measured simultaneously with $L_{Aeq,i}$ and also corrected for background noise	dB
R_i	Slant distance between the rotor center and positions 2, 3, or 4	m
R_1	Slant distance between the rotor center and the reference position	m

14.0 Uncertainty

The uncertainty is reported for the BW3 configuration only because the analysis from the SH3052 configuration did not yield reportable sound power levels.

The combined uncertainty is reported for the apparent sound power level and wind speed dependence. The combined standard uncertainty is the combination of Type A and Type B uncertainties. Type A uncertainty components are evaluated by using statistical methods to a series of repeated measurements. Type B uncertainty components are evaluated through estimations or calibrations. The methods used to evaluate the uncertainty components for the apparent sound power level and wind speed dependence will be explained in this section.

14.1 Apparent Sound Pressure Level

The Type A uncertainty for the apparent sound pressure level is the standard error of the estimated L_{Aeq} at the acoustic reference wind speed. This is found from the linear regression analysis.

$$U_A = \sqrt{\frac{\Sigma(y - y_{est})^2}{N - 2}} \qquad \textbf{Equation 6}$$

Table 19 lists the Type A uncertainty for the apparent sound power levels using the measured wind speed.

Table 19. Type A Apparent Sound Power Level Uncertainty Components BW3

Parameter	Description	Microphone				Unit
		1	2	3	4	
U_A	Type A uncertainty for apparent sound pressure level	2.6	2.6	2.6	2.6	dB
y	Measured sound pressure level	-	-	-	-	dB
y_{est}	Estimated sound pressure level using linear regression	58.9	56.5	57.8	56.2	dB
N	Number of measurements used in the linear regression	399	399	399	399	-

The Type B uncertainty components include:

$$U_B = \sqrt{U_{B1}^2 + U_{B2}^2 + U_{B3}^2 + U_{B4}^2 + U_{B5}^2 + U_{B6}^2 + U_{B7}^2 + U_{B8}^2 + U_{B9}^2} \qquad \textbf{Equation 7}$$

Table 20. Type B Apparent Sound Power Level Uncertainty Components

Parameter	Description	Microphone				Unit	Source
		1	2	3	4		
U_B	Type B uncertainty for apparent sound pressure level	0.9	1.0	1.0	1.1	dB	Equation 7
U_{B1}	Uncertainty for calibration of the instruments	0.1	0.2	0.1	0.2	dB	Calibrator specifications calibration and the standard error from field calibrating
U_{B2}	Uncertainty for tolerances on the chain of acoustic measurement instruments	0.2	0.2	0.2	0.2	dB	Signal analyzer, microphone, microphone adapter, and preamplifier specifications
U_{B3}	Uncertainty for acoustic conditions for microphone mounting board	0.3	0.3	0.3	0.3	dB	Estimate
U_{B4}	Uncertainty on the distance from microphone to hub	0.1	0.1	0.1	0.1	dB	Estimate
U_{B5}	Uncertainty on the acoustic impedance of air	0.1	0.1	0.1	0.1	dB	Estimate
U_{B6}	Uncertainty on the acoustic emission of the turbine because of changing weather conditions	0.6	0.6	0.6	0.6	dB	Estimate
U_{B7}	Uncertainty on the measured wind speed	0.5	0.5	0.5	0.5	dB	Anemometer calibration and estimate of the site effects
U_{B8}	Uncertainty on the wind direction measurement	0.3	0.3	0.3	0.3	dB	Wind vane alignment
U_{B9}	Uncertainty for the background correction	0.1	0.2	0.2	0.6	dB	Applied background correction

These uncertainties are combined into one standard uncertainty by Equation 8.

$$U_C = \sqrt{U_A^2 + U_B^2} \qquad \textbf{Equation 8}$$

Table 21. Overall Uncertainty Components

Parameter	Description	Microphone				Units
		1	2	3	4	
U_C	Overall standard uncertainty for apparent sound power level	2.8	2.8	2.8	2.8	dB
U_A	Type A uncertainty for apparent sound pressure level	2.6	2.6	2.6	2.6	dB
U_B	Type B uncertainty for apparent sound pressure level	0.9	1.0	1.0	1.1	dB

14.2 Wind Speed Sensitivity

Type A uncertainty for wind speed dependence is found from a linear regression analysis. The uncertainty, $U_{A,}$ is calculated for integer wind speeds as the root sum of the squared standard error of the estimated value at the actual wind speed. The squared standard error is given in Equation 9.

$$s_i = \sqrt{\frac{\sum (L_{Aeq} - L_{Aeq,j})^2}{(N-1)^2}} \qquad \textbf{Equation 9}$$

Table 22. Type A Wind Dependence Uncertainty Components

Parameter	Description	Units
s_i	Type A standard uncertainty for wind speed bin i	dB
L_{Aeq}	Average of the sound pressure levels in wind speed bin i	dB
$L_{Aeq,i}$	Sound pressure level in wind speed bin	dB
N	Number of measurement results in wind speed bin	

The Type B uncertainty for each bin is found using Equation 7.

Table 23. Type B Wind Dependence Uncertainty Components

Parameter	Description	Value	Unit	Source
U_B	Type B uncertainty for bin i	Varies by bin	dB	Equation 7
U_{B1}	Uncertainty for calibration of the instruments	0.1	dB	Calibrator calibration and the standard error from field calibrating microphones
U_{B2}	Uncertainty for tolerances on the chain of acoustic measurement instruments	0.2	dB	Signal analyzer, microphone, microphone adapter, and preamplifier
U_{B3}	Uncertainty for acoustic conditions for microphone mounting board	0.3	dB	Estimate
U_{B4}	Uncertainty on the distance from microphone to hub	0.1	dB	Estimate
U_{B5}	Uncertainty on the acoustic impedance of air	0.1	dB	Estimate
U_{B6}	Uncertainty on the acoustic emission of the turbine because of changing weather conditions	0.6	dB	Estimate
U_{B7}	Uncertainty on the wind speed derived from measured power	0.4	dB	Estimated uncertainty from the power curve and estimate of the site effects
U_{B8}	Uncertainty on the wind direction measurement	0.3	dB	Wind vane alignment
U_{B9}	Uncertainty for the background correction	Varies by bin	dB	Applied background correction

15.0 Exceptions

1. Measurement averaging period was reduced to 10 seconds to better characterize noise when the turbine responds to changes in the wind speed.

Appendix A: Pictures of Test Site

Figure 22. Picture taken from the reference microphone position.

(Picture not taken during test)

Figure 23. Picture taken from the meteorological tower.

(Picture not taken during test.)

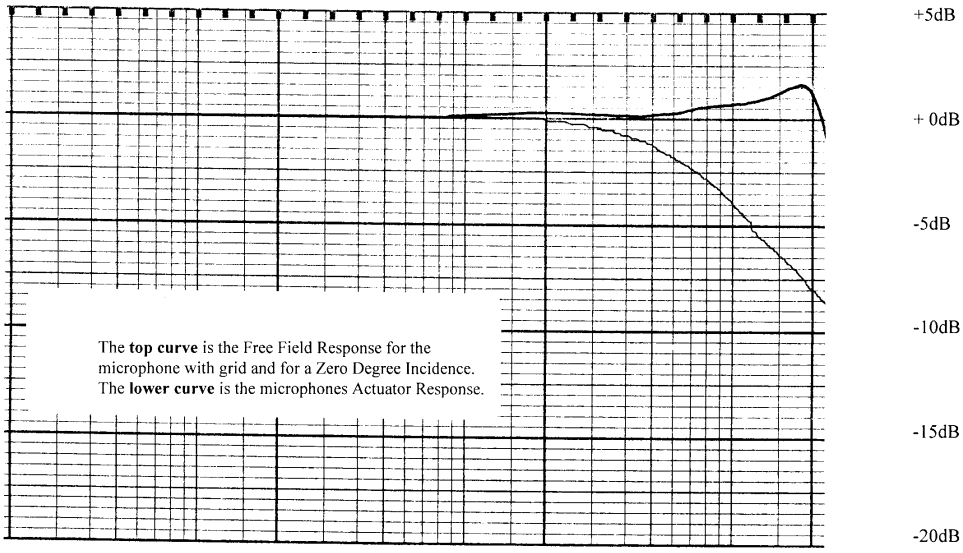
Appendix B: Calibration Sheets

CERTIFICATE OF CALIBRATION
FOR ACO MICROPHONE

The calibration is performed by comparison with
Calibration Service Standard Microphone Cartridge Type
4160 Serial No. **991820**
Calibrated by **TS** (BRÜEL & KJÆR) Date **18 AUG 1999**
Re-calibration due **18 AUG 2000**
a) Estimated uncertainty of comparison:
± **0.09** dB at 99% confidence level.
b) Estimated uncertainty of Calibration Service
Standard Microphone Cartridge:
± **0.06** dB at 99% confidence level.
c) Absolute uncertainty:
Sq. Root (a^2+b^2) = **0.11** dB at 99% confidence level.

Microphone Cartridge Type **7012**
Id No. 56484 **Serial No.** **17509**
Open Circuit Sensitivity
at 1013 mbar, 23° C, 65% R.H.: **-36.21** dB re. 1 V/Pa
or **15.47** mV/Pa
This calibration is traceable to:
NIST Test #822/259792-98.

Open Circuit Correction Factor K_0 = **+10.2** dB
Correction Factor K dB
Preamplifier Type:
Serial No.:



The lower curve is the pressure response recorded with Electrostatic Actuator Type : **UA 0033**
The Free-Field Frequency Response Curve (0°) (if shown) is obtained by applying the corrections, found on the supplied chart, to the measured actuator response curve.
The Random Incidence Frequency Response Curve

(if shown) is obtained by applying the corrections, found on the supplied chart to the measured actuator response curve.

Condition of Test:

Ambient Pressure:	**985.90**	hPa
Temperature:	**23**	°C
Relative Humidity:	**41**	%
Polarization voltage:	**200**	V
Frequency:	**250**	Hz
Date of calibration:	**10 MAY 2000**	
Re-calibration due on:	**10 MAY 2002**	

Note: The calibration data is both "AS FOUND" and "AS FINAL"

Certificate # **8635-8** PO# **017135**

For: **Instrument Repair Labs, Broomfield, CO 80020**

Note: At the time of calibration this microphone was performing **within** Mfg. specification

Calibration performed by:
Torben Ehlert , Quality Assurance Manager

ODIN METROLOGY, INC.

CALIBRATION OF BRÜEL & KJÆR INSTRUMENTS
3533 Old Conejo Road Suite 125
Thousand Oaks, CA 91320
Tel. (805) 375-0830 Fax (805) 375-0405

INSTRUMENTATION USED FOR CALIBRATION OF MICROPHONES

ODIN METROLOGY, INC.

INSTRUMENTATION USED FOR CALIBRATION PAGE 1 OF THIS DOCUMENT

CALIBRATION SYSTEM	TYPE NO.	SERIAL NO.	CAL. DATE	DUE	CAL. BY:
Precision Barometer	Druck 141	299/95-10	18 NOV 99	18 NOV 00	Schwien
Preamplifier	2645	1146929	09 AUG 99	09 AUG 00	HL
Preamplifier	2639	1374086	09 AUG 99	09 AUG 00	HL
Actuator Voltage Supply	WB0689	4	17 AUG 99	17 AUG 00	TS
Sine/Random Generator	1027	1050281	27 JUL 99	27 JUL 00	HL
Graphic Level Recorder	2307	1029255	27 JUL 99	27 JUL 00	HL
Precision Attenuator	WB 0566	04	17 AUG 99	17 AUG 00	TS
Polarization Voltmeter	WB0781	04	17 AUG 99	17 AUG 00	TS
Pistonphone	4220/40cc	1048747	18 AUG 99	18 AUG 00	TS
Multimeter	HP 34401	3146A48348	12 AUG 99	12 AUG 00	HP
Expanded Meter	111283	4	23 AUG 99	23 AUG 00	TE
Measuring Amplifier	2636	1423390	09 AUG 99	09 AUG 00	HL

REMARKS:

Calibration of reference microphones 4160 serial numbers 991820,991821,1054926, and standard pistonphones 4220 serial numbers 1048473, 1048795, 1510240 and 4228 # 1793011 and 4220 with 40 ccm volume serial # 1048747 are calibrated traceable to NIST with NIST Test number **822/259792-98**.

NOTE: The verification/calibration listed on page 1 of this document was performed on a test system which conforms to and operates under the requirements of **ANSI/NCSL Z540-1** which also covers the requirements for **MIL STD 45662A.**

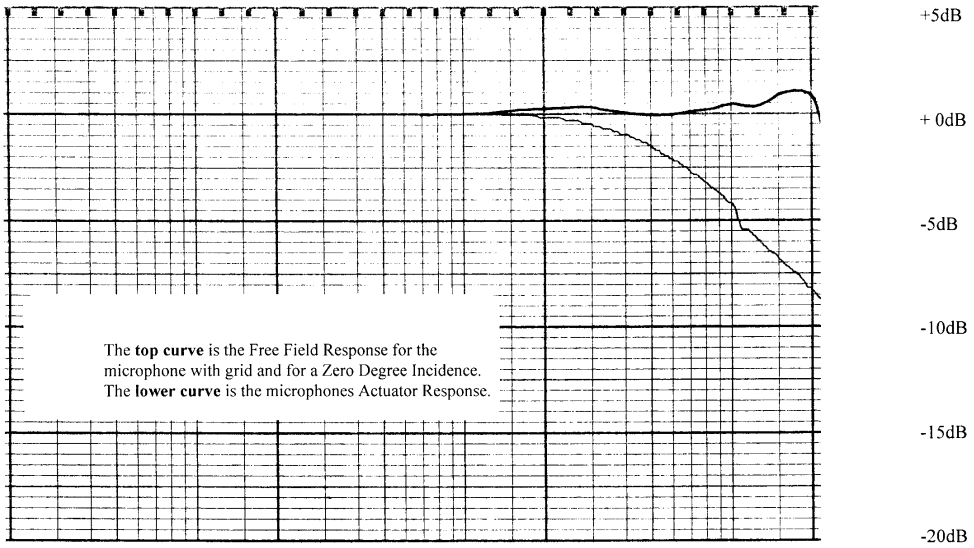
Revised: 18 NOV 1999

CERTIFICATE OF CALIBRATION
FOR ACO MICROPHONE

The calibration is performed by comparison with
Calibration Service Standard Microphone Cartridge Type
4160 Serial No. **991820**
Calibrated by **TS** (BRÜEL & KJÆR) Date **18 AUG 1999**
Re-calibration due **18 AUG 2000**
a) Estimated uncertainty of comparison:
± **0.09** dB at 99% confidence level.
b) Estimated uncertainty of Calibration Service
Standard Microphone Cartridge:
± **0.06** dB at 99% confidence level.
c) Absolute uncertainty:
Sq. Root (a^2+b^2) = **0.11** dB at 99% confidence level.

Microphone Cartridge Type **7012**
Id No. 56482 **Serial No.** **17510**
Open Circuit Sensitivity
at 1013 mbar, 23° C, 65% R.H.: **-35.74** dB re. 1 V/Pa
or **16.33** mV/Pa
This calibration is traceable to:
NIST Test #822/259792-98.

Open Circuit Correction Factor K_0 = **+9.7** dB
Correction Factor K dB
Preamplifier Type:
Serial No.:



30 50 100 200 500 1000 2000 5000 10 kHz 20

The lower curve is the pressure response recorded with Electrostatic Actuator Type : **UA 0033**
The Free-Field Frequency Response Curve (0°) (if shown) is obtained by applying the corrections, found on the supplied chart, to the measured actuator response curve.
The Random Incidence Frequency Response Curve

(if shown) is obtained by applying the corrections, found on the supplied chart to the measured actuator response curve.

Condition of Test:

Ambient Pressure:	**985.90**	hPa
Temperature:	**23**	°C
Relative Humidity:	**41**	%
Polarization voltage:	**200**	V
Frequency:	**250**	Hz
Date of calibration:	**10 MAY 2000**	
Re-calibration due on:	**10 MAY 2002**	

Note: The calibration data is both "AS FOUND" and "AS FINAL"

Certificate # **8635-10** PO# **017135**

For: **Instrument Repair Labs, Broomfield, CO 80020**

Note: At the time of calibration this microphone was performing **within** Mfg. specification

Calibration performed by:
Torben Ehlert , Quality Assurance Manager

ODIN METROLOGY, INC.

CALIBRATION OF BRÜEL & KJÆR INSTRUMENTS
3533 Old Conejo Road Suite 125
Thousand Oaks, CA 91320
Tel. (805) 375-0830 Fax (805) 375-0405

INSTRUMENTATION USED FOR CALIBRATION OF MICROPHONES

ODIN METROLOGY, INC.

INSTRUMENTATION USED FOR CALIBRATION PAGE 1 OF THIS DOCUMENT

CALIBRATION SYSTEM	TYPE NO.	SERIAL NO.	CAL. DATE	DUE	CAL. BY:
Precision Barometer	Druck 141	299/95-10	18 NOV 99	18 NOV 00	Schwien
Preamplifier	2645	1146929	09 AUG 99	09 AUG 00	HL
Preamplifier	2639	1374086	09 AUG 99	09 AUG 00	HL
Actuator Voltage Supply	WB0689	4	17 AUG 99	17 AUG 00	TS
Sine/Random Generator	1027	1050281	27 JUL 99	27 JUL 00	HL
Graphic Level Recorder	2307	1029255	27 JUL 99	27 JUL 00	HL
Precision Attenuator	WB 0566	04	17 AUG 99	17 AUG 00	TS
Polarization Voltmeter	WB0781	04	17 AUG 99	17 AUG 00	TS
Pistonphone	4220/40cc	1048747	18 AUG 99	18 AUG 00	TS
Multimeter	HP 34401	3146A48348	12 AUG 99	12 AUG 00	HP
Expanded Meter	111283	4	23 AUG 99	23 AUG 00	TE
Measuring Amplifier	2636	1423390	09 AUG 99	09 AUG 00	HL

REMARKS:

Calibration of reference microphones 4160 serial numbers 991820,991821,1054926, and standard pistonphones 4220 serial numbers 1048473, 1048795, 1510240 and 4228 # 1793011 and 4220 with 40 ccm volume serial # 1048747 are calibrated traceable to NIST with NIST Test number **822/259792-98**.

NOTE: The verification/calibration listed on page 1 of this document was performed on a test system which conforms to and operates under the requirements of **ANSI/NCSL Z540-1** which also covers the requirements for **MIL STD 45662A.**

Revised: 18 NOV 1999

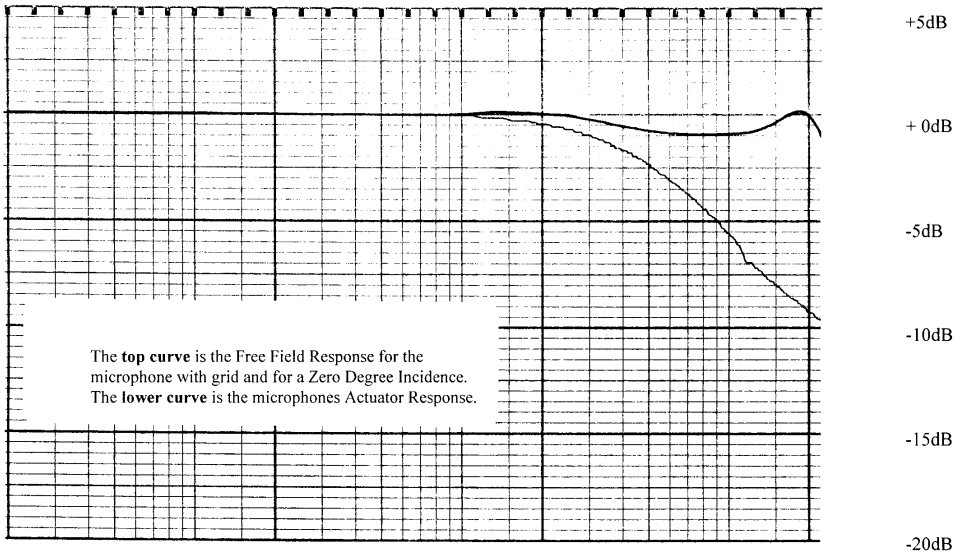
Page 2 of 2

CERTIFICATE OF CALIBRATION
FOR ACO MICROPHONE

The calibration is performed by comparison with Calibration Service Standard Microphone Cartridge Type **4160** Serial No. **991820**
Calibrated by **TS** (BRÜEL & KJÆR) Date **18 AUG 1999**
Re-calibration due **18 AUG 2000**
a) Estimated uncertainty of comparison:
± **0.09** dB at 99% confidence level.
b) Estimated uncertainty of Calibration Service Standard Microphone Cartridge:
± **0.06** dB at 99% confidence level.
c) Absolute uncertainty:
Sq. Root (a^2+b^2) = **0.11** dB at 99% confidence level.

Microphone Cartridge Type **7012**
Id No. 19033 **Serial No.** **19037**
Open Circuit Sensitivity
at 1013 mbar, 23° C, 65% R.H.: **-34.44** dB re. 1 V/Pa
or **18.97** mV/Pa
This calibration is traceable to:
NIST Test #822/259792-98.

Open Circuit Correction Factor K_0 = **+8.4** dB
Correction Factor K dB
Preamplifier Type:
Serial No.:



30 50 100 200 500 1000 2000 5000 10 kHz 20

The lower curve is the pressure response recorded with Electrostatic Actuator Type : **UA 0033**
The Free-Field Frequency Response Curve (0^0) (if shown) is obtained by applying the corrections, found on the supplied chart, to the measured actuator response curve.
The Random Incidence Frequency Response Curve

(if shown) is obtained by applying the corrections, found on the supplied chart to the measured actuator response curve.

Condition of Test:

Ambient Pressure:	**985.90**	hPa
Temperature:	**23**	^{0}C
Relative Humidity:	**41**	%
Polarization voltage:	**200**	V
Frequency:	**250**	Hz
Date of calibration:	**10 MAY 2000**	
Re-calibration due on:	**10 MAY 2002**	

Note: The calibration data is both "AS FOUND" and "AS FINAL"

Certificate # **8635-7** PO# **017135**

For: **Instrument Repair Labs, Broomfield, CO 80020**

Note: At the time of calibration this microphone was performing **within** Mfg. specification
Calibration performed by:
Torben Ehlert , Quality Assurance Manager

ODIN METROLOGY, INC.
CALIBRATION OF BRÜEL & KJÆR INSTRUMENTS
3533 Old Conejo Road Suite 125
Thousand Oaks, CA 91320
Tel. (805) 375-0830 Fax (805) 375-0405

INSTRUMENTATION USED FOR CALIBRATION OF MICROPHONES

ODIN METROLOGY, INC.

INSTRUMENTATION USED FOR CALIBRATION PAGE 1 OF THIS DOCUMENT

CALIBRATION SYSTEM	TYPE NO.	SERIAL NO.	CAL. DATE	DUE	CAL. BY:
Precision Barometer	Druck 141	299/95-10	18 NOV 99	18 NOV 00	Schwien
Preamplifier	2645	1146929	09 AUG 99	09 AUG 00	HL
Preamplifier	2639	1374086	09 AUG 99	09 AUG 00	HL
Actuator Voltage Supply	WB0689	4	17 AUG 99	17 AUG 00	TS
Sine/Random Generator	1027	1050281	27 JUL 99	27 JUL 00	HL
Graphic Level Recorder	2307	1029255	27 JUL 99	27 JUL 00	HL
Precision Attenuator	WB 0566	04	17 AUG 99	17 AUG 00	TS
Polarization Voltmeter	WB0781	04	17 AUG 99	17 AUG 00	TS
Pistonphone	4220/40cc	1048747	18 AUG 99	18 AUG 00	TS
Multimeter	HP 34401	3146A48348	12 AUG 99	12 AUG 00	HP
Expanded Meter	111283	4	23 AUG 99	23 AUG 00	TE
Measuring Amplifier	2636	1423390	09 AUG 99	09 AUG 00	HL

REMARKS:

Calibration of reference microphones 4160 serial numbers 991820,991821,1054926, and standard pistonphones 4220 serial numbers 1048473, 1048795, 1510240 and 4228 # 1793011 and 4220 with 40 ccm volume serial # 1048747 are calibrated traceable to NIST with NIST Test number **822/259792-98**.

NOTE: The verification/calibration listed on page 1 of this document was performed on a test system which conforms to and operates under the requirements of **ANSI/NCSL Z540-1** which also covers the requirements for **MIL STD 45662A.**

Revised: 18 NOV 1999

Page 2 of 2

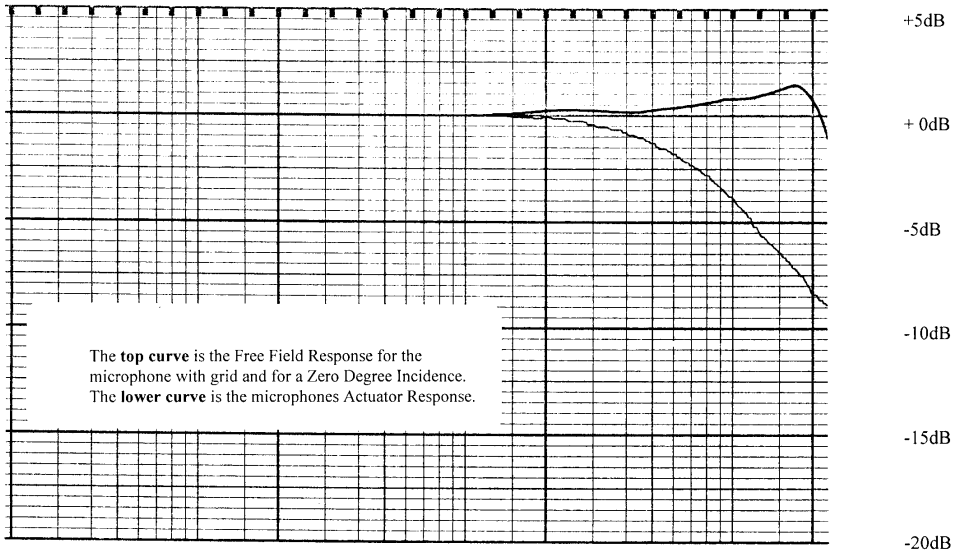
CERTIFICATE OF CALIBRATION
FOR ACO MICROPHONE

The calibration is performed by comparison with
Calibration Service Standard Microphone Cartridge Type
4160 Serial No. **991820**
Calibrated by **TS** (BRÜEL & KJÆR) Date **18 AUG 1999**
Re-calibration due **18 AUG 2000**

a) Estimated uncertainty of comparison:
± **0.09** dB at 99% confidence level.
b) Estimated uncertainty of Calibration Service
Standard Microphone Cartridge:
± **0.06** dB at 99% confidence level.
c) Absolute uncertainty:
Sq. Root (a^2+b^2) = **0.11** dB at 99% confidence level.

Microphone Cartridge Type **7012**
Id No. 19037 **Serial No.** **17508**
Open Circuit Sensitivity
at 1013 mbar, 23° C, 65% R.H.: **-36.14** dB re. 1 V/Pa
or **15.60** mV/Pa
This calibration is traceable to:
NIST Test #822/259792-98.

Open Circuit Correction Factor K_0 = **+10.1** dB
Correction Factor K dB
Preamplifier Type:
Serial No.:



The lower curve is the pressure response recorded with Electrostatic Actuator Type : **UA 0033**
The Free-Field Frequency Response Curve (0^0) (if shown) is obtained by applying the corrections, found on the supplied chart, to the measured actuator response curve.
The Random Incidence Frequency Response Curve

(if shown) is obtained by applying the corrections, found on the supplied chart to the measured actuator response curve.

Condition of Test:

Ambient Pressure:	**985.90**	hPa
Temperature:	**23**	^{0}C
Relative Humidity:	**41**	%
Polarization voltage:	**200**	V
Frequency:	**250**	Hz
Date of calibration:	**10 MAY 2000**	
Re-calibration due on:	**10 MAY 2002**	

Note: The calibration data is both "AS FOUND" and "AS FINAL"

Certificate # **8635-6** PO# **017135**

For: **Instrument Repair Labs, Broomfield, CO 80020**

Note: At the time of calibration this microphone was performing **within** Mfg. specification

Calibration performed by:
Torben Ehlert , Quality Assurance Manager

ODIN METROLOGY, INC.

CALIBRATION OF BRÜEL & KJÆR INSTRUMENTS
3533 Old Conejo Road Suite 125
Thousand Oaks, CA 91320
Tel. (805) 375-0830 Fax (805) 375-0405

INSTRUMENTATION USED FOR CALIBRATION OF MICROPHONES

ODIN METROLOGY, INC.

INSTRUMENTATION USED FOR CALIBRATION PAGE 1 OF THIS DOCUMENT

CALIBRATION SYSTEM	TYPE NO.	SERIAL NO.	CAL. DATE	DUE	CAL. BY:
Precision Barometer	Druck 141	299/95-10	18 NOV 99	18 NOV 00	Schwien
Preamplifier	2645	1146929	09 AUG 99	09 AUG 00	HL
Preamplifier	2639	1374086	09 AUG 99	09 AUG 00	HL
Actuator Voltage Supply	WB0689	4	17 AUG 99	17 AUG 00	TS
Sine/Random Generator	1027	1050281	27 JUL 99	27 JUL 00	HL
Graphic Level Recorder	2307	1029255	27 JUL 99	27 JUL 00	HL
Precision Attenuator	WB 0566	04	17 AUG 99	17 AUG 00	TS
Polarization Voltmeter	WB0781	04	17 AUG 99	17 AUG 00	TS
Pistonphone	4220/40cc	1048747	18 AUG 99	18 AUG 00	TS
Multimeter	HP 34401	3146A48348	12 AUG 99	12 AUG 00	HP
Expanded Meter	111283	4	23 AUG 99	23 AUG 00	TE
Measuring Amplifier	2636	1423390	09 AUG 99	09 AUG 00	HL

REMARKS:

Calibration of reference microphones 4160 serial numbers 991820,991821,1054926, and standard pistonphones 4220 serial numbers 1048473, 1048795, 1510240 and 4228 # 1793011 and 4220 with 40 ccm volume serial # 1048747 are calibrated traceable to NIST with NIST Test number **822/259792-98**.

NOTE: The verification/calibration listed on page 1 of this document was performed on a test system which conforms to and operates under the requirements of **ANSI/NCSL Z540-1** which also covers the requirements for **MIL STD 45662A.**

Revised: 18 NOV 1999

Page 2 of 2

Certificate #: 33666006 R

Dynamic Technology, Inc.

Certificate of Calibration

ACCREDITED CALIBRATION
CERT #: 1022.01

Acct #:	025390
Customer:	National Renewable Energy Laboratory
Shipper #:	No Shipper
Contact:	Arlinda Huskey
PO #:	

Manufacturer:	ACO Pacific
Model:	7012
Serial Number:	17561
Description:	Microphone
ID Number:	00017561

As Received	As Returned	Action Taken
In Tolerance X	In Tolerance X	Full Calibration X
Out of Tolerance	Out of Tolerance	Special Calibration
Malfunctioning	Malfunctioning	Oper. Verification
Operational	Operational	Adjusted
Damaged	N/A	Repaired
N/A		Charted
		Returned As Is

Cal Date:	06/16/2001
Due Date:	06/16/2003
Temperature	70.00 **deg. F**
Humidity:	52.00 **%**
Baro. Press.:	29.00 **in. HgA**
DCN #:	50262
Procedure:	manufacturer's manual
Barcode:	

Incoming Remarks:
w/case.

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Due Date
28655021	Bruel & Kjaer	1051	Sine Generator	09/05/01
29958019	Bruel & Kjaer	5936	Precision Attenuator	12/04/01
29958020	Bruel & Kjaer	5908	Expanded Meter	12/04/01
31263021	Bruel & Kjaer	4160	Standard Reference Microp	03/01/02
31263027	Bruel & Kjaer	WB0736	Actuator Voltage Supply	03/21/02
32086013	Bruel & Kjaer	2673	Microphone Preamplifier	04/26/02

The above identified unit was calibrated in our laboratory at the address shown below.

This unit has been calibrated utilizing standards with a Test Uncertainty Ratio (TUR) of greater than 4:1 at 95% confidence level unless otherwise stated above.
This report shall not be reproduced except in full, without the written approval of Dynamic Technology, Inc. This instrument has been calibrated using references traceable to national or international standards. Dynamic Technology's calibration program is in compliance with ANSI/NCSL Z-540-1, MILSTD-45662A, ISO/IEC Guide 25 and _____. Dynamic Technology warrants all material and labor performed for ninety (90) days unless covered under a separate policy. This report applies only to the item(s) identified above.

Technician Name/Date: Robert Deckman, 6/19/01 Signatory: _____ QA Approved: _____

1200 N. Old US 23, PO Box 559, Hartland, MI 48353-0559 (810) 225-4601 FAX (810) 225-4602

Certificate #: 33666005 R

Dynamic Technology, Inc.

Certificate of Calibration

ACCREDITED CALIBRATION
CERT #: 1022.01

Acct #:	025390	**Manufacturer:**	ACO Pacific
Customer:	National Renewable Energy Laboratory	**Model:**	7012
Shipper #:	No Shipper	**Serial Number:**	19037
Contact:	Arlinda Huskey	**Description:**	Microphone
PO #:		**ID Number:**	00019037

As Received	As Returned	Action Taken	
In Tolerance X	In Tolerance X	Full Calibration X	
Out of Tolerance	Out of Tolerance	Special Calibration	
Malfunctioning	Malfunctioning	Oper. Verification	
Operational	Operational	Adjusted	
Damaged	N/A	Repaired	
N/A		Charted	
		Returned As Is	

Cal Date:	06/16/2001
Due Date:	06/16/2003
Temperature	70.00 **deg. F**
Humidity:	52.00 **%**
Baro. Press.:	29.00 **in. HgA**
DCN #:	50262
Procedure:	manufacturer's manual
Barcode:	

Incoming Remarks:

w/case.

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Due Date
28655021	Bruel & Kjaer	1051	Sine Generator	09/05/01
29958019	Bruel & Kjaer	5936	Precision Attenuator	12/04/01
29958020	Bruel & Kjaer	5908	Expanded Meter	12/04/01
31263021	Bruel & Kjaer	4160	Standard Reference Microp	03/01/02
31263027	Bruel & Kjaer	WB0736	Actuator Voltage Supply	03/21/02
32086013	Bruel & Kjaer	2673	Microphone Preamplifier	04/26/02

The above identified unit was calibrated in our laboratory at the address shown below.

This unit has been calibrated utilizing standards with a Test Uncertainty Ratio (TUR) of greater than 4:1 at 95% confidence level unless otherwise stated above. This report shall not be reproduced except in full, without the written approval of Dynamic Technology, Inc. This instrument has been calibrated using references traceable to national or international standards. Dynamic Technology's calibration program is in compliance with ANSI/NCSL Z-540-1, MILSTD45662A, ISO/IEC Guide 25 and_____. Dynamic Technology warrants all material and labor performed for ninety (90) days unless covered under a separate policy. This report applies only to the item(s) identified above.

Technician Name/Date: Robert Deckman, 6/19/01 Signatory: QA Approved: DTI QA 08

1200 N. Old US 23, PO Box 559, Hartland, MI 48353-0559 (810) 225-4601 FAX (810) 225-4602

Certificate #: 33666001 R

Dynamic Technology, Inc.

Certificate of Calibration

ACCREDITED CALIBRATION CERT #: 1822.01

Acct #:	025390	**Manufacturer:**	ACO Pacific
Customer:	National Renewable Energy Laboratory	**Model:**	7012
Shipper #:	No Shipper	**Serial Number:**	17509
Contact:	Arlinda Huskey	**Description:**	Microphone
PO #:		**ID Number:**	00017509

As Received	As Returned	Action Taken	
In Tolerance X	In Tolerance X	Full Calibration X	**Cal Date:** 06/16/2001
Out of Tolerance	Out of Tolerance	Special Calibration	**Due Date:** 06/16/2003
Malfunctioning	Malfunctioning	Oper. Verification	**Temperature** 70.00 **deg. F**
Operational	Operational	Adjusted	**Humidity:** 52.00 **%**
Damaged	N/A	Repaired	**Baro. Press.:** 29.00 **in. HgA**
N/A		Cleaned	**DCN #:** 50262
		Returned As Is	**Procedure:** manufacturer's manual
			Barcode:

Incoming Remarks:

wscans.

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Due Date
28655021	Bruel & Kjaer	1051	Sine Generator	09/05/01
29058019	Bruel & Kjaer	5936	Precision Attenuator	12/04/01
29058020	Bruel & Kjaer	5908	Expanded Meter	12/04/01
31263021	Bruel & Kjaer	4160	Standard Reference Microp	03/01/02
31263027	Bruel & Kjaer	WB0736	Actuator Voltage Supply	03/21/02
32086013	Bruel & Kjaer	2673	Microphone Preamplifier	04/26/02

The above identified unit was calibrated in our laboratory at the address shown below.

This unit has been calibrated utilizing standards with a Test Uncertainty Ratio (TUR) of greater than 4:1 at 95% confidence level unless otherwise stated above. This report shall not be reproduced except in full, without the written approval of Dynamic Technology, Inc. This instrument has been calibrated using references traceable to national or international standards. Dynamic Technology's calibration program is in compliance with ANSI/NCSL Z-540-1, MIL-STD-45662A, ISO/IEC Guide 25 and _____. Dynamic Technology warrants all material and labor performed for ninety (90) days unless covered under a separate policy. This report applies only to the item(s) identified above.

Technician Name/Date: Robert Deckman, 6/19/01 Signatory: _____ QA Approval: _____

1200 N. Old US 23, PO Box 559, Hartland, MI 48353-0559 (810) 225-4601 FAX (810) 225-4602

CERTIFICATE OF CONFORMANCE
8635-4
FOR ACO PACIFIC MICROPHONE PREAMPLIFIER

Model **4012** Serial No. **XX9903**
ID No. **N/A**

Customer: **Instrument Repair Labs, Inc.**
Broomfield, CO 80020

PO **# 017135**

was tested and met factory specifications
according to the Referenced Test Procedure

on **17 May, 2000** **BY** **HAROLD LYNCH**
Service Manager

As received condition: Within Specification.
Re-calibration due on: **17 May, 2002**

Certified References*

Mfg.	Type	Serial No.	Date Due
HP	3458A	2823A07179	13 JUL 2000
B&K	111284	4	17 APR 2001
B&K	4134	1456123	10 SEP 2000

Performed in Compliance with ANSI, NCSL Z-540-1 (which also covers MIL STD 45662A)
*References are traceable to NIST (National Institute of Standards and Technology).

Odin Metrology, Inc. Reference Test Procedure: **ACO Pacific Microphone Preamplifier 4012**

Temperature	Relative Humidity	Barometric Pressure
23° C	**49** %	**989.69** hPa

Signed: Harold Lynch

ODIN METROLOGY, INC.
CALIBRATION OF BRÜEL & KJÆR INSTRUMENTS
3533 OLD CONEJO ROAD; SUITE 125 THOUSAND OAKS CA 91320
PHONE: (805) 375-0830 FAX: (805) 375-0405

CERTIFICATE OF CONFORMANCE
8635-2
FOR ACO PACIFIC MICROPHONE PREAMPLIFIER

Model **4012** Serial No. **L79900503**
ID No. **N/A**

Customer: **Instrument Repair Labs, Inc.**
Broomfield, CO 80020

PO # **017135**

was tested and met factory specifications
according to the Referenced Test Procedure

on **17 May, 2000** **BY** **HAROLD LYNCH**
Service Manager

As received condition: Within Specification.
Re-calibration due on: **17 May, 2002**

Certified References*

Mfg.	Type	Serial No.	Date Due
HP	3458A	2823A07179	13 JUL 2000
B&K	111284	4	17 APR 2001
B&K	4134	1456123	10 SEP 2000

Performed in Compliance with ANSI, NCSL Z-540-1 (which also covers MIL STD 45662A)
*References are traceable to NIST (National Institute of Standards and Technology).

Odin Metrology, Inc. Reference Test Procedure: **ACO Pacific Microphone Preamplifier 4012**

Temperature	Relative Humidity	Barometric Pressure
23° C	**49** %	**989.69** hPa

Signed: Harold Lynch

ODIN METROLOGY, INC.
CALIBRATION OF BRÜEL & KJÆR INSTRUMENTS
3533 OLD CONEJO ROAD; SUITE 125 THOUSAND OAKS CA 91320
PHONE: (805) 375-0830 FAX: (805) 375-0405

CERTIFICATE OF CONFORMANCE
8635-3
FOR ACO PACIFIC MICROPHONE PREAMPLIFIER

Model **4012** Serial No. **960032**
ID No. **N/A**

Customer: **Instrument Repair Labs, Inc.**
Broomfield, CO 80020
PO # **017135**

was tested and met factory specifications
according to the Referenced Test Procedure

on **17 May, 2000** **BY** **HAROLD LYNCH**
Service Manager

As received condition: Within Specification.
Re-calibration due on: **17 May, 2002**

Certified References*

Mfg.	Type	Serial No.	Date Due
HP	3458A	2823A07179	13 JUL 2000
B&K	111284	4	17 APR 2001
B&K	4134	1456123	10 SEP 2000

Performed in Compliance with ANSI, NCSL Z-540-1 (which also covers MIL STD 45662A)
*References are traceable to NIST (National Institute of Standards and Technology).

Odin Metrology, Inc. Reference Test Procedure: **ACO Pacific Microphone Preamplifier 4012**

Temperature	Relative Humidity	Barometric Pressure
23° C	**49** %	**989.69** hPa

Signed: Harold Lynch

ODIN METROLOGY, INC.
CALIBRATION OF BRÜEL & KJÆR INSTRUMENTS
3533 OLD CONEJO ROAD; SUITE 125 THOUSAND OAKS CA 91320
PHONE: (805) 375-0830 FAX: (805) 375-0405

CERTIFICATE OF CONFORMANCE
8635-1
FOR ACO PACIFIC MICROPHONE PREAMPLIFIER

Model **4012**

Serial No. **96050**
ID No. **N/A**

Customer: **Instrument Repair Labs, Inc.**
Broomfield, CO 80020

PO # **017135**

was tested and met factory specifications
according to the Referenced Test Procedure

on **17 May, 2000** **BY** **HAROLD LYNCH**
Service Manager

As received condition: Within Specification.
Re-calibration due on: **17 May, 2002**

Certified References*

Mfg.	Type	Serial No.	Date Due
HP	3458A	2823A07179	13 JUL 2000
B&K	111284	4	17 APR 2001
B&K	4134	1456123	10 SEP 2000

Performed in Compliance with ANSI, NCSL Z-540-1 (which also covers MIL STD 45662A)
*References are traceable to NIST (National Institute of Standards and Technology).

Odin Metrology, Inc. Reference Test Procedure: **ACO Pacific Microphone Preamplifier 4012**

Temperature	Relative Humidity	Barometric Pressure
23° C	**49** %	**989.69** hPa

Signed: Harold Lynch

ODIN METROLOGY, INC.
CALIBRATION OF BRÜEL & KJÆR INSTRUMENTS
3533 OLD CONEJO ROAD; SUITE 125 THOUSAND OAKS CA 91320
PHONE: (805) 375-0830 FAX: (805) 375-0405

CERTIFICATE OF CONFORMANCE
8635-2
FOR ACO PACIFIC MICROPHONE PREAMPLIFIER

Model **4012** Serial No. **L79900503**
ID No. **N/A**

Customer: **Instrument Repair Labs, Inc.**
Broomfield, CO 80020

PO # **017135**

was tested and met factory specifications
according to the Referenced Test Procedure

on **17 May, 2000** **BY** **HAROLD LYNCH**
Service Manager

As received condition: Within Specification.
Re-calibration due on: **17 May, 2002**

Certified References*

Mfg.	Type	Serial No.	Date Due
HP	3458A	2823A07179	13 JUL 2000
B&K	111284	4	17 APR 2001
B&K	4134	1456123	10 SEP 2000

Performed in Compliance with ANSI, NCSL Z-540-1 (which also covers MIL STD 45662A)
*References are traceable to NIST (National Institute of Standards and Technology).

Odin Metrology, Inc. Reference Test Procedure: **ACO Pacific Microphone Preamplifier 4012**

Temperature	Relative Humidity	Barometric Pressure
23° C	**49 %**	**989.69** hPa

Signed: Harold Lynch

ODIN METROLOGY, INC.
CALIBRATION OF BRÜEL & KJÆR INSTRUMENTS
3533 OLD CONEJO ROAD; SUITE 125 THOUSAND OAKS CA 91320
PHONE: (805) 375-0830 FAX: (805) 375-0405

Certificate #: 33666011 R

Dynamic Technology, Inc.

Certificate of Calibration

ACCREDITED CALIBRATION
CERT #: 1022.01

Acct #:	025390
Customer:	National Renewable Energy Laboratory
Shipper #:	No Shipper
Contact:	Arlinda Huskey
PO #:	

Manufacturer:	ACO Pacific
Model:	4012
Serial Number:	L79900504
Description:	Microphone Preamplifier
ID Number:	79900504

As Received	As Returned	Action Taken	
In Tolerance X	In Tolerance X	Full Calibration X	**Cal Date:** 06/18/2001
Out of Tolerance	Out of Tolerance	Special Calibration	**Due Date:** 06/18/2003
Malfunctioning	Malfunctioning	Oper. Verification	**Temperature** 70.00 **deg. F**
Operational	Operational	Adjusted	**Humidity:** 50.00 **%**
Damaged	N/A	Repaired	**Baro. Press.:** 29.00 **in. HgA**
N/A		Charted	**DCN #:** 03633
		Returned As Is	**Procedure:** local procedure
			Barcode:

Incoming Remarks:

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Due Date
28655021	Bruel & Kjaer	1051	Sine Generator	09/05/01
33297017	Bruel & Kjaer	2636	Measuring Amplifier	06/15/02

The above identified unit was calibrated in our laboratory at the address shown below.

This unit has been calibrated utilizing standards with a Test Uncertainty Ratio (TUR) of greater than 4:1 at 95% confidence level unless otherwise stated above. This report shall not be reproduced except in full, without the written approval of Dynamic Technology, Inc. This instrument has been calibrated using references traceable to national or international standards. Dynamic Technology's calibration program is in compliance with ANSI/NCSL Z-540-1, MILSTD-45662A, ISO/IEC Guide 25 and_____. Dynamic Technology warrants all material and labor performed for ninety (90) days unless covered under a separate policy. This report applies only to the item(s) identified above.

Technician Name/Date: Robert Deckman, 6/19/01 Signatory: _____ QA Approved: DTI QA 09

1200 N. Old US 23, PO Box 559, Hartland, MI 48353-0559 (810) 225-4601 FAX (810) 225-4602

Certificate #: 33666009 R

Dynamic Technology, Inc.

Certificate of Calibration

ACCREDITED CALIBRATION
CERT #: 1022.01

Acct #:	025390
Customer:	National Renewable Energy Laboratory
Shipper #:	No Shipper
Contact:	Arlinda Huskey
PO #:	

Manufacturer:	ACO Pacific
Model:	4012
Serial Number:	960032
Description:	Microphone Preamplifier
ID Number:	00960032

As Received	As Returned	Action Taken
In Tolerance X	In Tolerance X	Full Calibration X
Out of Tolerance	Out of Tolerance	Special Calibration
Malfunctioning	Malfunctioning	Oper. Verification
Operational	Operational	Adjusted
Damaged	N/A	Repaired
N/A		Charted
		Returned As Is

Cal Date:	06/18/2001
Due Date:	06/18/2003
Temperature	70.00 **deg. F**
Humidity:	50.00 **%**
Baro. Press.:	29.00 **in. HgA**
DCN #:	03633
Procedure:	local procedure
Barcode:	

Incoming Remarks:

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Due Date
28655021	Bruel & Kjaer	1051	Sine Generator	09/05/01
33297017	Bruel & Kjaer	2636	Measuring Amplifier	06/15/02

The above identified unit was calibrated in our laboratory at the address shown below.

This unit has been calibrated utilizing standards with a Test Uncertainty Ratio (TUR) of greater than 4:1 at 95% confidence level unless otherwise stated above.
This report shall not be reproduced except in full, without the written approval of Dynamic Technology, Inc. This instrument has been calibrated using references traceable to national or international standards. Dynamic Technology's calibration program is in compliance with ANSI/NCSL Z-540-1, MILSTD45662A, ISO/IEC Guide 25 and _____. Dynamic Technology warrants all material and labor performed for ninety (90) days unless covered under a separate policy. This report applies only to the item(s) identified above.

Technician Name/Date: Robert Deckman, 6/19/01 Signatory: _____ QA Approved: _____

1200 N. Old US 23, PO Box 559, Hartland, MI 48353-0559 (810) 225-4601 FAX (810) 225-4602

Certificate #: 33666007 R

Dynamic Technology, Inc.

Certificate of Calibration

ACCREDITED CALIBRATION
CERT #: 1022.01

Acct #:	025390
Customer:	National Renewable Energy Laboratory
Shipper #:	No Shipper
Contact:	Arlinda Huskey
PO #:	

Manufacturer:	ACO Pacific
Model:	4012
Serial Number:	6009
Description:	Microphone Preamplifier
ID Number:	00006009

As Received	As Returned	Action Taken
In Tolerance X	In Tolerance X	Full Calibration X
Out of Tolerance	Out of Tolerance	Special Calibration
Malfunctioning	Malfunctioning	Oper. Verification
Operational	Operational	Adjusted
Damaged	N/A	Repaired
N/A		Charted
		Returned As Is

Cal Date:	06/18/2001
Due Date:	06/18/2003
Temperature	70.00 **deg. F**
Humidity:	50.00 **%**
Baro. Press.:	29.00 **in. HgA**
DCN #:	03633
Procedure:	local procedure
Barcode:	

Incoming Remarks:

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Due Date
28655021	Bruel & Kjaer	1051	Sine Generator	09/05/01
33297017	Bruel & Kjaer	2636	Measuring Amplifier	06/15/02

The above identified unit was calibrated in our laboratory at the address shown below.

This unit has been calibrated utilizing standards with a Test Uncertainty Ratio (TUR) of greater than 4:1 at 95% confidence level unless otherwise stated above. This report shall not be reproduced except in full, without the written approval of Dynamic Technology, Inc. This instrument has been calibrated using references traceable to national or international standards. Dynamic Technology's calibration program is in compliance with ANSI/NCSL Z-540-1, MILSTD45662A, ISO/IEC Guide 25 and _____. Dynamic Technology warrants all material and labor performed for ninety (90) days unless covered under a separate policy. This report applies only to the item(s) identified above.

Technician Name/Date: Robert Deckman, 6/19/01 Signatory: _____ QA Approved: _____

1200 N. Old US 23, PO Box 559, Hartland, MI 48353-0559 (810) 225-4601 FAX (810) 225-4602

ISO 9002
FS 23253

HEWLETT PACKARD

Certificate Of Calibration

Model No:	35670A
Serial No:	3431A01613
Description:	DYNAMIC SIGNAL ANALYZER
Customer Name:	NATIONAL RENEWABLE ENERGY LABORATORY
Customer P.O. No:	VISA/ARLINDA HUSKEY
Agreement No:	
Certificate No:	2452K947701
Customer ID No:	123502

At the time of calibration, this certifies that the above product was calibrated in accordance with applicable Hewlett-Packard procedures.

At planned intervals, Hewlett-Packard measurement standards are calibrated by comparison to or measurement against national standards, natural physical constants, consensus standards, or by ratio type measurements using self-calibrating techniques.

National Standards are administered by NIST (National Institute of Standards and Technology) or other recognized national standards laboratories.

Initial testing found your instrument was IN-SPECIFICATION. No adjustment was necessary to ensure performance to published operating specifications where tested.

Supporting documentation relative to traceability is on file and is available for examination upon request.

The calibration interval for this unit is 12 months and the calibration due date based on this interval is 14-Aug-1999.

Temperature: 21.6 °C **Relative Humidity:** 40 %

Remarks or special requirements:

STE 9000 TEST PROGRAM HP35670A/REV.A.00.03.

Calibration Date: 14-Aug-1998

Dave McCarthy, Quality Manager

U.S. Test & Measurement Service Centers • Englewood Branch
24 Inverness Place East • Englewood, CO 80112 ph. (800 403 0801)

1 of 2

ISO 9002
FS 23253

HEWLETT PACKARD

Certificate Of Calibration

Model No: 35670A
Serial No: 3431A01613
Description: DYNAMIC SIGNAL ANALYZER
Customer Name: NATIONAL RENEWABLE ENERGY LABORATORY
Customer P.O. No: VISA/ARLINDA HUSKEY
Agreement No:
Certificate No: 2452K947701
Customer ID No: 123502

Calibration Equipment Used:

Model Number	Model Description	Trace Number	Cal Due Date
FLU5700A	AC DC CALIBRATOR	5700A15016	05-Mar-1999
3325A	SYNTHESIZER/FUNCTION GENERATOR	3325A01121	01-Apr-1999
3325B	SYNTHESIZER/FUNCTION GENERATOR	3325B01972	27-Sep-1998
3458A	SYSTEM MULTIMETER	3458A01113	25-Sep-1998

U.S. Test & Measurement Service Centers • Englewood Branch
24 Inverness Place East • Englewood, CO 80112 ph. (800 403 0801)

2 of 2

Agilent Technologies	U.S. Test & Measurement Service Centers Mountain View Branch 301 East Evelyn Avenue Mountain View CA 94041 (800) 403-0801	AGILENT TECHNOLOGIES INTERNAL ASSESSMENT PROGRAM : TMO-Q-07/95

Certificate of Calibration

ANSI/NCSL Z540-1-1994

Certificate No.: 2452N063501

Manufacturer:	Agilent Technologies / HP	**Description:**	DYNAMIC SIGNAL ANALYZER
Model No:	35670A	**Options installed:**	
Serial No:	3431A01613	**Customer asset No.:**	
Customer:		**Location of calibration:**	
	NATIONAL RENEWABLE ENERGY LABORATORY		U.S. Test & Measurement Service Centers Mountain View Branch 301 East Evelyn Avenue Mountain View CA 94041 (800) 403-0801

Customer PO No.:	VISA/ ARLINDA HUSKEY	**Agreement No.:**	
Date of calibration:	8 Aug 2001	**Received date:**	6 Aug 2001
Temperature:	18-28 °C	**Humidity:**	20-80 %RH
Procedure:	STE-5011-1014-A.00.06		

This certifies that the above product was calibrated in compliance with ANSI/NCSL Z540-1-1994 and a quality system registered to ISO9002:1994 using applicable Agilent Technologies procedures.

As received conditions: Initial testing found the equipment to be **IN-SPECIFICATION** at the points tested.

As shipped conditions: At the completion of the calibration, measured values were **IN-SPECIFICATION** at the points tested.

Remarks or special requirements:

Our calibration procedures are designed to provide measurement uncertainty of less than or equal to one quarter of the specification of the unit under test, where possible, with a coverage factor of 2.

The test limits stated in the report correspond to the published specifications of the equipment, at the points tested.

This certificate is composed of 2 pages containing a summary of calibration information.

Based on the recommended calibration interval, the next calibration is due on 8 Aug 2002.

Terron Beaulieu

Issue date: 9 Aug 2001

Terron Beaulieu Americas Delivery Mgr.

version 06-22-01

Agilent Technologies	U.S. Test & Measurement Service Centers Mountain View Branch 301 East Evelyn Avenue Mountain View CA 94041 (800) 403-0801	AGILENT TECHNOLOGIES INTERNAL ASSESSMENT PROGRAM : TMO-Q-07/95

Certificate of Calibration

ANSI/NCSL Z540-1-1994

Certificate No.: 2452N063501

Traceability information:

Technician ID number: 800225

Traceability is to national standards administered by the U.S. NIST, NRC Canada, Eurotest members (NPL, PTB, BNM, etc.) or other recognized standards laboratories.

Some measurements are traceable to natural physical constants, consensus standards or ratio type measurements.

Supporting documentation relative to traceability is available for review by appointment.

Calibration equipment used:

Model number:	Model description:	Trace number:	Cal due date:	Certificate number:
DTN4708	CALIBRATOR	470894091	23 Feb 2002	2451J877301
3325A	SYNTHESIZER/FUNCTION GENERATOR	3122	28 Nov 2001	2451H969201
3325A	SYNTHESIZER/FUNCTION GENERATOR	E90925	11 Nov 2001	2451H581401
3325B	SYNTHESIZER/FUNCTION GENERATOR	A50315	20 Oct 2001	2451J149401
339A	DISTORTION MEASUREMENT SET	3221	11 Dec 2002	2451K005901
3458A	SYSTEM MULTIMETER	A50313	24 Oct 2001	2451J205001

CERTIFICATE OF CALIBRATION

FOR BRÜEL & KJÆR

Sound Level Calibrator Type 4230

The Sound Pressure Level has been measured by comparison with Standard Reference Pistonphone.

Type: **4220** serial number **1476021**
and
Type: **4220** serial number **1510240**

Calibrated by: **TS** (BRÜEL & KJÆR)
Date of Calibration: **18 AUG 1999**
Re-calibration Due: **18 AUG 2000**

UNCERTAINTY OF MEASUREMENT:
A: Estimated Uncertainty of comparison:+/-0.09dB at 99% Confidence Level
B: Estimated Uncertainty of Ref. 4220: +/-0.10 dB at 99% Confidence Level
C: Total Uncertainty 0.13 dB (calculated as the square root of the summed squares of A and B) at 99% Confidence Level

The calibrator type **4230**
Serial No. **830235**
ID No. N/A

has been found to be within the **specifications** listed below.

Sound Pressure Level produced in the coupler terminated by a loading volume of 1.333 cm^3:
94.0 ± 0.3 dB
Frequency: **1000 ± 15 Hz**
Distortion: **< 1%**
Equivalent Coupler Volume: V > **140 cm^3**

ENVIRONMENTAL CONDITIONS:

Ambient Pressure	**988.68** hPa
Temperature	**23°** C
Relative Humidity	**48** %
Date of Calibration	**15 MAY 2000**
Re-calibration due on	**15 MAY 2001**

Calibration procedure: Brüel & Kjær 4230, Rev. 18 NOV 1999

Certificate No.: **8635-11** PO# **017135**
For: **Instrument Repair Labs, Broomfield, CO 80020**

PERFORMANCE AS RECEIVED:

Frequency	1006.4	Hz
SPL	94.04	dB
Volume Check	+0.80	dB
Distortion	0.3	%
Battery Voltage	8.8	VOLT

Was frequency and SPL adjusted for improvement? No!
Was battery replaced with new alkaline type? Yes!

FINAL PERFORMANCE:

Frequency	1006.4	Hz
SPL	94.04	dB
Volume Check	+0.03	dB
Distortion	0.3	%

Note: This calibrator was within Mfg. specifications as received.

Performed on a test system which operates in compliance with ANSI/ NCSL Z540-1. Reference standards: pistonphones calibrated traceable to NIST with, NIST test no.822/259793-98.
Signed:

Torben Ehlert, Quality Assurance Manager

ODIN METROLOGY, Inc.
CALIBRATION OF BRÜEL & KJÆR INSTRUMENTS
3533 OLD CONEJO ROAD, SUITE # 125
THOUSAND OAKS, CA 91320
PHONE: (805) 375-0830 FAX: (805) 375-0405

INSTRUMENTATION USED FOR CALIBRATION OF PISTONPHONES AND CALIBRATORS

ODIN METROLOGY, INC.

INSTRUMENTATION USED FOR THE CALIBRATION PAGE 1 OF THIS DOCUMENT

CALIBRATION SYSTEM	TYPE NO.	SERIAL NO.	CAL. DATE	DUE	CAL. BY:
Precision Barometer	Druck 141	259/95-10	18 NOV 99	18 NOV 00	Schwien
Expanded Meter	111283	4	23 AUG 99	23 AUG 00	TE
Measuring Amplifier	2636	1423390	09 AUG 99	09 AUG 00	HL
Measuring Amplifier	2608	523319	01 JUN 99	01 JUN 00	HL
Precision Attenuator	WB 0566	04	17 AUG 99	17 AUG 00	TS
Transducer Assembly	9545	08	17 AUG 99	17 AUG 00	TS
Band Pass Filter	1618	996538	29 JUL 99	29 JUL 00	HL
Pistonphone	4220	1476021	18 AUG 99	18 AUG 00	TS
Pistonphone	4220	1510240	18 AUG 99	18 AUG 00	TS
Multimeter	HP 3458A	2823A17713	11 AUG 99	11 AUG 00	HP
Universal Counter	HP 53131A	KR91200922	08 MAY 99	08 MAY 00	HP

REMARKS:

Calibration of reference microphones 4160 serial numbers 991820,991821,1054926, and standard pistonphones 4220 serial numbers 1048473,1048795,1510240,375837,1476021, and 4228 01793011 are calibrated traceable to NIST Test number : **822/259792-98.**

NOTE: The verification/calibration listed on page 1 of this document was performed on a test system which conforms to and operates under the requirements of **ANSI/NCSL Z540-1** which also covers the requirements for **MIL STD 45662A.**

Revised: 18 NOV 1999

Page 2 of 2

Certificate #: 37319001 R

Dynamic Technology, Inc.

Certificate of Calibration

ACCREDITED CALIBRATION
CERT # 1023.01

Acct #:	025390
Customer:	National Renewable Energy Laboratory
Shipper #:	
Contact:	Arlinda Huskey
PO #:	

Manufacturer:	Bruel & Kjaer
Model:	4230
Serial Number:	861619
Description:	Sound Level Calibrator
ID Number:	861619

As Received	As Returned	Action Taken
In Tolerance X	In Tolerance X	Full Calibration X
Out of Tolerance	Out of Tolerance	Special Calibration
Malfunctioning	Malfunctioning	Oper. Verification
Operational	Operational	Adjusted
Damaged	N/A	Repaired
N/A		Charted
		Returned As Is

Cal Date:	10/22/2001
Due Date:	10/22/2003
Temperature	70.00 **deg. F**
Humidity:	30.00 **%**
Baro. Press.:	28.93 **in. HgA**
DCN #:	00311
Procedure:	manufacturer's manual
Barcode:	41564

Incoming Remarks:

release

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
264800	Mensor	11900-402	Digital Pressure Gauge	04/27/00	04/27/02
29958019	Bruel & Kjaer	5936	Precision Attenuator	12/04/00	12/04/01
29958020	Bruel & Kjaer	5908	Expanded Meter	12/04/00	12/04/01
30851017	Bruel & Kjaer	1617	Band Pass Filter	02/26/01	02/26/02
32086018	Bruel & Kjaer	4228	Pistonphone	04/24/01	04/24/02
33297017	Bruel & Kjaer	2636	Measuring Amplifier	06/15/01	06/15/02
33635003	Bruel & Kjaer	9545	Preamplifier Kit	07/27/01	07/27/02
34597006	Keithley	2001	DMM	10/03/01	10/03/02

The above identified unit was calibrated in our laboratory at the address shown below.

This unit has been calibrated utilizing standards with a Test Uncertainty Ratio (TUR) of greater than 4:1 at 95% confidence level unless otherwise stated above. This report shall not be reproduced except in full, without the written approval of Dynamic Technology, Inc. This instrument has been calibrated using references traceable to national or international standards. Dynamic Technology's calibration program is in compliance with ANSI/NCSL Z-540-1, MIL-STD-45662A, ISO/IEC Guide 25, QS-9000 Rev Oct. 00, and _____. Dynamic Technology warrants all material and labor performed for ninety (90) days unless covered under a separate policy. This report applies only to the item(s) identified above.

Technician Name/Date: David Walworth, 10/24/01 Signature: _____ QA Approved: _____

1200 N. Old US 23, PO Box 559, Hartland, MI 48353-0559 (810) 225-4601 FAX (810) 225-4602

Dynamic Technology, Inc.

Report Number: 37319001

Report of Calibration

Manufacturer: Bruel & Kjaer
Model: 4230
Description: Sound Level Calibrator
Serial Number: 861619

Account Number: 025390
Technician: D. Walworth

Parameter	Range	Tolerance	Applied	Low Limit	As Found	High Limit	As Left
Calibration Accuracy	94.0 dB	94.0 dB ± 0.3 dB	N/A	93.7 dB	94.00 dB	94.3 dB	94.00 dB
Freq Accuracy	1000 Hz	1 kHz ± 1.5%	N/A	985 Hz	996.8 Hz	1015 Hz	996.8 Hz
Total Harmonic Distortion	N/A	<1%	N/A	N/A	0.33%	1%	0.33%

Form# 4230 AUG00 1200 N. Old US 23, Hartland, MI 48353 Ph 810-225-4601 Fax 810-225-4602

Sony Precision Technology America, Inc.

137 West Bristol Lane, Orange, CA 92865
Telephone: (714) 921-0630
Fax: (714) 921-1162

Certificate of Calibration

Customer Name: National Renewable Energy Laboratory Date: August 25, 1998

Instrument Information

Model No.	PC208Ax	Report No.	145401-1
Serial No.	U3538	Cust. P.O.	VISA Card
Asset No.	124037	Date Recvd.	08/18/98
Date Cal.	08/24/98	Accuracy:	Mfr. Specs.
Date Due:	08/24/99	Maint. Prco:	1341
Interval:	12	Temperature:	23
Description:	Data Recorder	Humidity:	47

Condition Instrument Received / Returned

Condition Received: In Tolerance
Remarks:

Condition Returned: In Tolerance
Remarks: Calibrated

Standards Used

ID #	Manufacturer	Model No.	Accuracy	Description	Due Date
569	Hewlett Packard	3325A	Mfr. Specs	Sweep Generator	11/14/98
533	Keithley	2000	Mfr. Specs	6 1/2 Digit DMM	03/20/99
616	Fluke	5500A/SC	Mfr. Specs	Multi Calibrator	10/14/98
643	Bruel & Kjaer	2032	Mfr. Specs	FFT Signal Analyzer	02/11/99
595	Hewlett Packard	8903B	Mfr. Specs	Audio Analyzer	06/17/99

Sony Precision Technology America, Inc. certifies that the instrument specified above meets the manufacture's specifications and has been calibrated using standards and instruments also listed above whose accuracy's are traceable to the National Institute of Standards and Technology (N.I.S.T.), and the calibration systems and records are in compliance to ISO-10012 and ANSI Z540-1. This document cannot be reproduced without prior approval.

Approved by: 8/25/98

SONY

Excalibur Engineering
11 Musick
Irvine, CA 92618
Phone : (949) 454-6603
Fax : (949) 454-6642

Certificate Of Calibration

Customer	SONY PRECISION TECHNOLOGY AMERICA, INC.	**Dept.**	NONE
Report #	25221-1	**Bar Code #**	
Date Received	THURSDAY, FEBRUARY 21, 2002	**P.O. #**	2027
Manufacturer	SONY	**Serial #**	U3538
Model #	PC208AX	**Asset #**	124037
Description	DATA RECORDER		

Calibration Information

Date Calibrated 2/22/2002 **Calibration Due Date** 2/22/2003 **Calibration Interval** 12

Maintenance Procedure 1341

Temperature 22 ° C **Humidity** 27 % **Calibration Performed By** 28

Accuracy ± 0.02% IV

Condition Received

Received In Tolerance

Remarks

Condition Returned

Returned In Tolerance

Remarks

Standards Employed

ID #	Manufacturer	Model #	Description	Calibration Expires
941	BRUEL & KJAER	1049	SINE & NOISE GENERATOR	07/06/2002
726	BRUEL & KJAER	2034	FFT ANALYZER	06/29/2002
923	BRUEL & KJAER	2706	POWER AMPLIFIER	03/14/2002
938	HEWLETT PACKARD	8903B	AUDIO ANALYZER	06/13/2002
713	FLUKE	8920A	TRUE RMS VOLTMETER	05/25/2002
876	FLUKE	5720A-03	CALIBRATOR	06/23/2002
933	HEWLETT PACKARD	3458A/002	8.5 DIGIT DMM	04/30/2002

Traceability Numbers

DC 105016,NAVLAP
AC 105016,NAVLAP
OHMS 105016,NAVLAP

Excalibur Engineering, Inc. certifies that the instrument specified above meets the manufacturer's specifications and has been calibrated using standards and instruments also listed above whose accuracies are traceable to the National Institute of Standards and Technology (NIST), and the calibration systems and records are in compliance to ISO-10012 and ANSI Z540-1-1994.

EEQA 4

FEB 2 5 2002

Approved By

Page #: 1

Deutsches Windenergie - Institut

GmbH
Ebertstr. 96
D-26382 Wilhelmshaven
Tel. 49 4421 48080
Fax. 49 4421 4808 43

Test laboratory according to DIN EN 45.001
accredited by the DAP
Deutsches Akkreditierungssystem
Prüfwesen GmbH

DAP-P-02.394-00-92-01

Member of MEASNET
International Network for Harmonised and
Recognised Measurements in Wind Energy

DEWI Anemometer Calibration

Calibration No.	**1103_00**
Object	**Cup Anemometer**
Manufacturer	**Met One Instruments USA**
Type	**010C-1**
Serial number	**Y4397**
Cup number	**Y4397**
Customer	**NREL Golden, Colorado**
Date	**12/14/00**
Remarks	**no**

This calibration certificate documents that the measured physical values frequency, voltage, air pressure, air temperature and difference pressure in the airflow are traceable to national standards.
The determination of the wind velocity follows to ISO 3966 1977 *Measurement of fluid flow in closed conduits [2]* and *MEASNET Cup Anemometer Calibration Procedure [1]*.

The presented results are valid only for the described anemometer and the measuring conditions.

This calibration report includes 3 pages (plus appendix). It is not permitted to publish this document partly without permission of DEWI. The test result documented in this report relates only to the item tested. The user has to recalibrate the anemometer at appropriate intervals.

Wilhelmshaven, 14.12.2000

i.V. Dipl. Phys. D. Westermann

i.A. Dipl. Ing. K. Junior

DEWI Calibration No. 1103_00

Deutsches Windenergie - Institut
GmbH
Ebertstr. 96
D-26382 Wilhelmshaven
Tel. 49 4421 48080
Fax. 49 4421 4808 43

Test laboratory according to DIN EN 45.001
accredited by the DAP
Deutsches Akkreditierungssystem
Prüfwesen GmbH

DPT-PL-2394.00

Member of MEASNET
International Network for Harmonised and
Recognised Measurements in Wind Energy

DEWI Anemometer Calibration

Calibration No.	**76_02**
Object	**Cup Anemometer**
Manufacturer	**Met One Instruments USA**
Type	**010C-1**
Serial number	**T2345**
Cup number	**T2345**
Customer	**NREL USA-Golden,Colorado**
Date	**01/18/02**
Remarks	**no**

This calibration certificate documents that the measured physical values frequency, voltage, air pressure, air temperature and difference pressure in the airflow are traceable to national standards.
The determination of the wind velocity follows to ISO 3966 1977 *Measurement of fluid flow in closed conduits [2]* and *MEASNET Cup Anemometer Calibration Procedure [1].*

The presented results are valid only for the described anemometer and the measuring conditions.

This calibration report includes 3 pages (plus appendix). It is not permitted to publish this document partly without permission of DEWI. The test result documented in this report relates only to the item tested. The user has to recalibrate the anemometer at appropriate intervals.

Wilhelmshaven, 20.01.2002

i.V. Dipl. Phys. D. Westermann

i.A. Dipl.-Ing. P.Busche

DEWI Calibration No. 76_02

Wind Vane Calibration Report

Calibration Laboratory:
National Wind Technology Center - Cert. Team
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401

Customer:
National Wind Technology Center - Certification Team
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401

Calibration Location:
National Wind Technology Center
Room 123, Industrial Users Facility

Calibration Date: **14-Jun-00**

Report Number: U1477-000614

Procedure:
NWTC-CT: GI24-000613, Wind Vane Calibration

Page: 1 of 1

Deviations from procedure: None

Item Calibrated:

Manufacturer	Met One Instruments, Inc
Model	020C
Serial Number	**U1477**
Vane Material	Aluminum
Condition	Refurbished

Results:

Slope:	**0.1424**	deg/mv
Offset to boom:	**89.7**	deg
Max error:	0.2	deg

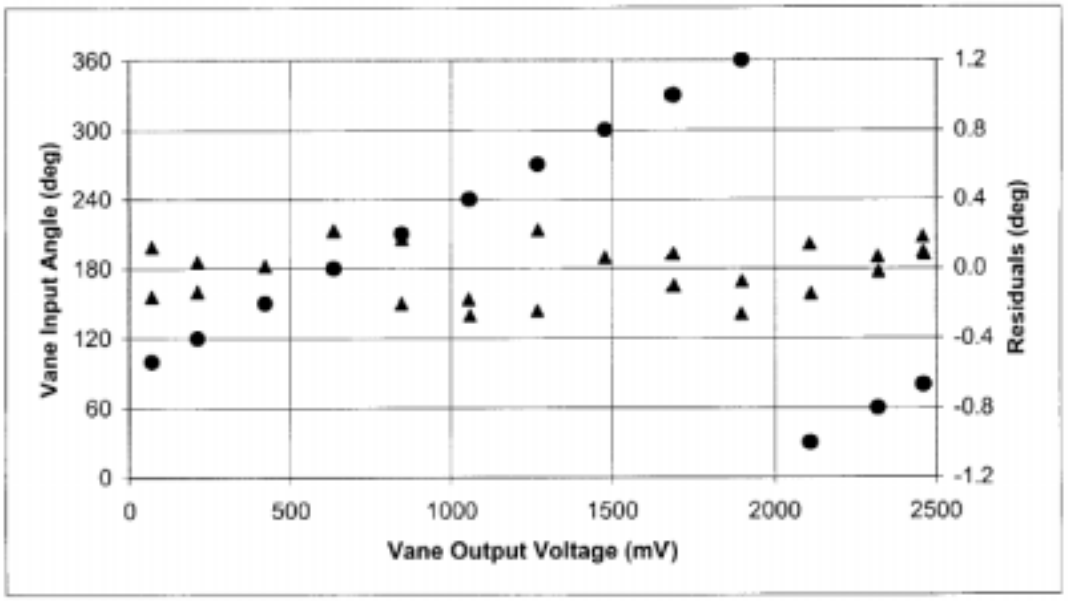
Estimated Uncertainty:

Inclinometer Uncertainty (deg)	Total Uncertainty (deg)
0.10	0.27

Traceability:

	Mfg & Model	Serial Number	Cal Date
Inclinometer	Lucas DP45	82860032	20-Jan-00
Voltmeter:	CR10X	X08210	25-Feb-00

Calibration by: Mark Meadors — Date: 6/14/00



Wind Vane Calibration Report

Calibration Laboratory:
National Wind Technology Center - Cert. Team
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401

Customer:
National Wind Technology Center - Certification Team
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401

Calibration Location:
National Wind Technology Center
Room 129, Industrial Users Facility

Calibration Date: **28 Jan, 2002**

Report Number: T1010-28 Jan, 2002

Procedure:
NWTC-CT: GI24-000613, Wind Vane Calibration

Page: 1 of 1

Deviations from procedure: None

Item Calibrated:

Manufacturer	Met One Instruments, Inc
Model	020C
Serial Number	**T1010**
Vane Material	Aluminum
Condition	Refurbished

Results:

Slope:	**0.1428**	**deg/mv**
Offset to boom:	**91.9**	**deg**
Max error:	0.5	deg

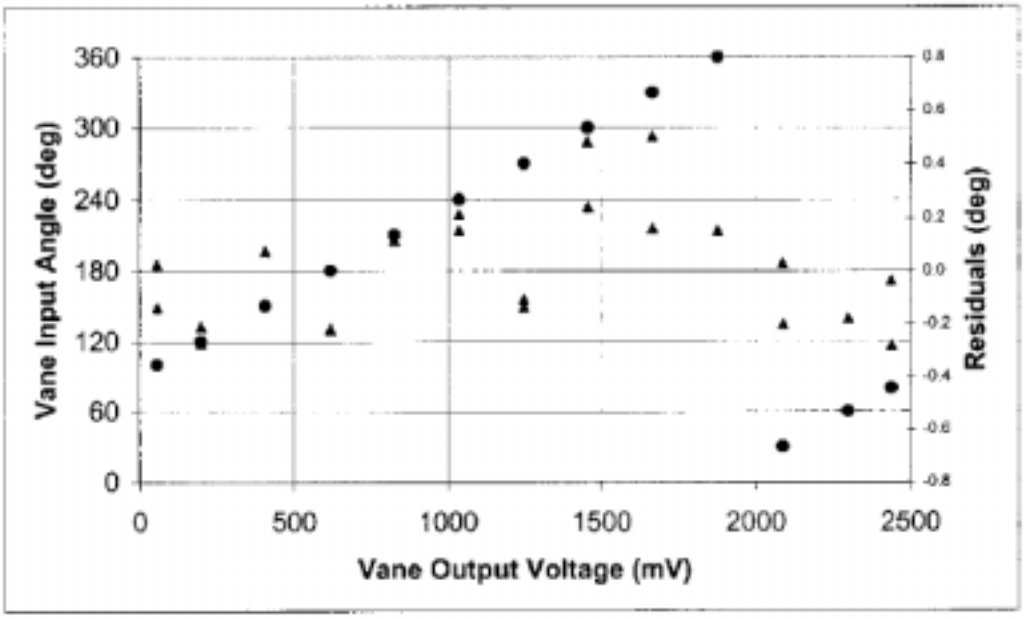
Estimated Uncertainty:

Inclinometer Uncertainty (deg)	Total Uncertainty (deg)
0.10	0.24

Traceability:

	Mfg & Model	Serial Number	Cal Date
Inclinometer:	Lucas DP45	82860032	12/13/02
Voltmeter:	Fluke 743B	6965608	1/2/03

Calibration by: Mark Meadors — 28-Jan-02
Mark Meadors — Date



Branch #: 5000 sheet: 1 of: 1

NREL METROLOGY LABORATORY

Test Report

Test Instrument: Pressure Transmitter DOE #: 02794C

Model # : PTB101B S/N : S2830007

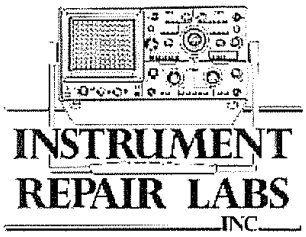
Calibration Date: 11/16/2001 Due Date: 11/16/2002

No	Function Tested	Nominal Value (mb)	Measured Values		( )Mfr. Specs. OR (X)Data only (mb)
			Output Voltage (VDC)	Equivalent Pressure (mb)	
*	Absolute Pressure	651.7	0.2815	651.8	
		701.7	0.5538	701.9	
		751.7	0.8266	752.1	
		801.7	1.0987	802.2	
		851.7	1.3712	852.3	
		901.7	1.6424	902.2	
		951.7	1.9152	952.4	
		1001.7	2.1875	1002.5	
		1051.7	2.4601	1052.7	
	Note: Uncertainty of the nominal value is ± 1 mb				

Tested By : Reda

Date : 11/16/2001

Calibration Certificate



2100A West 6th Avenue
Broomfield, CO 80020
PH: 303/469-5375 or 800/345-6140, FX: 303/469-5378

Company Name:	National Renewable Energy Lab	MFG:	Vaisala
Certification#:	001128059	Model:	PTB101B
Calibration Location:	Subcontractor	SN:	T3330002
Customer's P.O. Number:		Barcode:	17816
Received Status:	In Tolerance	Cust ID:	
Returned Status:	In Tolerance	Temp:	72 F
Procedure Used:	MFGR Cal Procedure	RH:	35 %
Calibration Date:	12/19/2000	Rec. Cal. Due:	12/19/2001
Standards Used:	Subcontracted - See attached		
Calibration Remarks:	Calibrated by CEESI, reference certificate		
Description:	Absolute Pressure Transducer		

It is Instrument Repair Labs, Inc. opinion that the above listed instrument meets or exceeds all manufacturer's or agreed upon local specifications. The instrument has been calibrated using standards whose accuracies are traceable to N.I.S.T. within the limitation of their calibration services, or have been derived from accepted values of natural physical constants. Our "Calibration System Requirements" satisfy ANSI/NCSL Z-540, MIL-STD 45662A, FDA GMP 820.61 and ISO/IEC 17025. The calibration environment was 70 Deg F, +/- 5 Deg F and <70% RH unless otherwise noted. This report is not to be reproduced, except in full, without the written approval of Instrument Repair Labs' Quality Manager.

CERTIFIED BY: Subcont. -Cal
QUALITY MANAGER: Bill Hedrick

Date Printed: 12/26/2000
Time Printed: 11:22:04

Instrument Repair Labs, is certified to ISO 9002 by TUV Management Service. Our ANSI-RAB certificate registration number is: 950-98-0218, and is valid until April 30, 2001.

Form 07, Rev. 06, 10/10/2000

Branch #: 5000

sheet: 1 of: 1

NREL METROLOGY LABORATORY

Test Report

Test Instrument: RTD Probe

DOE #: 02683C

Model # : N/A

S/N : 0653393

Calibration Date: 12/12/2000

Due Date: 12/12/2001

No	Nominal Values		Measured Values		
	Nominal Resistance	Equivalent Temperature	Measured Resistance	Equivalent Temperature	Temperature Error(M-N)
1	94.12 Ω	-15 °C	94.131 Ω	-14.97 °C	0.03 °C
2	100.00 Ω	0.0 °C	100.017 Ω	0.04 °C	0.04 °C
3	105.85 Ω	15.0 °C	105.872 Ω	15.06 °C	0.06 °C
4	111.67 Ω	30.0 °C	111.704 Ω	30.09 °C	0.09 °C
5	117.47 Ω	45.0 °C	117.506 Ω	45.09 °C	0.09 °C

Notes:

1. Total Uncertainty of Nominal Values = ±0.03 °C
2. Calibration was performed at 23 °C and 30% RH
3. Resistance is measured using 3-wire technique

Checked By: Reda

Date : 12/12/2000

RTD Calibration Certificate

Calibration Laboratory:
National Wind Technology Center - Cert. Team
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401

Calibration Location:
National Wind Technology Center
Building 257 room 101-04

Calibrated for:
NWTC - Certification Team

Procedure:
CI02 Calibrate RTD 011128
Deviations: NONE

Item Calibrated:
Mfgr: Met One Instruments, Inc
Model: T200
Serial No: **0464507**
Condition: good

Cal Date: November 19, 2001

Results:
Slope: **2.6034** C/ohm
Offset: **-260.20** C
Max Uncert*: 0.65 C
*over temperature range of -20 to +45 C

Certificate Number / File Name:
RTD Cal 0464507, 011119.xls

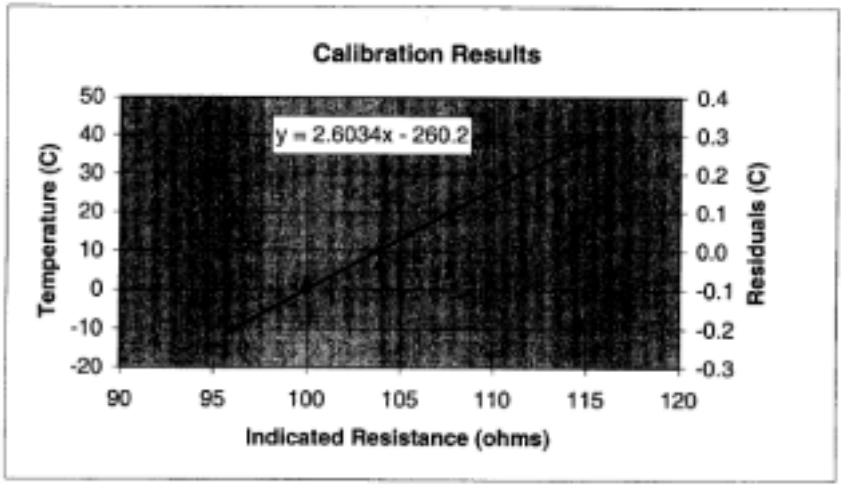
Reference Standard:
Hart Scientific, Model 9102 HDRC Dry-Well Calibrator
Last Calibration: Hart Scientific, 8/28/2001, A182623

Associated Equipment
Campbell Scientific, CR23X, Datalogger, s/n 3099
Vishay, S102C, 10 kohm Precision Resistor

The standard used in this calibration is traceable to the National Institute of Standards and Technology (NIST). Measurement uncertainty for this calibration was determined in accordance with the ISO "Guide to the Expression of Uncertainty in Measurement." It is based upon a 95% confidence level (coverage factor = 2).

Mark Meadors
Mark Meadors

11/29/01
Date



CAMPBELL SCIENTIFIC, INC.
815 W. 1800 N. Logan, Utah 84321-1784 (435) 753-2342 FAX (435) 750-9540 www.campbellsci.com

Certificate of Calibration

Customer:

Company Name: NATIONAL RENEWABLE ENERGY LAB
City/State/Strt: 18200 STATE HWY 128
ARVADA, CO 80007 US
PO #:
RMA #: 2742
Contract #:
Log Option: 2

Model: CR23X-4M Serial Number: 1214

Test Panel Loc. 1
CSI Calibration Number: 12510
Calibration Procedures: PRC32A R6 TST10517B R1 TST10517C R17

Instrument Calibration Condition

Received Disposition:	In Tolerance *		Out of Tolerance	Operational Failure
Returned Disposition:	In Tolerance *			

Recommended Calibration Schedule

Based on past experience and assumed normal usage, it is recommended that this instrument be calibrated by due date stated below to insure sustained accuracy and reliable performance.

Calibration Date: 1/31/2001 Manufacturer's suggested recalibration date: 1/31/2002

Report of Calibration Standards Used

Make/ Model	SN	Cal Due Date	NIST reference
DP 8200	A014824	9/15/2001	0269A10
CSI Oscillator	196319	5/18/2001	196319

Campbell Scientific., Inc. certifies the above instrument meets or exceeds published specifications and has been calibrated using standards and instruments whose accuracies are traceable to the National Institute of Standards and Technologies, an accepted value of a natural physical constant, or ratio type of self-calibration techniques. The collective measurement uncertainty of the calibration process exceeds a 4:1 accuracy ratio.

Quality Control Manager responsible for content of certificate: Clint Howell

Remarks:

Based on Report option, some fields are intentionally left blank.

CAMPBELL SCIENTIFIC, INC.

815 W. 1800 N. Logan, Utah 84321-1784 (435) 753-2342 FAX (435) 750-9540 www.campbellsci.com

Certificate of Calibration

Customer:

Company Name: NATIONAL RENEWABLE ENERGY LAB
City/State/Strt: MS 3911
1617 COLE BLVD
GOLDEN CO
Contract/PO #:
RMA #: 4492
Log Option: 2

Model: CR23X-4M Serial Number: 3101

Test Panel Loc. 1
CSI Calibration Number: 20780
Calibration Procedures: TST10517B R1 PRC32A R8 TST10517C R17 PRC33A R 1

Instrument Calibration Condition

Received Disposition: In Tolerance * Out of Tolerance Operational Failure
Returned Disposition: In Tolerance *

Recommended Calibration Schedule

Based on past experience and assumed normal usage, it is recommended that this instrument be calibrated by due date stated below to insure sustained accuracy and reliable performance.

Calibration Date: 10/30/01 Manufacturer's suggested recalibration date: 10/30/02

Report of Calibration Standards Used

Make/ Model	SN	Cal Due Date	NIST reference
DP 8200	A014824	9/6/02	A014824
CSI Oscillator	196319	5/18/02	196319

CSI certifies the above instrument meets or exceeds published specifications and has been calibrated using standards and instruments whose accuracies are traceable to the National Institute of Standards and Technology, an accepted value of a natural physical constant or a ratio calibration technique. The collective measurement uncertainty of the calibration process exceeds a 4:1 ratio. The policies and procedures at this calibration facility comply with ISO-9001. The calibration of this instrument was performed in accordance with CSI's Quality Assurance program.

Quality Control Manager responsible for content of certificate: Clint Howell

Remarks:

Based on Report option, some fields are intentionally left blank.

Appendix C: Log Sheets

NREL National Renewable Energy Laboratory

PA Wind Turbine Certification Team

MIC

To Campell +11 50 290°→301° mag Camp.

M1: 290° Mag. 46° M2: M3: 96° (14° offset to avoid met tower) M4

M1 17510 96050 M2 M3 M4

AF24, Acoustics Test Log

Turbine	Bergey XL10
Filename	
Comp time	Time in sync but one hour off 8:22:00
DAT time	DAT is +1 HR 9:22:00

Date mm/dd/yy	Time hh:mm:ss	DAT ID	Range mVpk	Sensitivity mVoruV/EU	Action	
4-19-01		226			TURBINE	
	09:34:00		126.0419	38.2898	CAL MIC 1	~~93.7867~~ POST 93.7867 93.72
	09:35:18			31.6879	CAL MIC 2	~~93.7938~~ 93.781 93.72
	09:36:49			39.0191	CAL MIC 3	~~93.7944~~ 93.794 93.678
	09:38:18			33.9245	CAL MIC 4	93.80 93.70
					TURBINE SPL LEVELS AROUND 68-70 dB 48-52 dBA	
	09:42:00				START MEAS AOC, Whisper, & other Bergey turned off	
	~~9:52:15~~ 9:52:50				Drilling near Mic 3 ~~4:~~	
					Birds singing & chirping	
	10:03:40-10:03:50				Noises from concrete plant CAR driving away	
					When turbine is running in higher WS >7, cannot hear any background	
	10:55				Turbine went off → very high winds >20"	
	11:00:00				Manually furled and shorted turbine	
	11:05-11:12:30				Ran furled but not shorted	
					Background Meas	
	~~11:0~~ 11:18:30				Start meas	
					CAL CHK	
	11:22:03			32.9775	MIC 1	93.796
	11:23:26			31.1878	MIC 2	~~93.7925~~ 93.79
					~~MIC 3~~	
	11:25:20			38.3719	MIC 3	93.812
	11:26:37			33.4768	MIC 4	93.790

Date mm/dd/yy	Time hh:mm:ss	DAT ID	Range mVpk	Sensitivity mVoruV/EU	Action
11:28:00					START MEAS
					28-31 dBA @ 8 m/s
11:29:20 -	11:29:30				car leaving
					grasshoppers, planes, concrete plant
11:47:00 -	11:47:10				loud noise in backgrd.
11:54:50 -	11:55:40				Drilling
12:27:20 -	12:27:30	22.7			switch DAT tape
12:28:30 -	12:28:40				Car noise
					TURBINE MEAS
12:58 to	1:00				Turbine on / on-line
~12:55	to 1:02				Back hoe noise at 1.2
					(Scott W. left at ~ 1:02)
13:28:20 -	13:28:30				Car noise
13:35:00 -	13:35:15				honking, loud
13:55:50 -	13:56:20				Wind on north side for
					Mic 4 and beeping from
					concrete plant Mic 3
14:36:20 -	14:36:40				beeping.
~~14:40:50~~	at				Input cal tone but
14:48:00 -	~~14:56:00~~	14:57:00			no calibration
					BACKGRD MEAS
15:13:00					TURBINE OFF
15:21:00					Start meas
15:21:15 -	15:21:30				car left
3:37:21 -	3:37:31				beeping from concrete plant
15:39:03 -	15:39:50				beeping
16:12:01 -	16:12:11				car passing
					Final Cal POST-

AF24, Acoustics Test Log

Turbine	Bergey XL.1C
Filename	No Acquest DAQ
Comp time	10:04:39
DAT time	10:04:40

Date mm/dd/yy	Time hh:mm:ss	DAT ID	Range mVpk	Sensitivity mVoruV/EU	Action
04/20/2001		228	126.0419		
	10:28:45				CAL MIC 1 93.786
					Sensitivity factor @ 1.2 millen
					Something not right
	10:32:55			32.3218	CAL MIC 2 93.807
	10:34:45			33.5655	CAL MIC 3 93.798
	10:36:00			33.5571	CAL MIC 4 93.809
					Changed MIC 1 & preamp
					Problem w/ power supply went
					back to original mic & preamp.
	11:07:05	230		32.747	CAL MIC 1 93.799
	11:08:55			33.2985	93.797
	11:09:30				Meas started Wheeper &
					Bergey off, NDC still running
	11:42:10				Turbine off
					BACKGRD
					~~Clear~~ Cloudy & overcast.
					Little hail & rain
	11:45:20				Meas starts
	No MEAS → RAIN				
	&				RAIN!
	HAIL				No measurements.

NREL National Renewable Energy Laboratory

Wind Turbine Certification Team

Test Turbine	XL10
DAT Time	~~10:~~ ~~10:37:~~ 10:38:42
Computer / Datalogger time	~~10:07:02~~ ~~10:52:~~ 10:53:00

Cal - calibration
N - interrupting noise
O - other
B - before calibration
A - after calibration

Date mm/dd/yy	Time hh:mm:ss	DAT ID	Regarding			Microphone				Sensitivity mV/Pa		SPL dB	Range mVpk	Action
			Cal	N	O	1	2	3	4					
2/14/02	10:27:25	005	X						X	35.4116	B	93.79	158.6774	Preamp sn: 6009
											A	93.68		
2/14/02	10:29:55	005	X			X				34.0597	B	93.801	126.0419	Preamp sn: 60032
											A	93.72		
2/14/02	10:31:50	005	X				X			32.9865	B	93.79	126.0419	Preamp sn: 504
											A	93.80		
2/14/02	10:33:37	005	X					X		32.917	B	93.80	126.0419	Preamp sn: 503
											A	93.49		
											B			
											A			
2/14/02	10:35:39	005									B			Collect Turbine Meas
											A			
											B			Neighboring NW100, AOC15/5
											A			
											B			& XL10(1.8) turned off.
											A			
	~10:40:00										B			Driving off
											A			
	12:00 noon										B			Drive back, begin Shutdown Tu
											A			
	12:09										B			Shut down complete; drive off
											A			
	1:50										B			Arrive back - winds died Turbine on - tear down Acoustics
											A			
2/14/02	14:04:05	007	X				~~X~~ NO	X			B			POST CAL Values written in post cal spaces above
											A			
2/14/02	14:05:28	007	X						X		B			
											A			
2/14/02	14:07:40	007	X			X					B			
											A			
2/14/02	14:09:15	007	X				X				B			
											A			

NREL
National Renewable Energy Laboratory

Wind Turbine Certification Team

Date mm/dd/yy	Time hh:mm:ss	DAT ID	Regarding			Microphone				Sensitivity mV/Pa		SPL dB	Range mVpk	Action
			Cal	N	O	1	2	3	4					
2/21/02			X						X	33.395	B	93.796		Replay of 2/14/02
											A			
2/21/02			X			X				34.0697	B	93.799		
											A			
2/21/02			X				X			32.4896	B	93.796		
											A			
2/21/02			X					X		32.8885	B	93.801		
											A			
											B			
											A			
											B			
											A			
											B			
											A			
											B			
											A			
											B			
											A			
											B			
											A			
											B			
											A			
											B			
											A			
											B			
											A			
											B			
											A			
											B			
											A			
											B			
											A			
											B			
											A			
											B			
											A			
											B			
											A			

(4)

NREL National Renewable Energy Laboratory

Wind Turbine Certification Team

Test Turbine	Bergey XL.1C
DAT Time	1:36:00
Computer / Datalogger time	~~11:49:30~~ 11:49:45

Cal - calibration
N - interrupting noise
O - other
B - before calibration
A - after calibration

Date mm/dd/yy	Time hh:mm:ss	DAT ID	Regarding			Microphone				Sensitivity mV/Pa		SPL dB	Range mVpk	Action
			Cal	N	O	1	2	3	4					
01/21/02	11:15:15	001	X			X		X		32.6331	B	93.847	126.0419	Cal
											A			
01/21/02	11:18:30	001	X		X				X	4.8118	B		126.0419	Not right sensitivity
											A			
01/21/02	11:23.02	001	X		X				X		B			Unstable - redo later
											A			
01/21/02	11:26:16	001	X			X				31.3838	B		126.0419	
											A			
01/21/02	11:28:20	001	X				X			30.7354	B		126.0419	
											A			
01/21/02	11:30:20	001	X						X	31.1477	B		126.0419	Try again
											A			
	11:45:00 (app)										B			Start Meas.
											A			
	1:15										B			Mark disc up
											A			
											B			Brakes furling cable
											A			
	1:50										B			Turbine off (output shorted)
											A			
											B			
											A			
02/08/02	17:39:00	004	X						X	34.3463	B	93.564	126.0419	
											A			
02/08/02	17:41:45	004	X			X				33.9691	B	93.525	126.0419	
											A			
02/08/02	17:43:53	004	X				X			33.356	B	93.511	126.0419	
											A			
02/08/02	17:45:39	004	X					X		34.8571	B	93.798	126.0419	
											A			
02/08/02	17:46:30	004									B			TURBINE ON MEAS
											A			

NREL
National Renewable Energy Laboratory

Wind Turbine Certification Team

Date mm/dd/yy	Time hh:mm:ss	DAT ID	Regarding			Microphone				Sensitivity mV/Pa		SPL dB	Range mVpk	Action
			Cal	N	O	1	2	3	4					
	19:47:50	004									B			Backgrd
											A			
	19:56:00										B			TURBINE
											A			
											B			Now to Running
											A			
											B			Couldn't get backgd
											A			
	20:10:00										B			STOP
											A			
											B			
	20:12:45		X					X			A			
											B			
	20:16:50		X			X					A	93.77		
											B			
	20:		X						X		A	93.153		
											B			
	20:25:20		X				X				A	93.721		MIC 2 fell off board
											B			
											A			
											B			
											A			
											B			
											A			
											B			
											A			
											B			
											A			
											B			
											A			
											B			
											A			
											B			
											A			

C-8

(1)

NREL National Renewable Energy Laboratory

Wind Turbine Certification Team

Test Turbine	Bergey XL.10
DAT Time	13:42:49 - 50
Computer / Datalogger time	13:56:00

Cal - calibration
N - interrupting noise
O - other
B - before calibration
A - after calibration

	MIC	PREAMP
Mic 1	17541	99er503
2	17516	980032
3	17509	990564
4	17528	6669

Date mm/dd/yy	Time hh:mm:ss	DAT ID	Regarding Cal	N	O	Microphone 1	2	3	4	Sensitivity mV/Pa		SPL dB	Range mVpk	Action
tape 1											B			
3/26/02	13:28:40	008	X						X		A			double check calibrator level
3/26/02	13:30:53	008	X						X	31.2818	B	93.852	158.6774	
											A			
3/26/02	13:34:46	008	X			X				30.6062	B	93.856	158.6774	
											A			
3/26/02	13:36:59	008	X				X			32.2745	B	93.853	158.6774	
											A			
3/26/02	13:39:20	008	X					X		31.0052	B	93.852	158.6774	
											A			
				X							B			Concrete plant operating
											A			
											B			
3/26/02	13:42:00	008									A			TURBINE ON MEAS.
3/26/02	13:48:45-13:49:15										B			Mark driving away
											A			
3/26/02	14:29:40			X							B			lower frequency Some concrete/car noises
											A			
3/26/02	14:32:30-14:34:05			X							B			Plane
											A			
3/26/02	14:42:30-14:43:40			X							B			Plane
											A			
3/26/02	14:48:25-14:48:50			X							B			Car
											A			
3/26/02	14:49:40-14:50:50			X							B			Plane
											A			
3/26/02	14:55:40-14:57:00			X							B			Plane & train
											A			
3/26/02	15:11:00-15:12:30										B			Plane & Car
											A			

15:19:11

Stop measurements/no wind

Helicopter LF noises when turned & unturned:

NREL
National Renewable Energy Laboratory

Wind Turbine Certification Team

Type 1	Date mm/dd/yy	Time hh:mm:ss	DAT ID	Regarding Cal	N	O	Microphone 1	2	3	4	Sensitivity mV/Pa		SPL dB	Range mVpk	Action
	3/27/02	9:13:58	009	X						X	31.4799	B	93.85	158.6774	Unsteady, high winds
												A	93.803		
	3/27/02	9:17:20	009	X			X				30.8585	B	93.842	158.6774	Unsteady
												A	93.818		
	3/27/02	9:19:55	009	X				X			32.5589	B	93.852	158.6774	"
												A	93.809		
	3/27/02	9:22:50	009	X					X		31.3249	B	93.847	158.6774	"
												A	93.816		
												B	93.832		Mic 4 not moved. Moved boards ~20° counterclkws
												A			
	3/27/02	9:25:00	009									B			TURBINE MEAS
												A			
												B			Close to end of DAT tape.
												A			
	3/27/02	10:24:50	009	X						X	31.3229	B	93.866	158.6774	
												A	93.811		
	3/27/02	10:27:22	010	X			X				30.6864	B	93.844	158.6774	
												A	93.834		
	3/27/02	10:30:11	011	X				X			32.4668	B	93.866	158.6774	
												A	93.863		
	3/27/02	10:32:50	012	X					X		31.2616	B	93.851	158.6774	
												A	93.833		
												B			New DAT tape
												A			
Type 2												B			Trying to get backgrd.
												A			
	3/27/02											B			Cannot stop turbine for bkgrd.
												A			
	3/27/02	11:15:50	013									B			Start turbine meas.
												A			
		11:28:50-11:29:00										B			Sound from concrete plant
												A			
		11:32:07										B			Train horn
												A			
		11:45:25-11:47:00										B			Helicopter/plane Concrete plant
												A			
		11:53:27-11:53:37										B			Concrete plant
												A			

(2)

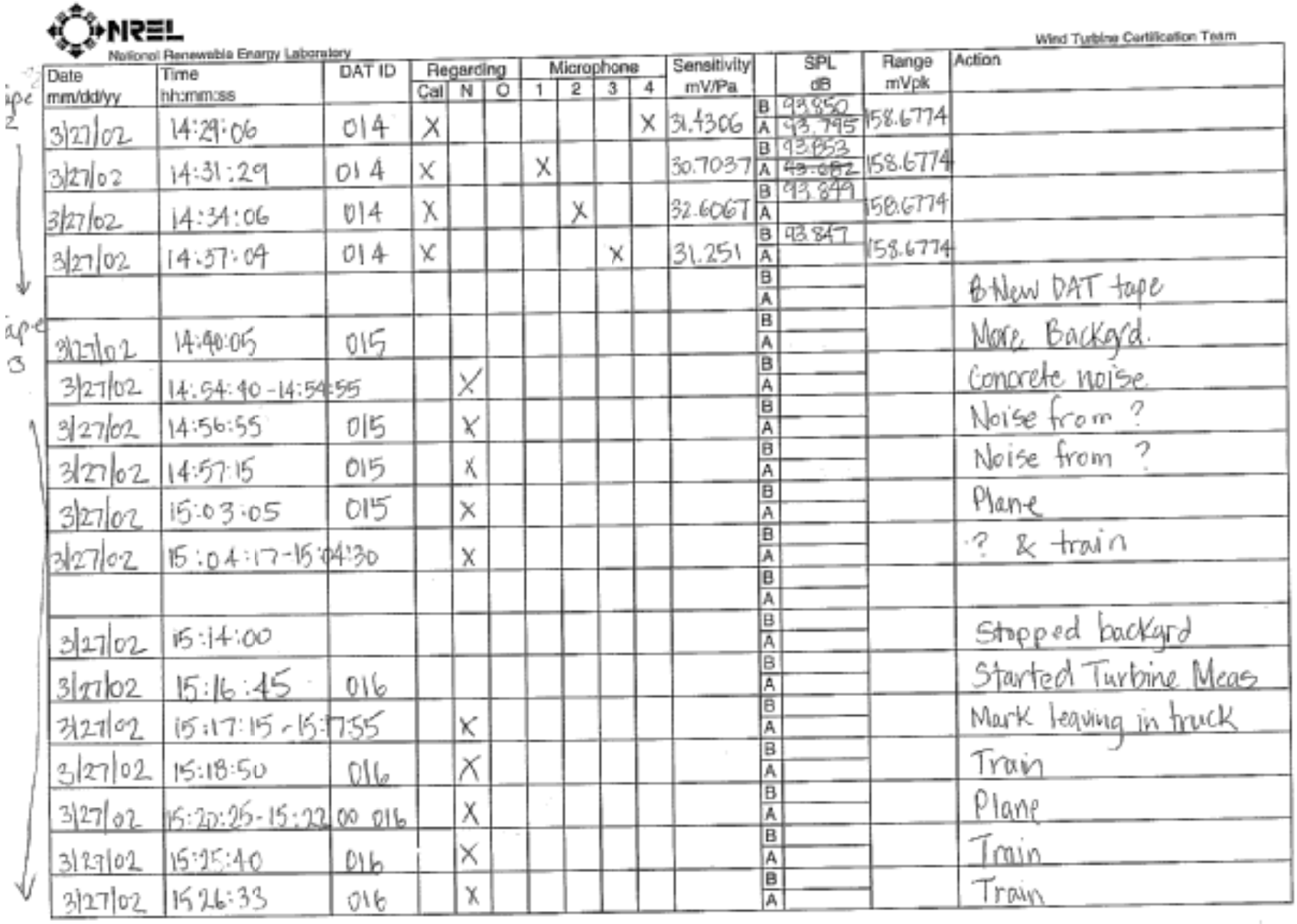
NREL National Renewable Energy Laboratory — Wind Turbine Certification Team

Test Turbine	Bergey XL.10
DAT Time	
Computer / Datalogger time	

Cal - calibration
N - interrupting noise
O - other
B - before calibration
A - after calibration

Date mm/dd/yy	Time hh:mm:ss	DAT ID	Regarding			Microphone				Sensitivity mV/Pa		SPL dB	Range mVpk	Action
			Cal	N	O	1	2	3	4					
3/27/02	11:54:00-11:54:20	013			X						B			Furling noise
											A			
3/27/02	11:57:00-11:57:30			X							B			Concrete plant noise
											A			
3/27/02	11:57:45-11:58:32				X						B			Furling noise
											A			
3/27/02	12:46:08										B			Stopped DAT
											A			
											B			Stopped turbine for backgrd
											A			
3/27/02	13:09:00	014	X						X	31.2947	B	93.856	158.674	
											A	93.834		
3/27/02	13:11:29	014	X			X				30.6643	B	93.852		
											A	93.851	158.674	
3/27/02	13:14:05	014	X				X			32.7025	B	93.849		
											A	93.831	158.674	
3/27/02	13:17:02	014	X					X		31.2117	B	93.851		
											A	93.867	158.674	
											B			
											A			
3/27/02	13:19:00	014									B			Start Background Meas.
											A			
	~~13:24:38-13:29:58~~	06									B			Noise from Concrete plant present during turbine
											A			
				X							B			NW100 running
											A			
3/27/02	13:29:38-13:29:58			X							B			Concrete plant noise
											A			
3/27/02	13:31:00			X							B			NW100 stopped
											A			
	? 14:20:00-14:24:20	014		X							B			NW100 started again
											A			

9/27/02 14:26:50-14:27:10 014 Truck



NREL
National Renewable Energy Laboratory

Wind Turbine Certification Team

Date mm/dd/yy	Time hh:mm:ss	DAT ID	Regarding			Microphone				Sensitivity mV/Pa		SPL dB	Range mVpk	Action
			Cal	N	O	1	2	3	4					
3/27/02	14:29:06	014	X						X	31.4306	B	93.850	158.6774	
											A	93.795		
3/27/02	14:31:29	014	X			X				30.7037	B	93.853	158.6774	
											A	~~93.082~~		
3/27/02	14:34:06	014	X				X			32.6067	B	93.849	158.6774	
											A			
3/27/02	14:37:09	014	X					X		31.251	B	93.847	158.6774	
											A			
											B			B New DAT tape
											A			
3/27/02	14:40:05	015									B			More Backgrd.
											A			
3/27/02	14:54:40-14:54:55			X							B			Concrete noise
											A			
3/27/02	14:56:55	015		X							B			Noise from ?
											A			
3/27/02	14:57:15	015		X							B			Noise from ?
											A			
3/27/02	15:03:05	015		X							B			Plane
											A			
3/27/02	15:04:17-15:04:30			X							B			? & train
											A			
											B			
											A			
3/27/02	15:14:00										B			Stopped backgrd
											A			
3/27/02	15:16:45	016									B			Started Turbine Meas
											A			
3/27/02	15:17:15-15:17:55			X							B			Mark leaving in truck
											A			
3/27/02	15:18:50	016		X							B			Train
											A			
3/27/02	15:20:25-15:22:00	016		X							B			Plane
											A			
3/27/02	15:25:40	016		X							B			Train
											A			
3/27/02	15:26:33	016		X							B			Train
											A			

NREL National Renewable Energy Laboratory — Wind Turbine Certification Team

Test Turbine	Bergey XL10
DAT Time	
Computer / Datalogger time	

Cal - calibration
N - interrupting noise
O - other
B - before calibration
A - after calibration

page 3

Date mm/dd/yy	Time hh:mm:ss	DAT ID	Regarding Cal	N	O	Microphone 1	2	3	4	Sensitivity mV/Pa		SPL dB	Range mVpk	Action
3/27/02	15:49:20-15:	016		X							B			Other XL10 furling
											A			
3/27/02	15:55:41	016		X							B			?
											A			
3/27/02	15:13:30-15:13:55	016		X							B			Mark driving up
											A			
3/27/02	15:25:06	016		X							B			Honking
											A			
											B			
											A			
3/27/02	16:29:23	017	X						X	31.2918	B	93.859	158.6774	
											A	93.821		
3/27/02	16:31:50	017	X			X				30.7087	B	93.856	158.6774	
											A	93.830		
3/27/02	16:34:39	017	X				X			32.1875	B	93.856		
											A	93.804	158.6774	
3/27/02	16:37:16	017	X					X		31.1143	B	93.857		
											A	93.852	158.6774	
3/27/02	16:39:20	017									B			TURBINE MEAS.
											A			
3/27/02	16:42:40	017		X							B			Mark driving off (20 sec)
											A			
3/27/02	17:11:53	017		X							B			Train
											A			
3/27/02	17:15:49	017		X							B			Train
											A			
3/27/02	17:18:20-	017		X							B			?
											A			
3/27/02	17:19:51-17:19:57			X							B			Train
											A			
3/27/02	17:30:08	017		X							B			Train
											A			

NREL National Renewable Energy Laboratory

Wind Turbine Certification Team

Date mm/dd/yy	Time hh:mm:ss	DAT ID	Regarding Cal	N	O	Microphone 1	2	3	4	Sensitivity mV/Pa		SPL dB	Range mVpk	Action
3/27/02	17:47:15										B / A			Stopped Meas
3/27/02	17:51:00	018	X						X		B / A	93.860	158.6774	Post cal
3/27/02	17:53:10	019	X			X					B / A	93.844	158.6774	↓
3/27/02	17:55:21	020	X				X				B / A	93.836	158.6774	
3/27/02	17:59:21	021	X					X			B / A	93.869	158.6774	
											B / A			
											B / A			
											B / A			
											B / A			
											B / A			
											B / A			
											B / A			
											B / A			
											B / A			
											B / A			
											B / A			
											B / A			
											B / A			
											B / A			

C-14