Summary Test Report For

Ampair 600/230 Mk 2.5

Date : 27/05/2009

Version : 2.0

REVISION CONTROL

Issue #	Date of Approval	Modification	Prepared By	Approved By
1	01/12/08	Original issue	D Hails	
2	27/5/09	Durability & Strength and Safety data appended	D. Hails	

Index

Index of Tables

Index of Figures

1 Document Purpose

This report summarises the results of the testing performed on an Ampair 600/230 Mk 2.5 wind turbine which was installed at the TUV NEL wind test facility at Myres Hill, near East Kilbride. The tests were conducted in accordance with British Standard BS EN 61400 sections 2, 11, 12, and 14, where applicable to small wind turbines, and incorporating the amendments given in the British Wind Energy Association (BWEA) document 'Small Wind Turbine Performance and Safety Standard'.

2 Reference Documents

The documents in Table 1 have been referenced in the production of this report;

Table 1 - Table of Reference Documents

Title	Reference	Date	Revision
Design Requirements For Small Wind Turbines	BS EN 61400-2	July 2006	Original
Acoustic Noise Measurement Techniques	BS EN 61400-11	August 2003	Original
Power performance measurements of electricity producing wind turbines	BS EN 61400-12-1	31 July 2006	Original
Declaration of Apparent Sound Power Level and Tonality Values	BS EN 61400-14	January 2006	Original
British Wind Energy Association Small Wind Turbine Performance and Safety Standard		29 Feb 2008	

3 Power Performance Test Summary

Manufacturers Turbine Specifications

Rated Power	600w
Cut-In Wind Speed	3m/s
Cut-Out Wind Speed	n/a
Rated Wind Speed	12.6m/s
Rotor Diameter	1.7m
Control Type	Pitch control over 13m/s

Site Conditions

Maximum Air Density	1.185kg/m³
Minimum Air Density	1.175kg/m³
Average Air Density	1.181kg/m³
Measurement Sectors	0° - 19° & 160° – 360°

Test Statistics

Start Date & Time	21/06/08 12:00
End Date & Time	20/08/08 00:00
Valid Data Collected	961Hrs
Highest Bin Filled	16.5m/s
Test Completed	No *
BWEA Ref Power @ 11m/s	231w
BWEA Ref Annual Energy	481.45kWh/yr

* Criteria for completion is a minimum of 10 data points in each bin up to wind speed equivalent to 85% of rated power, or 95% measured AEP versus extrapolated AEP, neither of which has yet been achieved.

Table 2 – Summary Wind Speed vs Power Data

Average Wind Speed m/s	Average Power (W)	Data Points	Cp
0.40	-6.52	58	
0.81	-6.45	382	
1.27	-6.56	977	
1.76	-6.65	1258	
2.27	-6.60	1929	
2.76	-6.61	2542	
3.25	-6.20	3094	
3.76	-1.39	3492	
4.25	11.18	3653	0.105
4.76	27.19	3992	0.181
5.25	44.41	4768	0.220
5.75	63.38	5012	0.240
6.25	83.79	4906	0.247
6.74	104.16	4403	0.245
7.24	124.09	3635	0.235
7.74	142.82	2939	0.221
8.24	159.98	2314	0.205
8.74	176.12	1856	0.189
9.24	190.38	1616	0.174
9.75	204.28	1276	0.158
10.24	216.15	986	0.145
10.74	226.19	784	0.131
11.23	234.67	633	0.119
11.74	240.95	392	0.107
12.23	243.26	292	0.096
12.73	245.43	175	0.086
13.25	244.43	98	0.076
13.78	245.60	67	0.067
14.26	247.38	41	0.061
14.75	249.21	24	0.056
15.24	251.45	18	0.051
15.74	252.29	20	0.047
16.18	254.45	11	0.043
16.74	258.84	7	0.040
17.16	258.88	3	0.037
17.72	267.06	1	0.034

4 Power Curve and AEP at Sea Level Air Density

From the data summarised in Table 2, the power curve and power coefficient can be plotted as shown in Figure 1 below;

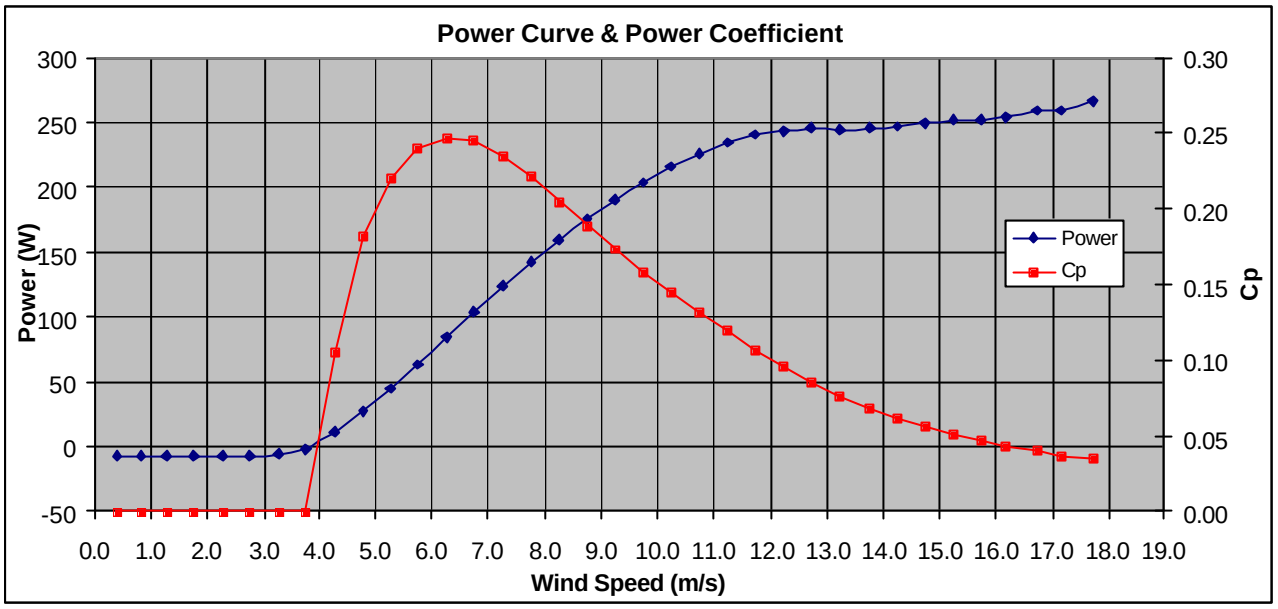

Figure 1 - Power Curve & Power Coefficient

4.1 BWEA Reference Annual Energy

Table 3 below summarises the annual energy production that could be expected of the Ampair 600/230 Mk 2.5, including extrapolated values where appropriate, and uncertainty of power output (U_{AEP}) as a result of accuracy of measurements etc.

Table 3 - AEP and Extrapolated AEP at Sea Level

Data Bin	Average Wind Speed m/s	Rayleigh Distribution Function *F(Vi)*	Average Power (*Pi*)	Annual Energy Production (AEP)	Category A Uncertainty (si)	Category B Uncertainty (ui)	Extrapolated AEP
1	0.40	0.004994	-6.5207	-0.0163	0.0637	6.2691	-0.0163
2	0.81	0.020463	-6.4513	-0.1003	0.0260	6.2133	-0.1003
3	1.27	0.049751	-6.5624	-0.1906	0.0168	6.2133	-0.1906
4	1.76	0.092696	-6.6483	-0.2837	0.0143	6.2133	-0.2837
5	2.27	0.149509	-6.6008	-0.3764	0.0120	6.2133	-0.3764
6	2.76	0.213412	-6.6145	-0.4222	0.0113	6.2133	-0.4222
7	3.25	0.283054	-6.1962	-0.4461	0.0231	6.2136	-0.4461
8	3.76	0.358394	-1.3906	-0.2858	0.0689	6.2537	-0.2858
9	4.25	0.432745	11.1831	0.3640	0.0895	6.5360	0.3640
10	4.76	0.509380	27.1885	1.4703	0.0940	6.7439	1.4703
11	5.25	0.579949	44.4118	2.5264	0.0984	6.9488	2.5264
12	5.75	0.646170	63.3843	3.5692	0.1068	7.1900	3.5692
13	6.25	0.706531	83.7921	4.4419	0.1150	7.4598	4.4419
14	6.74	0.759963	104.1610	5.0214	0.1246	7.6159	5.0214
15	7.24	0.807685	124.0908	5.4463	0.1305	7.6571	5.4463
16	7.74	0.847799	142.8243	5.3535	0.1487	7.6938	5.3535
17	8.24	0.881818	159.9803	5.1506	0.1591	7.5971	5.1506
18	8.74	0.909488	176.1247	4.6501	0.1719	7.6166	4.6501
19	9.24	0.931571	190.3847	4.0468	0.1864	7.4969	4.0468
20	9.75	0.949568	204.2819	3.5514	0.2089	7.5043	3.5514
21	10.24	0.962851	216.1501	2.7923	0.2349	7.4072	2.7923
22	10.74	0.973291	226.1884	2.3088	0.2794	7.1867	2.3088
23	11.23	0.981030	234.6663	1.7833	0.3211	7.0593	1.7833
24	11.74	0.986820	240.9532	1.3770	0.4117	6.8260	1.3770
25	12.23	0.990901	243.2621	0.9879	0.5354	6.5280	0.9879
26	12.73	0.993865	245.4290	0.7243	0.6499	6.5283	0.7243
27	13.25	0.995966	244.4305	0.5147	0.6922	6.4851	0.5147
28	13.78	0.997439	245.5968	0.3609	0.7389	6.4920	0.3609
29	14.26	0.998324	247.3803	0.2180	0.8079	6.5309	0.2180
30	14.75	0.998925	249.2137	0.1492	0.9222	6.5409	0.1492
31	15.24	0.999321	251.4467	0.0991	0.6488	6.5806	0.0991
32	15.74	0.999583	252.2868	0.0662	0.6036	6.5033	0.0662
33	16.18	0.999732	254.4453	0.0376	1.2357	6.6186	0.0376
34	16.74	0.999850	258.8400	0.0303	0.8468	6.8442	0.0303
35	17.16	0.999904	258.8845	0.0142	1.6403	6.5042	0.0142
36	17.72	0.999948	267.0557	0.0115	1.6403	7.7991	0.0115
37		0.999971			1.6403	7.7991	0.0062
38		0.999984			1.6403	7.7991	0.0034
39		0.999991			1.6403	7.7991	0.0019
40		0.999995			1.6403	7.7991	0.0011
41		0.999997			1.6403	7.7991	0.0006
42		0.999999			1.6403	7.7991	0.0003
43		0.999999			1.6403	7.7991	0.0002
44		1.000000			1.6403	7.7991	0.0001
45		1.000000			1.6403	7.7991	0.0000
46		1.000000			1.6403	7.7991	0.0000
47		1.000000			1.6403	7.7991	0.0000
48		1.000000			1.6403	7.7991	0.0000
49		1.000000			1.6403	7.7991	0.0000
50		1.000000			1.6403	7.7991	0.0000

Annual Avge Wnd Speed (m/s)	5
Annual Hours	8760
Total AEP (kWh/yr)	481.10
Total Extrapolated AEP (kWh/yr)	481.45
Total U_{AEP} (kWh/yr)	59.53

As can be seen from Table 3 above, the result of this test shows the BWEA reference annual energy production at an annual average wind speed of 5 m/s to be 481.45kWh/yr.

4.2 Annual Energy Production Curve

Following the same Rayleigh distribution as detailed in Table 3 above, the expected annual energy production at varying annual average wind speeds for the Ampair 600/230 Mk 2.5 can be derived from the curve shown in Figure 2;

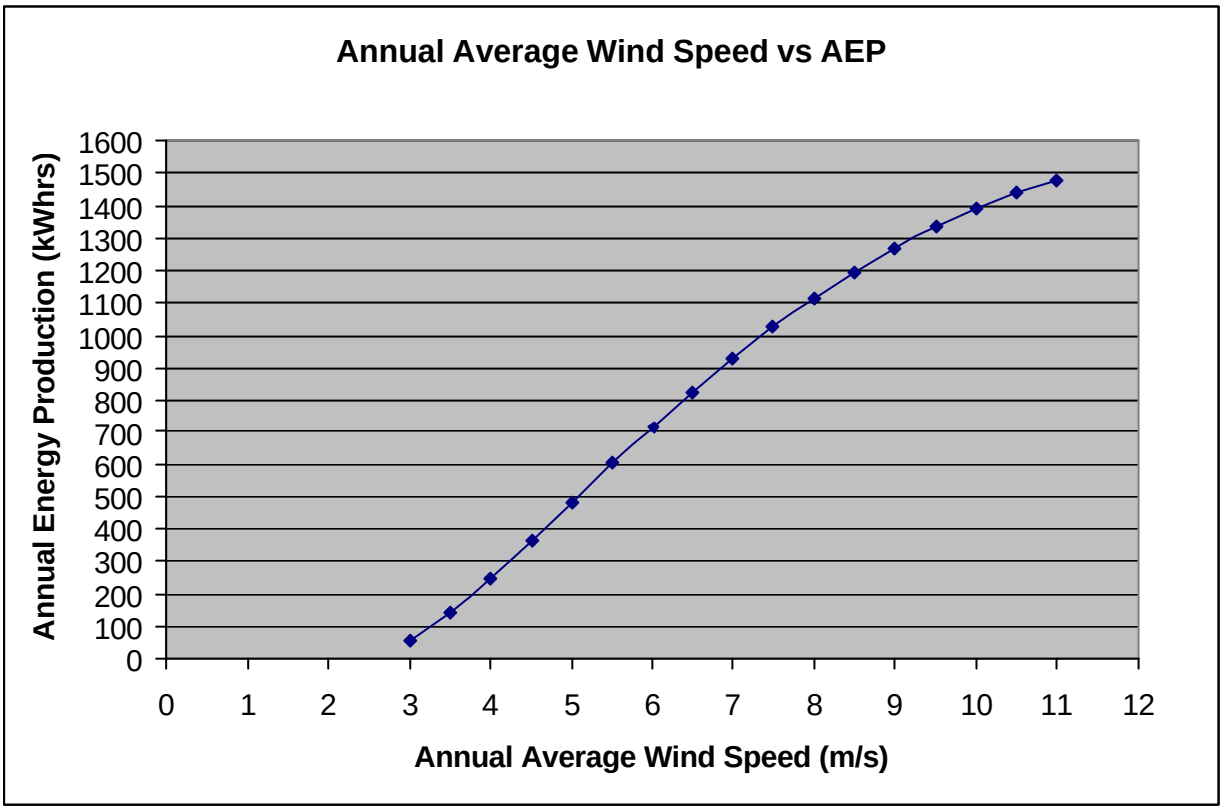

Figure 2 – Annual Average Wind Speed vs Annual Energy Production

The same data as indicated in Figure 2 above is summarised in Table 4 below.

Table 4 - Annual Average Wind Speed vs Annual Energy Production

Annual Average Wind Speed (m/s)	Annual Energy Production (kWhrs)
3.0	57.25
3.5	144.31
4.0	248.37
4.5	362.69
5.0	481.45
5.5	600.12
6.0	715.52
6.5	825.59
7.0	929.15
7.5	1025.54
8.0	1114.42
8.5	1195.54
9.0	1268.73
9.5	1333.81
10.0	1390.67
10.5	1439.30
11.0	1479.77

5 Acoustic Test Results

During the course of the test campaign, acoustic measurements were undertaken for both background noise and turbine operational noise, in both low and high wind speed occurrences. The resulting acoustic results for normal operation in accordance with the BWEA standard are as follows;

Declared apparent sound pressure level	89.5dB (A)
Wind speed dependence	3.38dB/m/s
Immission sound pressure level at 60m L_{P60m}	46dB (A)
Immission sound pressure level at 25m L_{P25m}	54dB (A)

5.1 Immission Noise Map

In accordance with section 3.1.4 of the BWEA standard, the immission noise map for the Ampair 600/230 Mk 2.5 is shown in Figure 3 below;

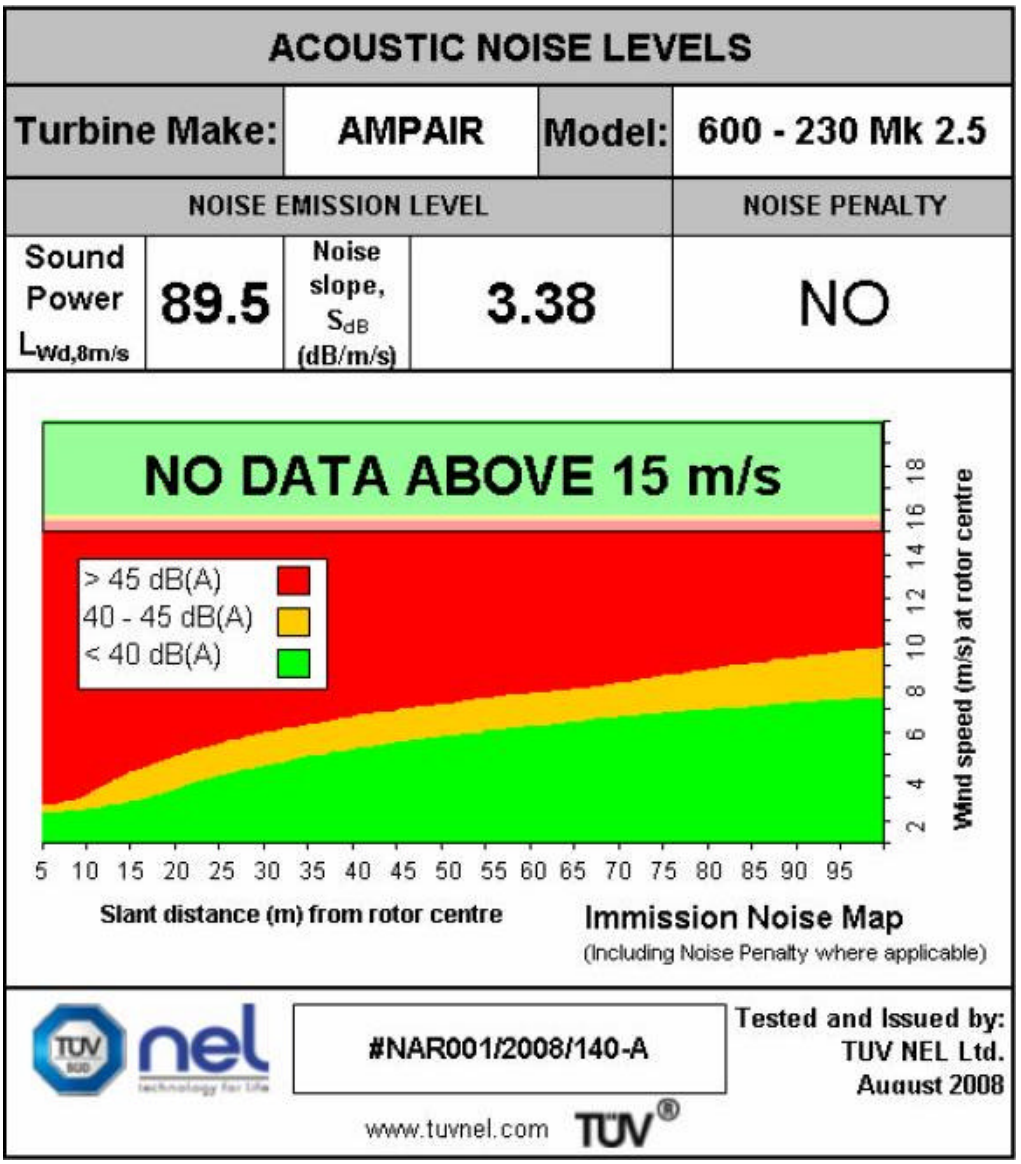

Figure 3 - Ampair 600/230 Mk2.5 Immission Map

6 Durability and Strength & Safety Test Results

6.1 Durability Testing

The Ampair 600/230 Mk 2.5 has been designed as a class 1 turbine, and has physically been in operation, with data being logged, since May 15th 2008. In accordance with section 9.4.1 of BS 61400-2 the turbine has therefore achieved the following operational statistics as of 19th November (where V_{ave} =10m/s);

Over 6 months of operation.	188 days
Total number of hours of power production	3,488hrs
Total number of hours in winds in excess of $1.2V_{ave}$	140hrs
Total number of hours in excess of 15m/s	29hrs 50mins
Total number of hours in winds in excess of $1.8V_{ave}$	3hrs 20mins

Whilst these results show that the turbine has not yet satisfied the requirements to claim Class 1 compliance, it has now achieved the requirements for a Class 2 turbine, i.e. where V_{ave} =8.5m/s rather than 10m/s, total hours in excess of $1.2V_{ave}$ were 372.5 and total hours in excess of $1.8V_{ave}$ were 29.8.

6.2 Reliable Operation

In accordance with BS 61400-2 the turbine is deemed to be reliable if the operational time fraction O is greater than 90%. This is calculated from the following equation;

$$O = \frac{T_T - T_N - T_U - T_E}{T_T - T_U - T_E} * 100\%$$

From the foregoing calculation and accumulated data, the operational time fraction for this test was therefore 100% as the turbine had no component failure, and was always in its operational state.

6.3 Safety & Function Test

A safety and function test was satisfactorily performed in accordance with section 9.6 of BS 61400-2.

6.4 Strength & Safety Testing

As referenced in section 6.1 above the turbine has been designed to meet the requirements of class 1, and NaREC can confirm that the manufacturer submitted design data for stress and load calculations as per the requirements of BS 61400-2 sections 7.4 and 7.8. This was subsequently reviewed and confirmed as accurate.

6.5 Tower Top Loads

The manufacturer additionally submitted data regarding the thrust loads and bending moments apparent to the wind turbine at various wind speeds. This data has been verified, and is referenced in Table 5 below.

Table 5 - Thrust Loads & Bending Moments

Turbine Class	Reference Wind Speed $Vref_{Vr}(m/s)$	50 Year Extreme Wind Speed $Ve50_{Vr}(m/s)$	Shaft Thrust $Frot_{Vr}(kN)$	Bending Moment $FBM_{Vr}(kNm)$
	5	7	0.03	0.01
	7.5	10.5	0.07	0.01
	10	14	0.13	0.02
	12.5	17.5	0.20	0.04
	15	21	0.29	0.05
	17.5	24.5	0.39	0.07
	20	28	0.51	0.09
	22.5	31.5	0.64	0.12
	25	35	0.80	0.14
	27.5	38.5	0.96	0.17
IV	30	42	1.15	0.21
	32.5	45.5	1.34	0.24
	35	49	1.56	0.28
III	37.5	52.5	1.79	0.32
	40	56	2.04	0.37
II	42.5	59.5	2.30	0.41
	45	63	2.58	0.46
	47.5	66.5	2.87	0.52
I	50	70	3.18	0.57

End Summary Report