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18 June 2012

Intertek Project 12057516
Report Number 12057516LHD-001

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Subject: Summary Report for the C&F Green Energy CF20 tested at the C&F test location in Ballyspellan, Ireland.

Dear Mr. Young,

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

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

The original 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 31st, 2011. Duration testing was completed on the 13th December, 2011. All testing on the CF20 turbine was conducted under Intertek Project No. G100373741. This Summary Report covers additional testing performed as a 'change to a certified product' under Intertek Project No. G100694490

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

Completed by:	Kevin Sweeney
Title:	Business Development Director
Signature:	

Reviewed by:	Nick Jones
Title:	Consultant Engineer
Signature:	

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C&F Green Energy

Test Report No. 12057516LHD-001
18 June 2012

Wind Turbine Generator System Summary Test Report for the C&F Green Energy CF20





C&F Green Energy

Test Report No. 12057516LHD-001
18 June 2012

Master Reports

Report	Report Title	Date
100373741CRT-016a	Wind Turbine Generator System Duration Test Report for the C&F Green Energy CF20	20 December 2011
100373741CRT-016c	Wind Turbine Generator System Strength and Safety Test Report for the C&F Green Energy CF20	21 December 2011
100373741CRT-026b	Wind Turbine Generator System Acoustics Test Report for the C&F Green Energy CF20	17 February 2012
100694490CRT-001	Wind Turbine Generator System Power Performance Test Report for the C&F Green Energy CF20	8 May 2012



1.0 Background

1.1 General

This Summary Report updates the Power Performance characteristics of the CF20 following additional testing carried out as a result of change to a certified product. The CF20 was installed at the C&F Green Energy testing location in Ballyspellan, Ireland, and was tested alongside two other C&F Green Energy turbines; the CF11, and CF15. Testing was performed in March and April 2012.

All other testing was conducted as part of the full MCS Certification test program for the C&F Green Energy CF20 horizontal-axis wind turbine completed in December 2011.

The power performance data contained within this summary covers the performance of the 3 phase CF20 fitted with the Gendrive Totus Inverters.

1.2 Changes to the Certified Product

The C & F Green Energy CF20 is currently the Subject of MCS Certification (Intertek Certificate nos. INT WT20880/1, INT WT 20880/2 & INT WT20880/3). This report has been issued to detail changes to the Certified Product and has been prepared in accordance with the requirements of the BWEA Small Wind Turbine Performance and Safety Standard (2008), Section 8 as detailed below:

- 8.1.1 Changes to the BWEA Reference Annual Energy are detailed in Section 5.0 of this report and will be the subject of re-certification.
- 8.1.2 A limited study of the Acoustics performance is currently being undertaken to determine whether or not the original data (here reproduced in Section 4.0) remains valid for this configuration. Further investigation and re-certification may be required.
- 8.1.3 No changes have been made which could reduce strength and safety margins by 10%, or increase operating voltages and current by more than 10%. Hence the original Wind Turbine Generator System Strength and Safety Test Report is still applicable, re-certification is not required.
- 8.1.4 No changes have been made which could materially affect the results of the Duration Test. Hence the original Wind Turbine Generator System Duration Test Report is still applicable, re-certification is not required.

1.3 Description of the wind turbine

The CF20 is designed for grid-connected power delivery, with a manufacturer's declared rated power output of 20 kW. The CF20 is an upwind turbine with active speed and power control through active blade pitch actuation and turbine yaw control. The CF20 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 and the output configuration of the CF20 tested in Ballyspellan was three phase. 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	CF20
Production Year	2 nd Quarter, 2011
Rotor Diameter	13.1 m (42 ft) – Verified by Intertek to be 13.1 m with calibrated tape measure
Hub Height	20.1 m (66 ft)
Swept Area	134.8 m ² (1451 ft ²)
IEC 61400-2 SWT Class	III ($V_{ave} = 7.5$ m/s)
Test Tower Type	Tubular
Rated Electrical Power	20000 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 – 110 RPM
Generator Identification	CFGE 20kW
Generator Specification	Direct coupled to rotor, maximum design speed 400 RPM, 56 Hz, 485VAC, 3 plate
Inverter Identification	Gendrive Totus Wind 3 10 (Qty 2) Serial Numbers : 100000046, 100000026
Inverter Specifications	14000W peak, 50 Hz, 230 VAC, IP 44 CE, EN50178, EN61000-6-2, EN61000-6-3, EN61000-3-3, EN61000-3-12, G59/2, EN 50438 Processor software revision: SC_001_00500_Rev1_18 Configuration software revision: SC_001-00002_Rev2_22 User files: CF_20_Master_v1.txt CF_20_Slave_v1.txt
Controller Identification	CFGE controller
Controller Specification	CFGE turbine controller 24v volt DC UPS battery back-up PIC embedded control system
Control Software Version	CFGE V1.00
Number of Blades	3
Fixed or variable pitch	Variable
Blade Pitch Angle	Variable
Blade Identification	CFGE-BS-6-0008 SN – 38, 39, 44
Blade Specification	Composed of a mix of glass and carbon fibre infused with vinylester, polyurethane foam core with double spar, 16° twist from root to tip

Table 1 – Test Turbine Configuration



2.0 Objective

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

Section	Summary Results	Reference,
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 CF20

Sea-Level Density Power Curve

Report Created: 8-May-2012

Turbine Specifications:

Rated power	20.56	kW
Cut-in wind speed:	2.5	m/s
Cut-out wind speed:	25	m/s
Rated wind speed	11	m/s
Rotor diameter:	13.1	m
Rotor swept area	134.8	m ²
Control type:	Active	
Pitch setting:	Variable	

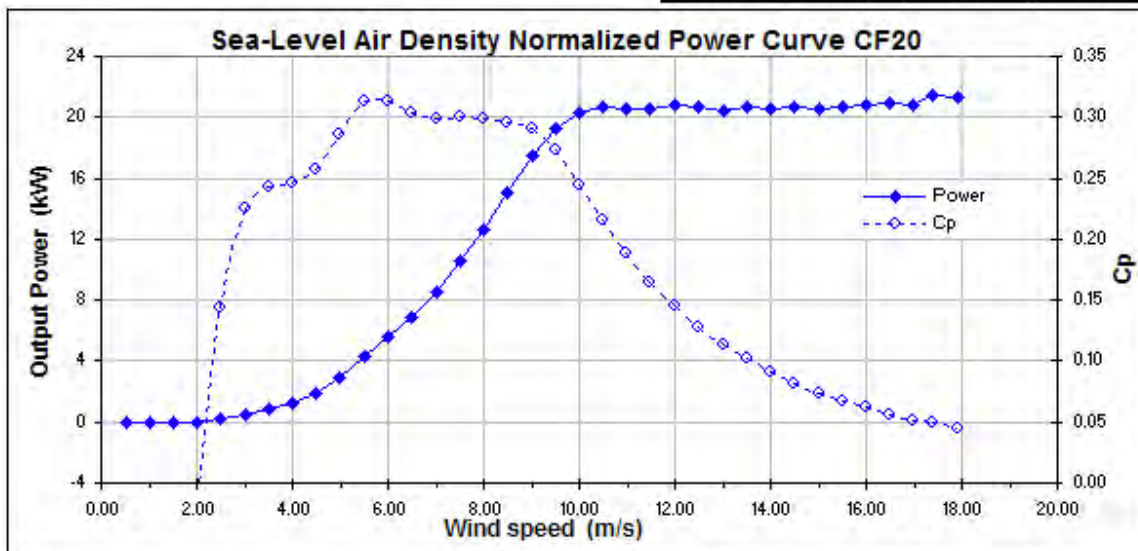
Site Conditions:

Location:	Ballyspellan, Ireland
Average air density:	1.217 kg/m ³
Measurement sectors:	190 - 290 °True

Test Statistics:

Start date:	1-Mar-2012	
End date:	29-Apr-2012	
Amount of data collected:	317.17	Hours
Highest bin filled:	18	m/s
Test completed?	YES	

Bin Wind Speed (m/s)	Bin Power (kW)	Number of Data Points	Cp
0.55	-0.06	49	-4.43
1.04	-0.06	139	-0.67
1.53	-0.06	310	-0.20
2.01	-0.01	477	-0.02
2.50	0.19	516	0.14
3.02	0.51	705	0.23
3.51	0.86	1022	0.24
3.99	1.30	1067	0.25
4.50	1.92	823	0.26
5.00	2.95	684	0.29
5.51	4.31	783	0.31
5.99	5.55	833	0.31
6.50	6.87	812	0.30
7.01	8.50	845	0.30
7.51	10.53	1052	0.30
8.00	12.65	1087	0.30
8.50	15.02	993	0.30
9.00	17.48	895	0.29
9.50	19.28	788	0.27
10.00	20.24	789	0.25
10.50	20.64	719	0.22
10.99	20.56	653	0.19
11.48	20.50	519	0.16
11.99	20.75	397	0.15
12.51	20.73	321	0.13
13.01	20.47	291	0.11
13.50	20.67	282	0.10
14.00	20.57	255	0.09
14.51	20.72	277	0.08
15.01	20.58	203	0.07
15.50	20.68	180	0.07
15.98	20.84	104	0.06
16.51	20.94	63	0.06
16.98	20.82	47	0.05
17.40	21.44	29	0.05
17.92	21.30	21	0.04



4.0 Acoustic Test Results including Noise label

New data for Acoustics Tests with the Gendrive inverter has been collected but analysis not yet completed. The data below refers to the evaluation of the CF20 with Aurora inverters and should be considered as indicative only with respect to the Gendrive inverter configuration.

This is a summary of the evaluation of the CF20 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 three separate days in January 2012. The wind direction varied from East to South (89° to 166°). Meteorological and wind turbine data has been gathered continuously since commissioning of the CF20.

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

Wind speed dependence **2.97 dB/m/s**

Immission Sound Pressure Level at 60m $L_{p,60m}$ **45 dBA**

Immission Sound Pressure Level at 25m $L_{p,25m}$ **53 dBA**

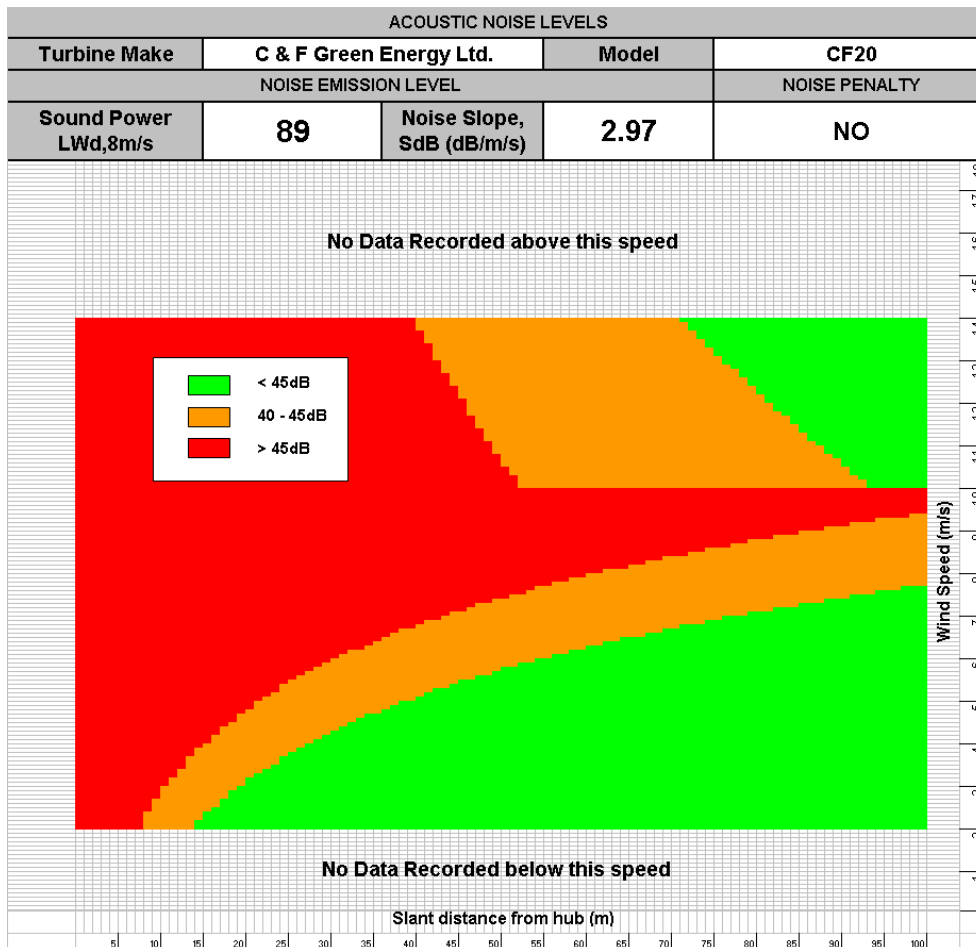


Figure 1 – Noise Immission Map for CF20

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 m/s	AEP- Measured kWh	Standard Uncertainty		AEP- Extrapolated kWh	Complete if AEP-Measured is at least 95% of AEP- Extrapolated
		kWh	%		
4	24670	1557	6.3	24670	Complete
5	43799	2236	5.1	43807	Complete
6	63475	2704	4.3	63643	Complete
7	80638	2966	3.8	81712	Complete
8	93578	3075	3.3	97111	Complete
9	101817	3077	3.0	109661	Incomplete
10	105783	3004	2.8	119369	Incomplete
11	106348	2884	2.7	126305	Incomplete

Table 2 – Estimated annual energy production of the CF20 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 43,799kWh

6.0 BWEA Reference 60m Sound Level, $L_{p,60m}$

From the summary presented in section 4.0 of this report:

BWEA Reference 60m Sound Level, $L_{p,60m}$ 45 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 20.56kW

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

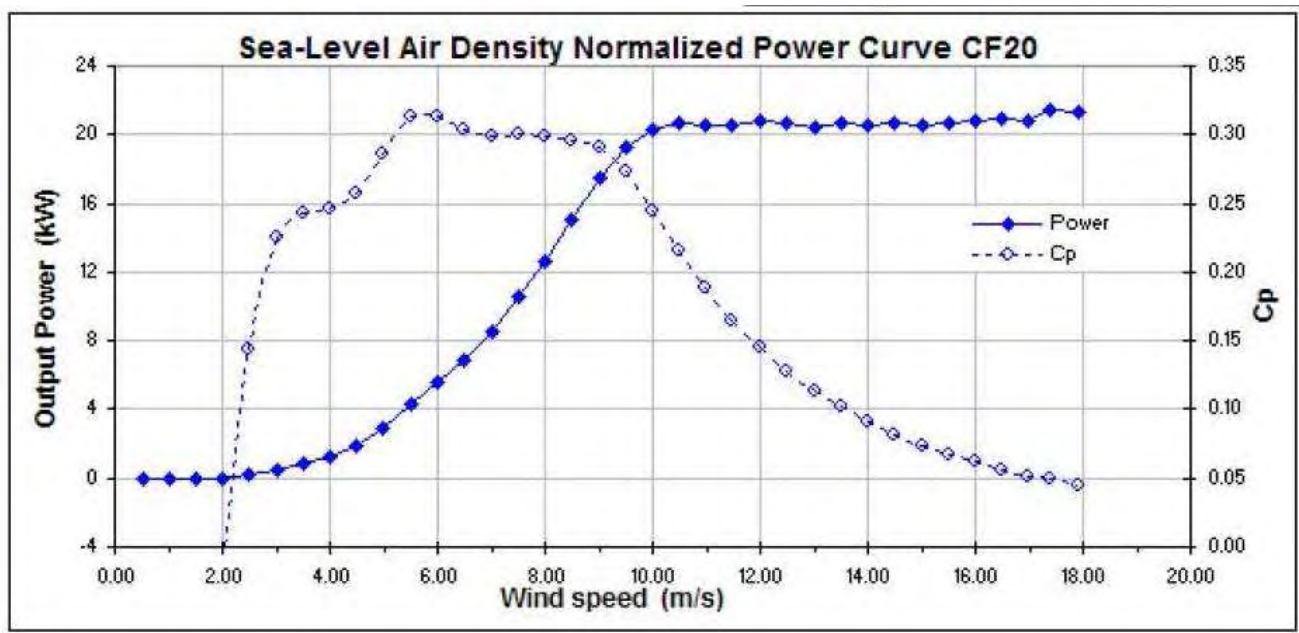


Figure 2 – Power Curve and Power Coefficient at Sea Level Air Density of 1.225kg/m³



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 CF20 Foundation was installed according to C&F Green Energy's Standard Operating Procedure *CGFE-SOP_082 Foundation Installation for 15kW and 20kW 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, 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-016b.

No adverse faults, deterioration or malfunction due to wind turbine performance were recorded during the test period.

No maintenance was performed on the CF20 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 Test Report 100373741CRT-016c.

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 V_{e50} (m/s)	Total Topple Moment (kNm)
III	7.5	37.5	52.5	786
Tower data CF20				
Wind force on Nacelle	1,720 N			
Wind force on blades	27,900 N			
Wind force on Mast	25,110 N			
Mass of Nacelle	2,200 kg			
Mass of Blades	320 kg			
Mass of Tower	3,700 kg			
Tower Height	20 m			
Tower base diameter	877 mm			
Tower top diameter	364 mm			
Sheet steel thickness	8 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	2696.5	2500	Pass
> 1.2 V _{ave}	746.7	250	Pass
> 1.8 V _{ave}	185.7	25	Pass
> 15 m/s	95.2	25	Pass

Table 4 – Duration test hourly power production results for the CF20 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 **96.7%**. 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 CF20 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	4392.0
T _N	100.8
T _U	291.7
T _E	1041.7

Table 5 – Hourly results for operational time fraction values for the CF20 turbine

The primary reasons for wind turbine system downtime during the test period are 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 120 Watts), and grid anomalies that prevented proper export of power. The inverter stand-by accounted for 99 hours of the 100.5 hours that was included in T_N.

Intertek report 100373741CRT-016a 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	34.98 m/s
Highest 10-minute average wind speed	24.14 m/s
Average turbulence intensity at 15 m/s	7.88%

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-016a 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 CF20 turbine.