3933 US Route 11
Cortland, NY 13045

Telephone: (607) 753-6711
Facsimile: (607) 753-1045
www.intertek-etlsemko.com

February 23, 2012

Intertek Project G100373741
Report Number 100373741CRT-001b

Dermot Young
C&F Green Energy
Cashla, Athenry
Co. Galway
Republic of Ireland

Ph: +353-91-790-868
Fx: +353-91-790-873
email: dermot.young@cftooling.ie

Subject: Summary Test Report for the C&F Green Energy CF11 tested at the C&F test location in Ballyspellan, Ireland.

Dear Mr. Young,

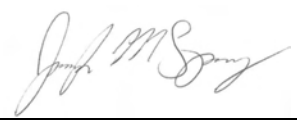
This test report summarises the results of the evaluation and tests of the above referenced equipment to the requirements contained in the following standards:

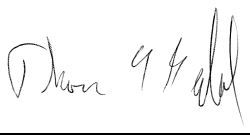
Title	Reference	Date	Revision
BWEA Small Wind Turbine Performance and Safety Standard		*29 Feb 2008*	
Wind turbines – Part 2:Design requirements for small wind turbines	*IEC 61400-2*	*March 2006*	*Second edition*
Wind turbines – Part 12-1: Power performance measurements of electricity producing wind turbines	*IEC 61400-12-1*	*December 2005*	*First edition*
Wind turbine generator systems – Part 11: Acoustic noise measurement techniques	*IEC 61400-11*	*November 2006*	*Edition 2:2002 consolidated with amendment 1:2006*

This investigation was authorized by signed proposal number 50027050, dated December 2nd, 2010. A production sample was installed at the test location in Ballyspellan, Ireland on May 30th, 2011. Duration testing was completed on the 13th December, 2011. All testing on the CF11 turbine was conducted under Intertek Project No. G100373741.

If there are any questions regarding the results contained in this report, or any of the other services offered by Intertek, please do not hesitate to contact the signatories on this report.

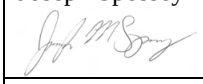
Please note, this Test Report on its own does not represent authorization for the use of any Intertek certification marks. Completed test reports for Duration, Power Performance, Acoustic, and Strength and Safety, are required to complete the Microgeneration Certification Scheme (MCS) certification process.

Completed by:	Joseph M Spossey
Title:	Project Engineer
Signature:	

Reviewed by:	Tom Buchal
Title:	Senior Staff Engineer
Signature	

Wind Turbine Generator System
Summary Test Report
for the
C&F Green Energy CF11

Revision history page

Revised by	Section	Description of change	Date
Joseph Spossey 	Entire document	Initial report	23 February 2012

1.0 Background

1.1 Background

This testing was conducted as part of the full MCS Certification test program for the C&F Green Energy CF11 horizontal-axis wind turbine. The CF11 was installed at the C&F Green Energy testing location in Ballyspellan, Ireland, and was tested alongside three other C&F Green Energy turbines; the CF6, CF15, and CF20.

1.2 Description of the wind turbine

The CF11 is designed for grid-connected power delivery, with a manufacturer's declared rated power output of 11 kW. The CF11 is an upwind turbine with active speed and power control through active blade pitch actuation and turbine yaw control. The CF11 has a three phase permanent magnet variable-speed generator; the output of which is fully converted in the grid-tie inverter. Inverter output configurations can vary according to the electrical network the turbine is connected to, and can accommodate single or three phase, 50 Hz or 60 Hz. The electrical network at the testing location is three-phase 230 VAC at 50 Hz, but the output configuration of the CF11 tested in Ballyspellan was single phase 230 VAC at 50 Hz. Normal electrical network operating voltage and frequency ranges are 207 – 253 V and 49.8 to 50.2 Hz, respectively.

A summary of the test turbine configuration and manufacturer's declared ratings can be found in Table 1 below.

Turbine Manufacturer	C&F Green Energy
Model	CF11
Production Year	2nd Quarter, 2011
Rotor Diameter	9.0m (29.5 ft) – Verified by Intertek to be 9.36 m with calibrated tape measure
Hub Height	15.65 m (51.3 ft)
Swept Area	63.6 m^2 (685 ft^2) – 68.8 m^2 using verified rotor diameter
IEC 61400-2 SWT Class	III
Test Tower Type	Tubular
Rated Electrical Power	11000 W
Cut-in Wind Speed	2.2 m/s (5 mph)
Cut-out Wind Speed	25 m/s (56 mph)
Rated Wind Speed	9 m/s (20 mph)
Survival Wind Speed	70 m/s (157 mph)
Rotor speed range	0 – 220 RPM
Generator Identification	CFGE 11kW
Generator Specification	230 RPM, 34 Hz, 485VAC, 1 plate
Inverter Identification	Power-One Aurora PVI-6000-TL-OUTD-UK-W (Qty 2) SN – 359241, 359414
Inverter Specifications	6000 W, 50 Hz, 230 VAC, IP 65 CE, EN50178, EN61000-6-1, EN6100-6-3, EN61000-3-11, EN61000-3-12, DK 5940, VDE 0126-1-1, G59/2, EN 50438, RD1663, AS4777
Controller Identification	Power-One Aurora Wind Interface Box 7200 PVI-Windbox-20A-EU (Qty 2) SN – 458905, 002247
Controller Specification	Input – 400 V, 0-600 Hz, 16.6 A Output – 600 V, 7.2 kW CE, EN 50178, EN 61000-6-2, EN 61000-6-4
Control Software Version	Inverters – C 0.1.6, Controllers – 1.036
Transformer Identification	Briglec 7.5 kW (Qty 1 isolation transformer) SN – No ID
Transformer Specification	7.5 kW, 230/230 single phase, 50 Hz
Number of Blades	3
Fixed or variable pitch	Variable
Blade Pitch Angle	Variable
Blade Identification	CFGE-BS-4.1-0006 SN – 37, 38, No ID
Blade Specification	Closed mould infusion of glass-filled vinylester resin over a polyurethane foam core with double spar, 7° twist from root to tip

Table 1 – Test Turbine Configuration

2.0 Objective

The purpose of this test report is to provide a summary of the following:

Section	Summary Results	Reference[1]
3.0	Power Performance Test Summary	6.1.2
4.0	Acoustic Test Results including noise label	6.1.3
5.0	BWEA Reference Annual Energy	6.1.4
6.0	BWEA Reference 60m Sound Level, Lp,60m	6.1.5
7.0	BWEA Reference Power, at 11.0 m/s (24.6 mph)	6.1.6
8.0	Wind Turbine Strength and Safety Report	6.1.7
9.0	Top tower design loads	6.1.7.1
10.0	Duration Test Summary	6.1.8

Note 1: Reference - *BWEA Small Wind Turbine Performance and Safety Standard 29 Feb 2008*

3.0 Power Performance Test Summary

Test Summary

Power Performance Test
CF11

Sea-Level Density Power Curve

Report Created: 27-Jan-2012

Turbine Specifications:

Serial number:		
Rated power	11000	W
Cut-in wind speed:	3.0	m/s
Cut-out wind speed:	25.0	m/s
Rated wind speed	11.0	m/s
Rotor diameter:	9.36	m
Rotor swept area	68.8	m^2
Control type:	Active	
Pitch setting:	Variable	

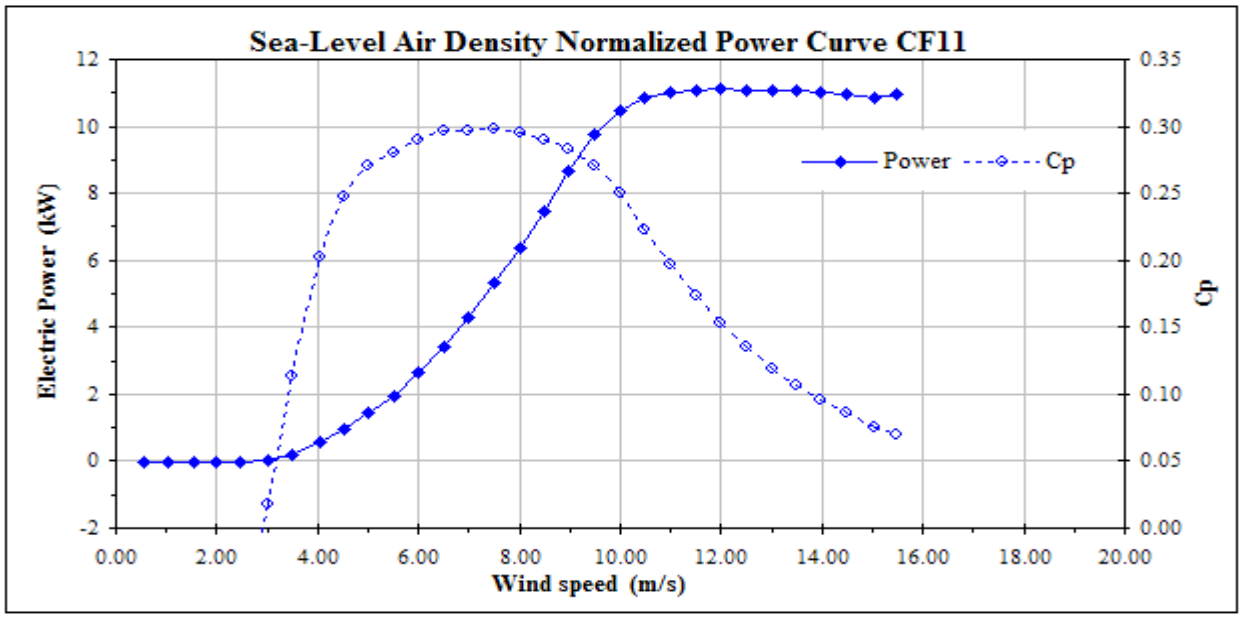
Site Conditions:

Location:	Ballyspellan, Ireland	
Average air density:	1.188	kg/m^3
Measurement sectors:	180 - 280	°True

Test Statistics:

Start date:	12-Aug-2011	
End date:	29-Aug-2011	
Amount of data collected:	226.7	Hours
Highest bin filled:	15.5	m/s
Test completed?	**YES**	

Bin Wind Speed (m/s)	Bin Power (kW)	Number of Data Points	Cp
0.55	-0.04	69	-6.10
1.04	-0.04	125	-0.88
1.53	-0.04	200	-0.27
2.00	-0.04	304	-0.12
2.47	-0.04	186	-0.06
3.03	0.02	222	0.02
3.47	0.20	211	0.11
4.03	0.56	212	0.20
4.53	0.97	366	0.25
5.01	1.43	771	0.27
5.50	1.96	1012	0.28
6.01	2.64	1095	0.29
6.50	3.43	1203	0.30
6.99	4.28	1251	0.30
7.50	5.31	1189	0.30
8.00	6.37	1218	0.30
8.49	7.45	1031	0.29
8.98	8.66	806	0.28
9.49	9.73	583	0.27
9.98	10.50	390	0.25
10.48	10.84	295	0.22
11.00	11.02	205	0.20
11.50	11.09	150	0.17
11.98	11.10	139	0.15
12.48	11.10	106	0.14
13.00	11.08	97	0.12
13.50	11.05	69	0.11
13.96	11.03	49	0.10
14.47	10.96	24	0.09
15.04	10.87	12	0.08
15.47	10.98	14	0.07



4.0 Acoustic Test Results including Noise label

This is a summary the evaluation of the CF11 wind turbine noise over a range of wind speeds and directions. Characterizations of the turbines apparent sound power level, 1/3 octave bands, and tonality are made.

Acoustic noise data was gathered on five separate days in December 2011. Across all five days, winds ranged from the South to the North West, from 197° to 324°. Meteorological and wind turbine data has been gathered continuously since commissioning of the CF11.

The resulting acoustic performance for normal operation in accordance with the BWEA standard is as follows:

Wind speed dependence	**2.56 dB/m/s**
Immission Sound Pressure Level at 60m Lp60	**53 dBA**
Immission Sound Pressure Level at 25m Lp25	**61 dBA**

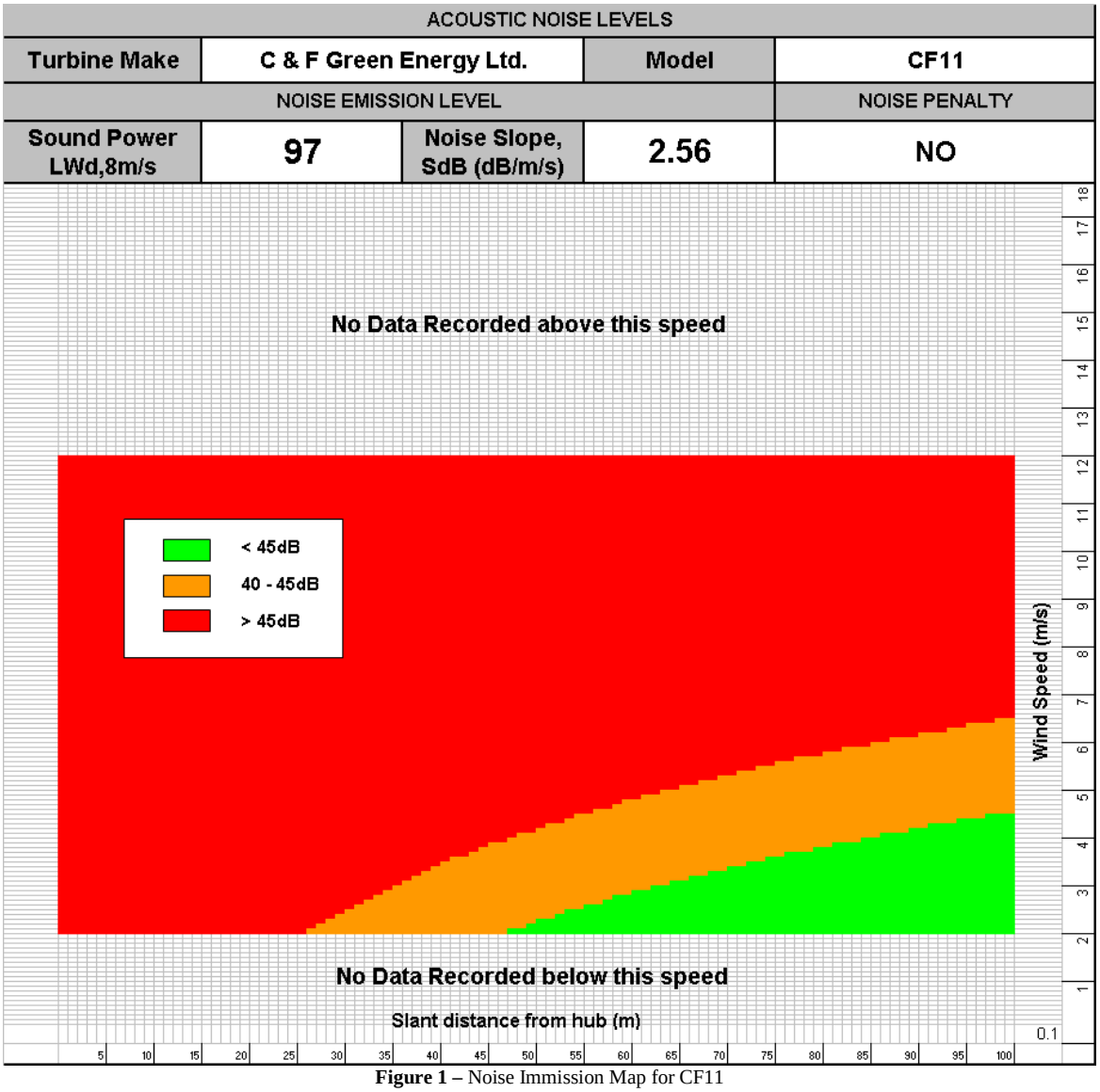


Figure 1 – Noise Immission Map for CF11

5.0 BWEA Reference Annual Energy

Table 2 below summarizes the estimation of expected annual energy production (AEP) at sea-level air density.

Estimated annual energy production, database A (all valid data)					
Reference air density:	1.225	kg/m^3			
Cut-out wind speed:	25.00	m/s			
Hub height annual average wind speed	**AEP-Measured**	**Standard Uncertainty**		**AEP-Extrapolated**	**Complete if AEP-Measured is at least 95% of AEP-Extrapolated**
m/s	**kWh**	**kWh**	**%**	**kWh**	
4	11666	861	7.4	11666	Complete
5	**21530**	**1166**	**5.4**	**21582**	**Complete**
6	31533	1345	4.3	32053	Complete
7	39630	1407	3.6	41703	Complete
8	44909	1390	3.1	49969	Incomplete
9	47477	1326	2.8	56707	Incomplete
10	47925	1240	2.6	61907	Incomplete
11	46921	1145	2.4	65613	Incomplete

Table 2 – Estimated annual energy production of the CF11 at sea-level air density

An indication of "incomplete" in the far-right column of Table 2 does not imply that the database for the test is incomplete. "Incomplete" means that AEP-Measured is not within 95% of AEP-extrapolated. AEP-extrapolated is an estimated extrapolation of annual energy production, where:

- AEP-Measured assumes zero power below cut-in wind speed and between the highest valid wind speed bin and cut-out wind speed, and
- AEP-Extrapolated assumes zero power below cut-in wind speed and constant power between the highest valid wind speed bin and cut-out wind speed.

From the above table:

BWEA Reference Annual Energy **21,530kWh**

6.0 BWEA Reference 60m Sound Level, Lp 60m

From the summary presented in section 4.0 of this report:

BWEA Reference 60m Sound Level, Lp 60m **53 dBA**

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

From the data summarised in the table in Section 2.0 of this report:

BWEA reference output power (11.0m/s) is 11.0kW

The power curve and power coefficient from the same data can be seen in Figure 2 below:

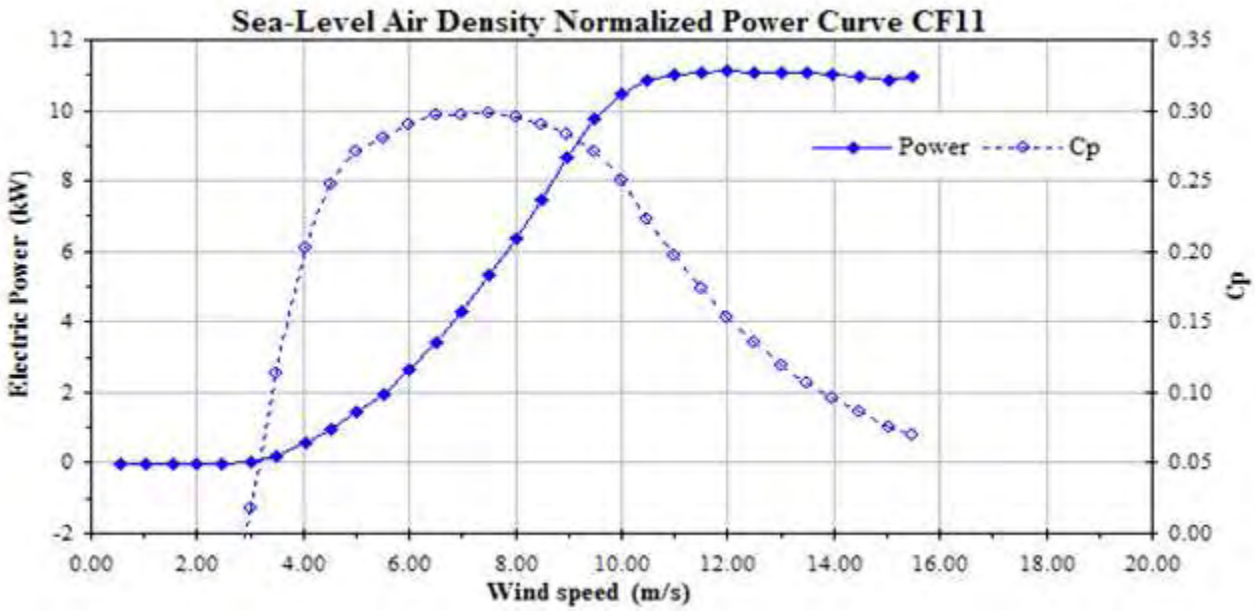


Figure 2 – Power Curve and Power Coefficient at Sea Level Air Density of 1.225kg/m^3

8.0 Strength and Safety Test Results

8.1 Mechanical Safety

The C&F Green Energy design file was evaluated over in the months of July and August 2011. The design file, identified as "CFMCS_2.2" dated 10 August 2011 was the last submission by C&F Green Energy in regards to simplified load model compliance. The design file indicates ultimate and fatigue loading analysis, as well as final material and load factors of safety, for the CF20, CF15, CF11, and CF6 horizontal-axis direct-drive wind turbines. The design file was found to be in compliance with all requirements of the Standards regarding structural integrity. All supporting documentation is maintained within the project file.

Intertek reports 100373741CRT-016, 100373741CRT-021 provide full details of these calculations and analysis

8.2 Visual inspection

The CF11 Foundation was installed according to C&F Green Energy's Standard Operating Procedure *CGFE-SOP_0020 Foundation Installation for 6kW & 11kW Turbines Rev 2.*

Installation and commissioning of the turbines was witnessed by Intertek personnel and was completed in accordance with C&F Green Energy's Technical Document *CGFE-TD-0001 Installation, Operation and Maintenance Manual.*

Following completion of the duration testing, a post-test inspection was performed in accordance with the requirements of *IEC 61400-2 Wind turbines – Part 2:Design requirements for small wind turbines – Clause 9.4.* The results of this inspection are reported in the Intertek Duration Test Report 100373741CRT-029 for the CF11.

No adverse faults, deterioration or malfunctions were recorded during the test period.

No maintenance was performed on the CF11 during the test period.

8.3 Safety and Function

A Safety and Function test in accordance with *IEC 61400-2 Wind turbines – Part 2:Design requirements for small wind turbines – Clause 9.6* was completed. The results of this test are reported in the Intertek Strength and Safety Report 100373741CRT-030

No adverse faults, control problems or safety issues were raised during the observation period.

9.0 Tower Top Loads

Table 3 below summarizes the top tower topple moment and tower data. This data has been supplied by C&F Green Energy

Turbine Class	**Average Wind Speed** V_{ave} (m/s)	**Reference Wind Speed** V_{ref} (m/s)	**50 year Extreme Wind Speed** $Ve50_{Vr}$ (m/s)	**Total Topple Moment (kNm)**
III	7.5	37.5	52.5	311.7
Tower data CF11				
Wind force on Nacelle	1,720 N			
Wind force on blades	12,777 N			
Wind force on Mast	16,673 N			
Mass of Nacelle	2,000 kg			
Mass of Blades	96 kg			
Mass of Tower	2,060 kg			
Tower Height	15 m			
Tower base diameter	755 mm			
Tower top diameter	364 mm			
Sheet steel thickness	6 mm			

Table 3 – Tower Top Loads and Tower data

10.0 Duration Test Summary

10.1 Operational Time

The test turbine system was installed on May 30th, 2011. The system was ready for testing on June 13th, 2011. The duration test was completed on December 13th, 2011, after sufficient data was collected to satisfy the hourly test requirements

10.2 Months of Operation

The duration test was conducted over a period of 6 months, or 183 days, from June 13th, 2011 through December 13th, 2011. The turbines were shut down for post-test inspection on December 13th, 2011.

10.3 Hours of Power Production

Table 4 below indicates the number of power production hours that were observed during the 6 month test duration.

Hours of Power Production IEC SWT Class III – V_{ave} = 7.5 m/s			
Wind Speed	**Measured**	**Required**	**Pass/Fail**
> cut in	2707	2500	Pass
> 1.2 V_{ave}	691	250	Pass
> 1.8 V_{ave}	135	25	Pass
> 15 m/s	64	25	Pass

Table 4 – Duration test hourly power production results for the CF11 turbine

10.4 Operational Time Fraction

The operational time fraction is defined by the following equation:

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

where:

T_T is the total time period under consideration,
T_N is the time during which the turbine is known to be non-operational,
T_U is the time during which the turbine status is unknown, and
T_E is the time which is excluded in the analysis.

The **overall operational time fraction** of the combined wind turbine system in the total test period was **97.1%.** The pass criteria for this parameter is 90% (*IEC 61400-2 Wind turbines – Part 2:Design requirements for small wind turbines Clause 9.4.2.1)* so the CF11 is deemed to **PASS**

(Table 5 below displays the values that were used for determination of overall operational time fraction.

Operational Time Fraction Values	
Variable	**Hours**
T_T	4392.00
T_N	90.50
T_U	12.17
T_E	1223.17

Table 5 – Hourly results for operational time fraction values for the CF11 turbine

The primary reason for wind turbine system downtime during the test period is related to periods of data in which the turbine would be expected to be exporting power, but was instead consuming the typical amount of power needed to remain in a stand-by state (around 60 Watts). This inverter stand-by accounted for all 90.5 hours that was included in T_N.

Intertek report 100373741CRT-029 provides full details of this analysis.

10.5 Environmental Conditions

In order to understand environmental conditions over the testing period, several wind speed statistics were required by the Standard. These values are summarized in Table 6 below.

Environmental Conditions During Test Period	
Description	**Value**
Highest instantaneous wind speed	30.41 m/s
Highest 10-minute average wind speed	24.26 m/s
Average turbulence intensity at 15 m/s	8.2 %

Table 6 – Environmental conditions during test

10.6 Power Degradation

No significant power degradation over the test period at comparable wind speeds was recorded.

Intertek report 100373741CRT-029 provides full details of this analysis

10.7 Dynamic Behavior

During the test period the turbine and tower were observed for any potentially harmful turbine or tower dynamics. The turbine was observed over a wide range of wind speeds. During these observations there was no presence of any observable problems.

10.8 Post-Test Inspection

The post test inspection was performed on December 13th, 2011 and December 14th, 2011. There were no significant findings that would relate to excessive wear, degradation, or corrosion that would lead to potentially harmful situations over the expected 20 year life of the CF11 turbine.