Wind Turbine Generator System Pika T701

Safety and Function Test Report

Conducted by

High Plains Small Wind Test Center
Colby, KS

August, 2015

Approval By: ______ **August, 2015 _______**

Ruth Douglas Miller, Lead Engineer, Date

Review By: ____

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1. Background

The Pika Wind T701 small wind turbine was tested in accordance with AWEA (American Wind Energy Association) Small Wind Turbine Performance and Safety Standard (AWEA Standard 9.1 – 2009) and IEC (International Electrotechnical Commission) 61400-2 ed 2.0 (2006-03) Wind Turbines Part 2: Design requirements for small wind turbines. This test report refers to these procedures collectively as the Standard.

Testing of the Pika T701 was conducted under contract as part of NREL's Regional Test Center (RTC) program.

2. Test Summary

The Pika T701 is a three bladed, Horizontal Axis Wind Turbine. It has a 3m diameter rotor resulting in a rotor swept area of 7.1 m2; peak power is 1.7kW and power at 11 m/s is 1.5kW. The data presented in this report was collected during a power performance test conducted at High Plains Small Wind Test Center ("High Plains SWTC") in Colby, KS from July 2014 through April, 2015.

This test was conducted in accordance with the International Electrotechnical Commission's (IEC) standard, Wind Turbines Part 2: Design Requirements for Small Wind Turbines, IEC 61400-2 Ed.2.0, 2006, part 9.6. The additional requirements of AWEA (American Wind Energy Association) Small Wind Turbine Performance and Safety Standard (AWEA Standard 9.1 – 2009) were also considered.

The following deviations from the Standard were taken during this test (details in Section 9): 1) The temperature probe is located at the DAQ box, 1.5m above ground and 15.4m below turbine hub height to keep it out of direct sunlight. The uncertainty associated with this move is included in the uncertainty calculations; it comes to 0.2°C. 2) A calibration certificate for the temperature sensor was not available at start of test; the sensor will be calibrated at end of test. 3) The pressure sensor is located on the met mast also at the instrument box, about 1.5m above ground. The air pressure was corrected for elevation according to the Standard. 4) The distance between turbine and met tower is 0.3m outside the Standard-specified 2-4D distance. The turbine and met tower foundations had been installed for a slightly larger turbine. We placed the primary anemometer on the leg of the tower closest to the turbine, so the exact distance between primary anemometer and turbine hub is 12.17m = 4.05 D. 5) The Ohio Semitronics power transducer does not have documents showing that it meets the IEC 60688 class 0.5 requirements. However documents from OSI show that the power transducer meets the minimum accuracy requirements of the Standard; this does not affect results or uncertainty. 6) Manufacturer's designed turbine shut down conditions of wind over 30 m/s, high temperature and high vibration were not tested because these conditions did not occur during the test period.

3. Test Turbine Configuration

The data presented in this report were collected during tests conducted from July 2014 through April, 2015 at the High Plains Small Wind Test Center in Colby, Kansas. The Pika Energy T701 model specifications are summarized in Table 1. This turbine will be referred to as the Pika T701 for the rest of this report. The turbine has a direct-drive, permanent-magnet generator which can be braked using back-EMF, and a single-use emergency centripetal brake that is factory-tested before each turbine is shipped. A photo of the Pika T701 turbine and met tower is included as Figure 1; Figure 2 shows the turbine rotor up close with a tape measure verifying radius as 1.51 m (diameter 3.0 m). For this test the turbine was installed on a 16.8m guyed tower.

Figure 1. Pika T701 turbine installed at High Plains Small Wind Test Center, met tower behind; view is towards the northwest.

Table 1. Summary of Pika T701 published specifications. *: rotor diameter was verified manually by measuring the radius of the rotor when it was on the ground.

Parameter	Value	Units
Manufacturer and address	Pika Energy Inc 35 Bradley Dr Stop 1 Westbrook, ME 04092	
Turbine Serial Number	T701-00021	
Inverter Serial Number	X3001-00044	
Production Date	2014	
Tower Type	Guyed monopole	
Tower Height	16.8	m
Hub Height	16.94	m
Blade make, type, serial number	Pika Energy, glass-filled polypropylene, no serial number	
Turbine Control System	Pika Energy proprietary	Software v. 1030
Turbine Interface	Pika Energy Review (via	

	inverter)	
Rotor Diameter	3.0*	m
Rotor Swept Area	7.1	m^2
Blade Pitching	Fixed	
11m/s Reference Power (REbus DC)	1.6	kW
11m/s Reference Power (AC after inverter)	1.48	kW
Cut-in Wind Speed	3.0	m/s
Rated Wind Speed	11	m/s
Rated Rotor Speed	420	RPM
Speed Regulation Type	Stall regulation w/ redundant mechanical brake	
Yaw Control	Passive, upwind with tail	
IEC Turbine Design Class	II	
Turbine DC Output Voltage (nominal)	380	V
Turbine Max Output Current	7	A
Inverter Output Voltage	220/240	VAC
Inverter Output Current Max	13	A
Inverter Output Frequency	60	Hz

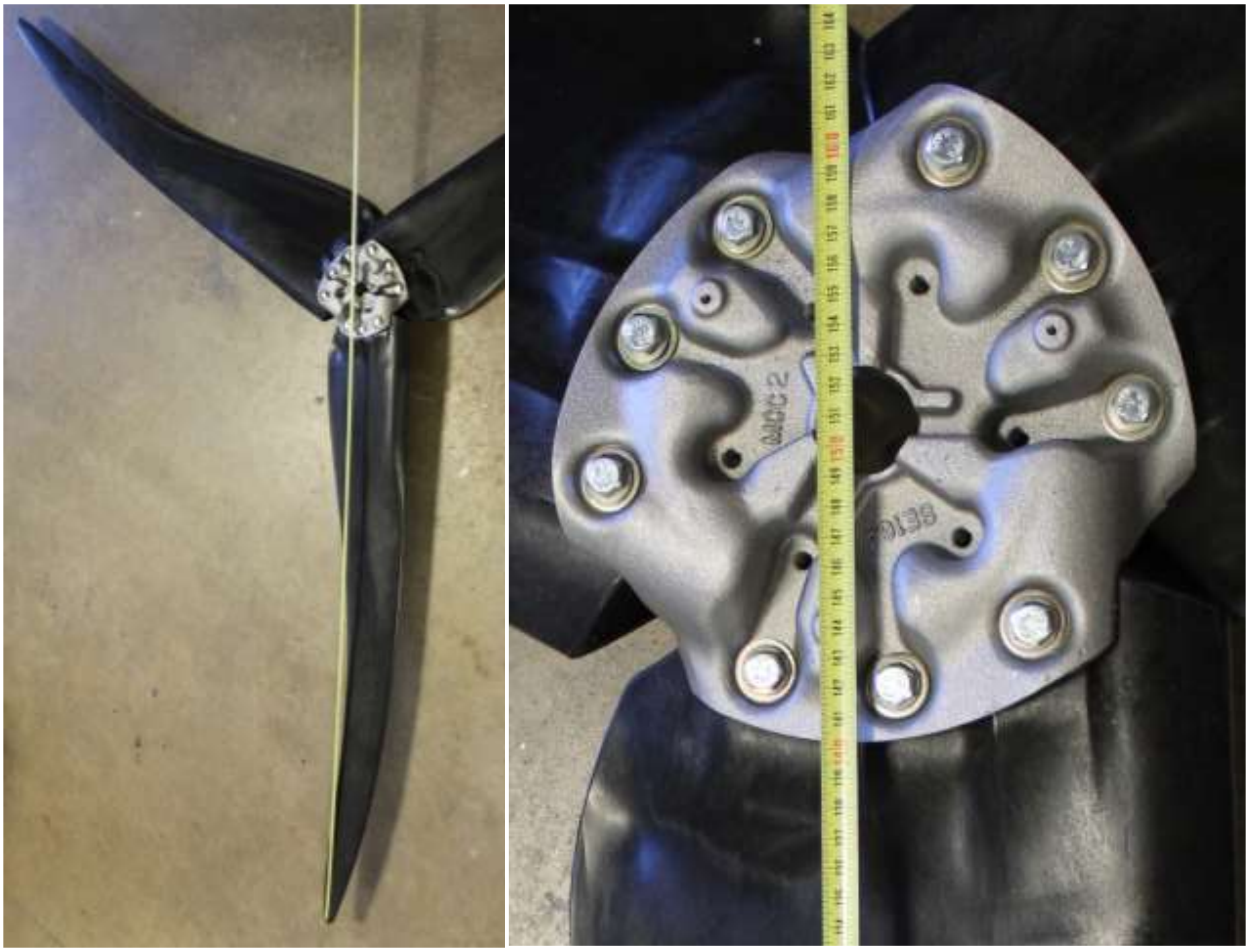


Figure 2. Pika T701 rotor showing radius measurement

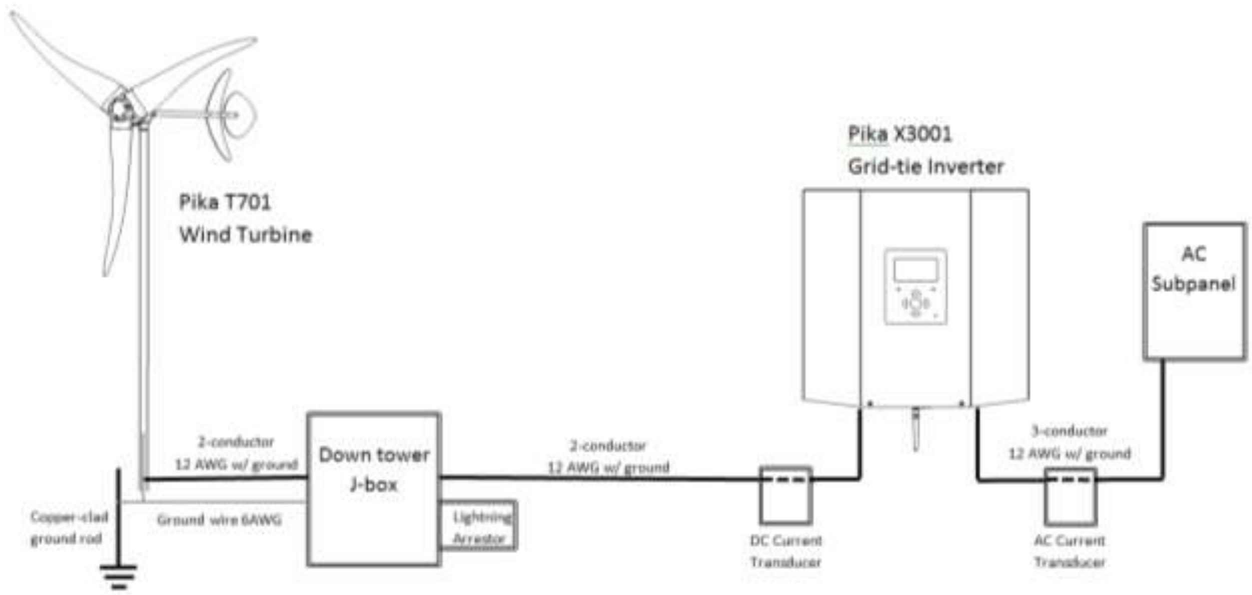


Figure 3. Wiring diagram for Pika T701 turbine and inverter installation, from Pika literature.

A one-line diagram of the installation wiring for the turbine is shown in Figure 3. The Pika T701 was connected to the Pika X3001 grid-tie inverter via Pika's REbus DC Microgrid technology (internal to the inverter in Fig. 3) operating at approximately 380VDC, in accordance with the Pika T701 installation manual. The Pika X3001 inverter was connected to the electric utility at a nominal voltage of 240VAC and frequency of 60Hz. The inverter electrical connection to the grid was done in accordance with the Pika X3001 Installation manual. Wiring between the tower top and the inverter were provided by Pika Energy and installed as part of the turbine system. Specifications for the installed wires from the tower base control panel to the grid point of common connection (PCC) are listed in Table 2. The total length of the wire run was approximately 65 meters.

The Pika T701 has a nominal rated power of 1.8kW at 11 m/s per the user manual. At winds above design wind speed (11 m/s), the REBus controller controls generator torque to regulate speed and thus output power. The inverter shuts off at loss of grid or when the "disable" function is used at the inverter front panel. It will also shut down upon any fault condition including very high wind (>30 m/s), high temperature, or excessive vibration (such as due to imbalance from icing.) A redundant centripetal overspeed safety brake will deploy should primary control fail; this brake is a single-use part, individually factory-tested before shipping, and must be replaced by field-qualified personnel.

Table 2. System wiring summary

Segment	**Type**	**Approx. length**
Turbine to tower base junction box	AWG-12 Type UF, 2 conductor + ground	16.9m
Tower base junction box to inverter	AWG-12 Type THHN, 2 conductor + ground	48m, compliant with AWEA minimum 8 rotor diameters
Inverter to subpanel	AWG-12 Type NM-B	2m

4. Test Site Description

The test site is located about 1 mile south and two miles west of the town of Colby, KS. It is essentially flat with no obstructions. Prevailing winds measured at the test site are from the north in winter, south in summer (see wind rose in Fig. 7); the average wind speed at 30m is over 7 m/s. Figure 4 shows an aerial view of the site, perimeter outlined in red. Figure 5 is a panoramic photo montage of the site from the base of the Pika turbine tower. Figure 6 shows a plot of the turbines, obstacles and data shed positions to scale. The turbine is located 122.3m east and 30m north of the SW corner of the site. Other obstacles on the property and their locations are listed in Table 3 below. A gravel road forms the property's southern border; the other borders are farm implement tracks.

Figure 4. Aerial view of High Plains SWTC (Google Maps). Red outlines the field allocated to the Test Center; arrows indicate the SW corner of the site (0,0) and the location of the datashed.

A summary of the test site conditions is listed in Table 6. The High Plains Small Wind Test Center annual wind rose in Figure 9 illustrates that wind on-site tends to come from the north-northwest and south-southeast.

Figure 5. Panoramic photo from Pika turbine base. Green lines mark western (≥238°-≤301°) exclusion sector and black lines mark eastern (≥60°-≤120°) exclusion sector. Red line marks power pole at SW corner of site. Data shed is due East, lattice met tower is due West, sun glare is at about 150°E. Apparent roll of horizon is a photographic artifact.

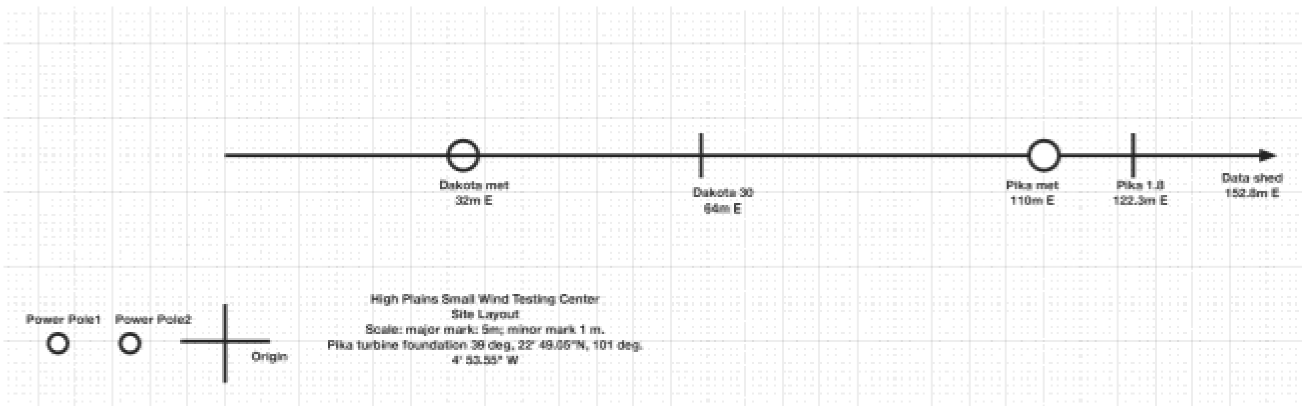


Figure 6. High Plains SWTC Site Layout, to scale. For text see Table 3 below.

Table 3. Structures on and near test site.

Structure	Height	East Coordinate (m)	North Coordinate (m)
Pika T701	16.9m	122	30
Pika met	16.9m	110	30
2nd turbine	30.48m	64	30
2nd met	30.38m	32	30
Power pole 1	10m	-13.4	0
Power pole 2	10m	-12.4	0
Data shed	3m	152.8	30

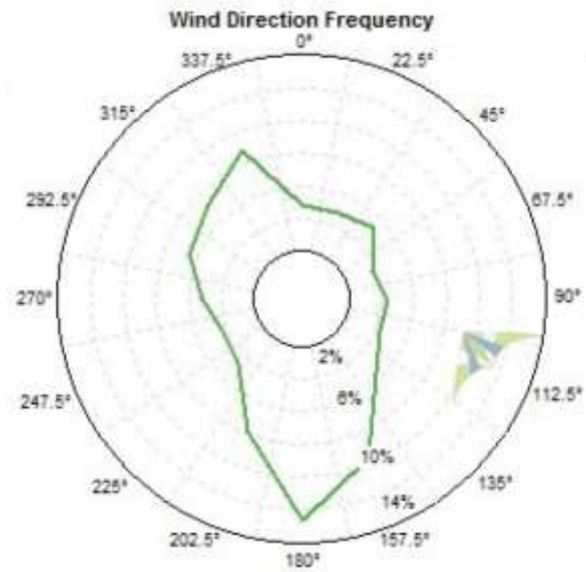


Figure 7. Wind rose for High Plains SWTC for the period May 2014-May 2015.

Figure 8. Aerial view of High Plains SWTC, from USDA/Google. Red box: initial SWTC area. Yellow box: 51-acre plot allotted to Test Center by KSU Agricultural Extension. Orange lettering indicates lengths of longest dimensions of yellow box.

5. Description of Test Equipment

All test equipment was calibrated except the temperature sensor (see Exceptions); calibration sheets are included in Appendix A. Table 4 shows the equipment used and calibration due dates. Figure 9 shows placement of the meteorological instruments on the met mast (note that one wetness sensor is employed for the entire site and is located outside the data shed, not on the met mast).

Since the pressure transducer is not located near hub height, the measured air pressure is corrected for pressure gradient in accordance with ISO 2533. According to ISO 2533 the gradient in the pressure at 1850m is 0.09996 mbar/m3. The hub height for the Pika701 is 16.94m, and the height of the pressure sensor is ~1.5m above ground level, which is a difference of 15.44m. Thus the correction is 0.09996 mbar/m*15.44m = 1.543mbar (0.154kPa).

The Data Acquisition System is comprised of National Instruments modules and LabVIEW programming. The National Instruments cards and chassis were located in the site's data shed, as was the computer running the LabVIEW VI. The power transducer measures power inside the data shed next to the kWh meter and breaker box shown in the one-line diagram of Figure 4.

End-to-end checks were conducted on all data channels and results are listed in the turbine commissioning report.

Relevant data for this test include wind speed (primary and secondary), electrical power and temperature. Grid voltage and RPM could be directly measured by the inverter, but a Labview program provided by Pika to pull those data into the primary program could not be made to work well—both programs would crash. So RPM data and grid voltage for those tests where they were needed were obtained separately from Pika's remote monitoring database. Both Pika's monitoring and the on-site Labview program use the internet's clock so data are synchronous; for tests of braking system clocks were checked by voice between Pika and test site engineers on the telephone at the time of test.

Table 4. List of instrumentation

Channel	Instrument	Make & Model	Mfger Accuracy	Calibration Dates
Primary wind speed	Anemometer	NRG 1^{st} Class Ser #596700001838	+/-0.06 m/s @ 10m/s	13 Nov, 2013
Turbine power output	AC Watt transducer	Ohio Semitronics PC5-059EY25 Ser #11110431	+/-0.5% of full scale (=2kW)	23 Oct, 2013
Wind direction	Wind Vane	NRG #200P	1%	N/A
Turbine Status	Internal to Pika Inverter	Download from Pika web server	N/A	N/A
Reference wind speed	Anemometer	NRG #40H Ser. # 17970000907	1.48%	31 Oct, 2013
Air Pressure	Pressure sensor	NRG BP20 Ser. #180512465	+/- 0.218 kPa	15 Nov, 2010
Air Temperature	Temperature sensor	NRG #110S Ser. #3365	+/- 1.1 °C max	N/A
Rain	Wetness sensor	Novalynx 260-2590	N/A	N/A
Rotor speed	Status signal from Pika	Pika	0.003% (miss 1 click	N/A

	powerline data carrier		in 84/rev)	
Temperature and Pressure	DAS	NI-9205 (voltage: WS channel)	3,230 µV	28 Oct., 2013
Current (power transducer)	DAS	NI-9203	+/-0.18% slope +/- 0.06% offset	28 Oct., 2013
Wind Speed	DAS	NI-9421	digital	N/A

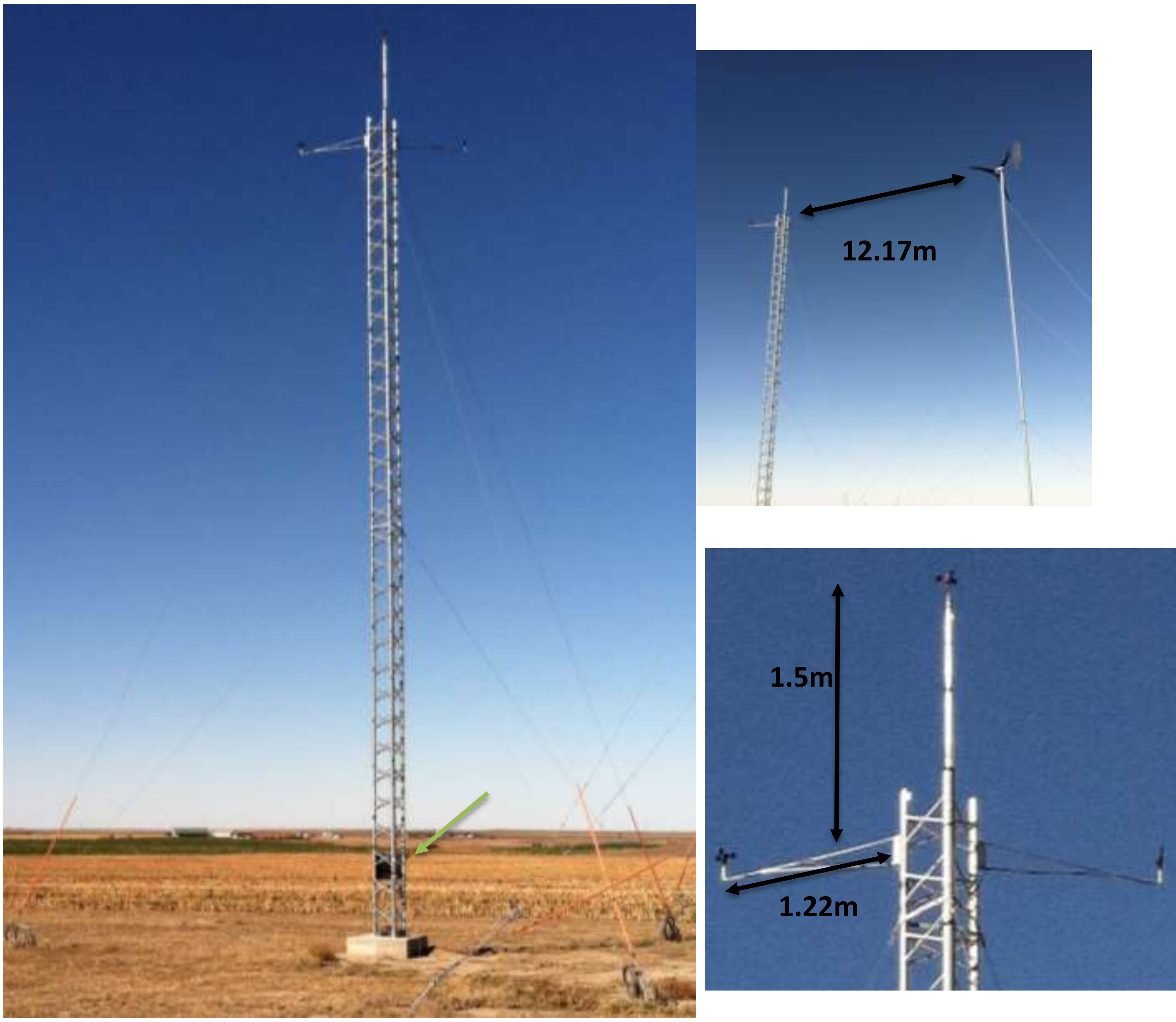


Figure 9. Photographs and measurements of met tower and Pika T701 turbine on High Plains SWTC site. Close-up shows primary anemometer on top, secondary to left and wind vane to right. Air pressure and temperature sensors are located at the black box at the base of the met tower, 1.5m above ground (green arrow). The met tower is a triangular Rohn 25G tower, center-to-center leg spacing 12.5”= 0.3175m, tube diameter 1.25” = 3.175cm. The center-to-center spacing between met tower and turbine tower is 12.3m = 4.1 turbine diameters; however, the primary anemometer is mounted on the leg closest to the turbine tower, so the exact distance between primary and turbine hub is 12.17m = 4.05 D. The primary anemometer is centered at turbine hub height, 16.94m.

6. Description of Test Procedure

The test was conducted with procedures designed to meet the Standard. None of the safety and function tests placed operators in unusual risk; shutdown tests that might risk the turbine hardware were conducted with Pika personnel monitoring turbine health remotely through the inverter.

The Pika T701 was installed and operated in a standard mode, and its configuration was not altered during the test. No alterations to the turbine (e.g. pitch angle) were made to compensate for reduced air density at the test site. A test log was kept to record maintenance and other events relating to testing the Pika T701.

Test Objectives

The objectives of the Safety and function test are to:

- verify that the turbine displays behaviour as predicted by design and in the user manual
- determine if provisions related to personal safety are implemented, and
- characterize the behaviour of the turbine in all wind speed conditions.

The AWEA Small Wind standard specifies that the turbine be observed for dynamic interactions between it and its tower, in particular watching for resonance behaviour at various wind speeds. Other safety aspects of the turbine shall be evaluated, including:

- procedures used to operate the turbine;
- provisions to prevent dangerous operation in high wind;
- methods to slow or stop the turbine in an emergency or for maintenance;
- adequacy of maintenance and component replacement provisions; and
- susceptibility to harmful reduction of control function at lowest claimed operating ambient temperature.

In addition, IEC 61400-2 ed.2 specifies that the following behaviours shall be tested:

- power and speed control,
- yaw control (turbine aligns with wind),
- designed behaviour on loss of load,
- overspeed protection at designed wind speed and above, and
- start-up and shut-down above design wind speed.

Measured Data

All measurements were sampled at a rate of 1 Hz. These data were then averaged into 1-minute or 10-minute mean and standard deviation and logged. The 1-minute or 10-minute minimum and maximum are also logged and are based on 1-second readings. In addition to automatically collected data, extensive field notes were logged and are included in this report as appropriate. Some data were analyzed in Excel; some analyses were performed in Windographer v. 3.3.7.

Procedures

- Dynamic tower interaction, yaw control, general operation, shut-down for maintenance: the turbine was observed regularly while operating at different wind speeds, turned on and off according to manual directions, and notes made in the log book.

- Loss of load: the grid connection was manually broken through the breaker switch and turbine manual directions were followed to restart, with notes in the logbook. A video was made of this test, while wind speeds were over 12 m/s; it is posted on the High Plains test center website here: http://wac.ece.ksu.edu/?q=node/28
- Cold temperature behaviour: check data for temperature, wind speed and turbine power through cold periods. Confirm with observation of turbine in cold weather, with notes in logbook.
- Behaviour in high wind: data collection through high wind periods combined with observation notes in log book and time-correlated RPM data from the manufacturer.
- Manual shut-down in high wind: during a period of wind over 12 m/s, with the Labview program collecting one-minute data, a video was made of the turbine while it was shut down using the manual disconnect; simultaneously but separately, the turbine RPM was recorded. The video is posted on the High Plains test center website here: http://wac.ece.ksu.edu/?q=node/28
- Emergency shut-down: each centripetal brake is tested by Pika in the shop before each turbine is shipped.
- Maintenance and component replacement: the user manual recommends only visual and auditory inspection yearly for the first 10 years of operation. These observations were carried out at the test site as part of acoustic and safety-and-function testing.
- Personnel safety measures: verify that owners' and installation manuals agree with hardware; check labelling and compare with expected use, that the turbine is safe to operate.
- Designed automatic shutdowns due to wind over 30m/s, high temperature and vibration were not tested as these conditions were not encountered during the test period (see Exceptions). While the turbine was on line, the highest 10-minute average wind speed encountered was 18.4 m/s; the highest gust encountered was 25.6 m/s; and the highest temperature recorded was 42°C (over 40°C for over 7 hours)

7. Test Results

General operation: During the entire period, daily observation saw no unusual tower or turbine vibration or failure to yaw. The turbine was turned off for background acoustics measurements and it nearly always shut down and came back up as expected. When inverter shutdown via control panel failed, grid disconnection by opening the main breaker did stop the turbine. Logbook notes on 8, 13, 14, 15 August, 16, 19 September, 27, 30 October, 22 December all state that the turbine shut down and restarted as expected without incident. Exceptions: 20 August, 21 October (Fig. 10), it was necessary to cut the grid power; inverter disable did not work. Pika believes the problem is at the inverter, not the turbine itself. Later on 21 October, inverter disable did work (Figs. 11, 12).

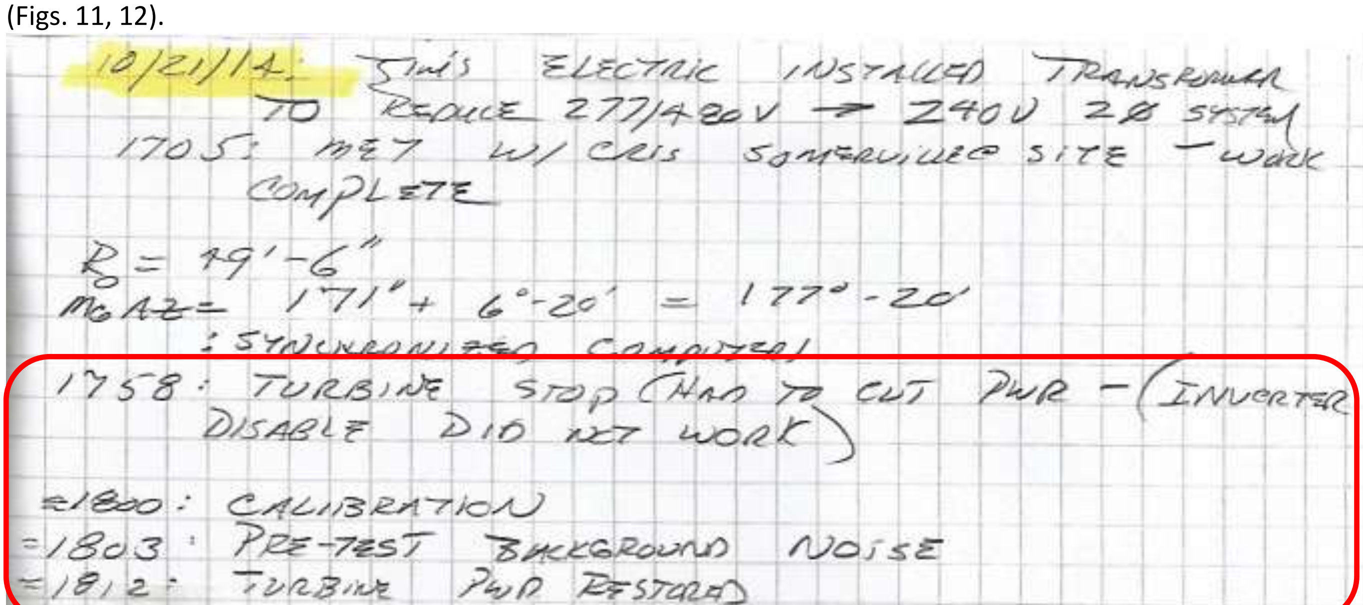

10/21/14: JIM'S ELECTRIC INSTALLED TRANSFORMER
TO REDUCE 277/480V → 240V 2Ø SYSTEM
1705: MET W/ CRIS SOMERVILLE SITE — WORK
COMPLETE
R = 49'-6"
MG AZ = 171° + 6°-20' = 177°-20'
: SYNCHRONIZED COMPUTER!
1758: TURBINE STOP (HAD TO CUT PWR — (INVERTER
DISABLE DID NOT WORK)
≈1800: CALIBRATION
≈1803: PRE-TEST BACKGROUND NOISE
≈1812: TURBINE PWR RESTORED

Figure 10. Field notes on 21 October: inverter shutdown did not work but loss of grid did; restart worked.

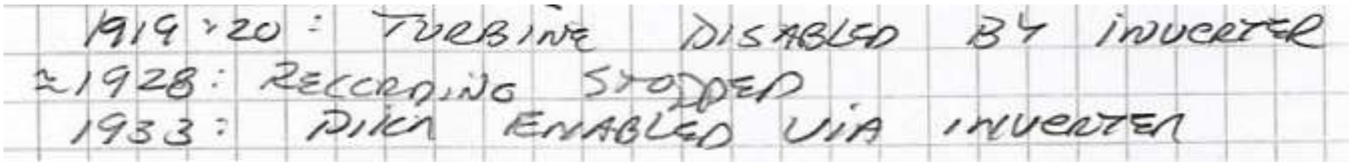


Figure 11. Field notes, 21 October: later, inverter shutdown and restart worked properly.

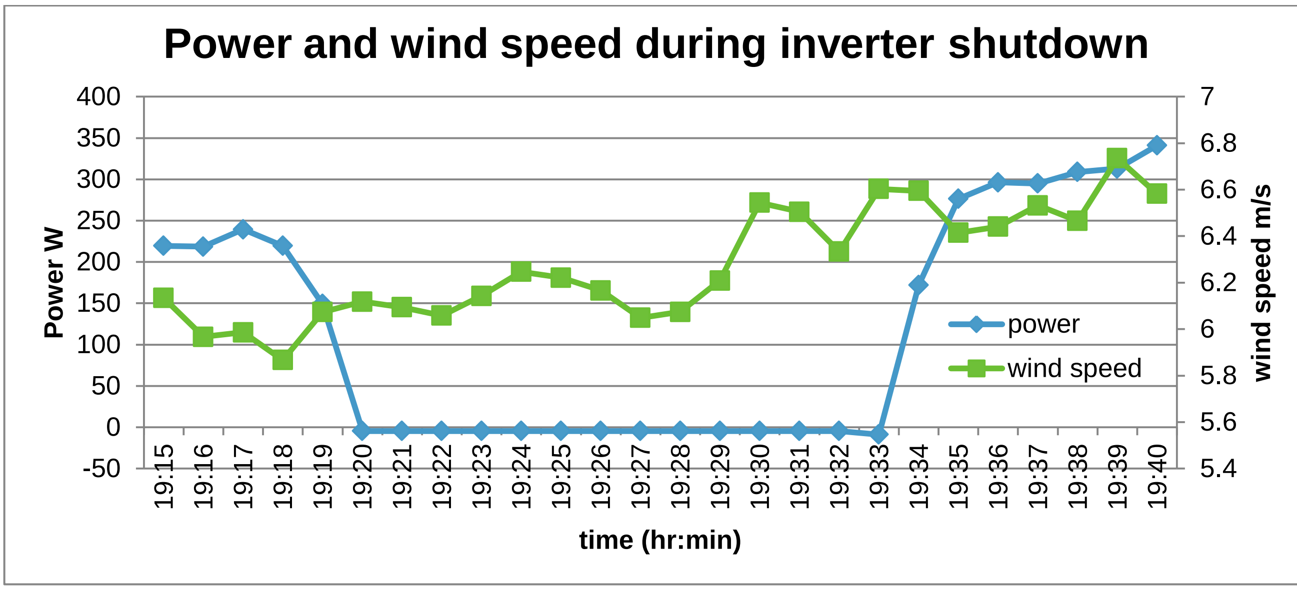


Figure 12. Time trace of power (left axis, blue diamonds) and wind speed (right axis, red squares) during shutdown at inverter, 21 October.

Loss of load: Besides the high-wind shutdown noted below the Pika T701 was shut down by opening the electric breaker at various times. Figure 10 notes one time when this method had to be used because the inverter switch did not work. Figure 13 records wind speed and turbine power from 5:45pm to 6:25pm on 21 October. Shutdown information with RPM data are described under high-wind shutdown.

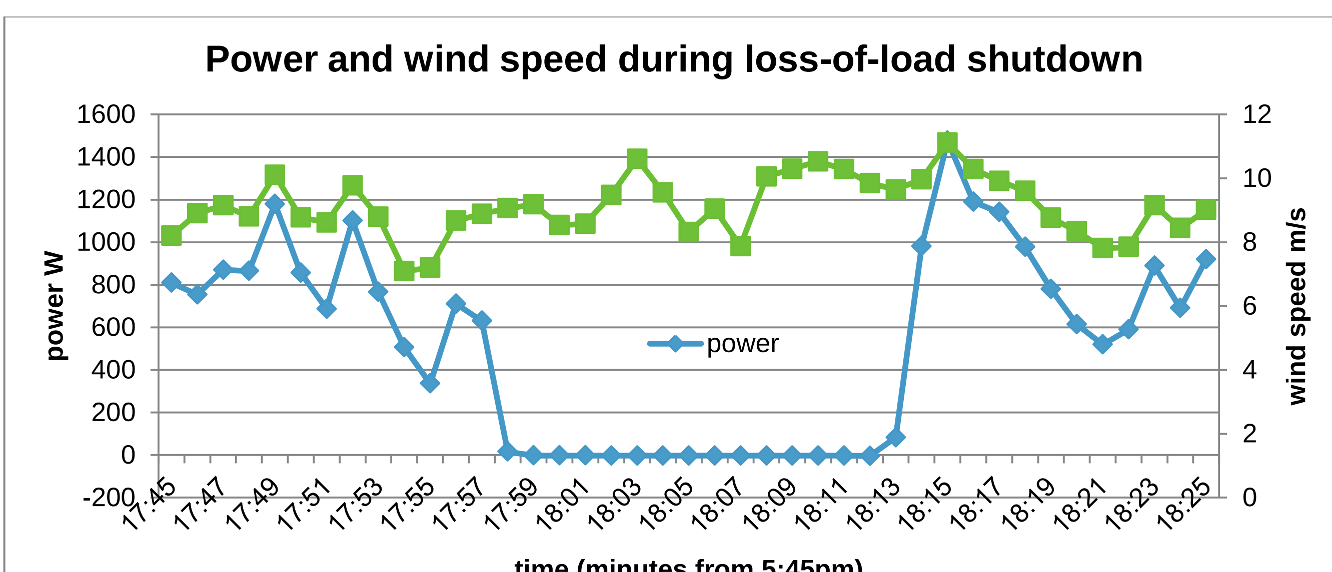


Figure 13. Time trace of power (left axis, blue diamonds) and wind speed (right axis, red squares) during shutdown by disconnecting main grid breaker, 21 October.

Cold temperature behaviour: Over the course of the test the minimum temperature recorded was -24°C. The turbine showed no change in behaviour with temperature. Figures below show power vs. wind speed (Fig. 14) and a strip chart of wind speed, power and temperature vs. time (Fig. 15), both for the period from midnight 3 January to 6:56 am 4 January (10-minute average data). The period was chosen nearly randomly; it is one that includes high wind for which Pika recorded turbine RPM, which coincidentally includes some very low temperatures, with -18.4°C being the lowest. Gaps in the wind speed trace in Fig. 15 are where the primary anemometer read zero (apparently froze); readings are omitted for clarity. Through this entire period and other similar windows the turbine behaved the same as it did during warmer temperatures.

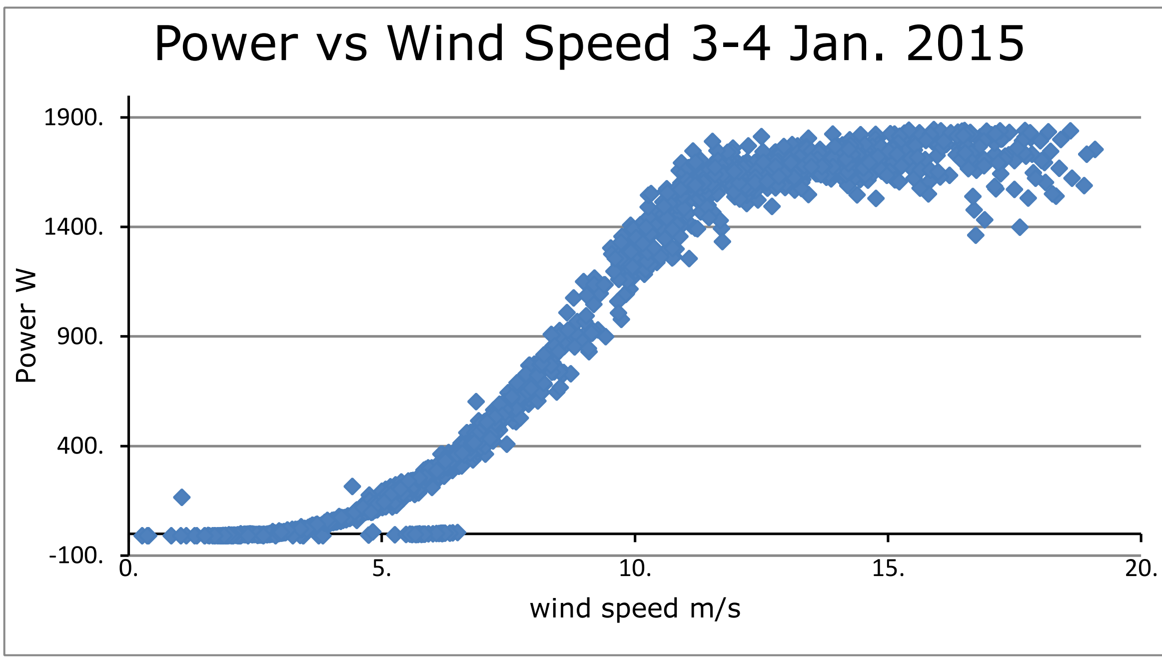


Figure 14. Output power vs. wind speed with temperature 0° to -18°C.

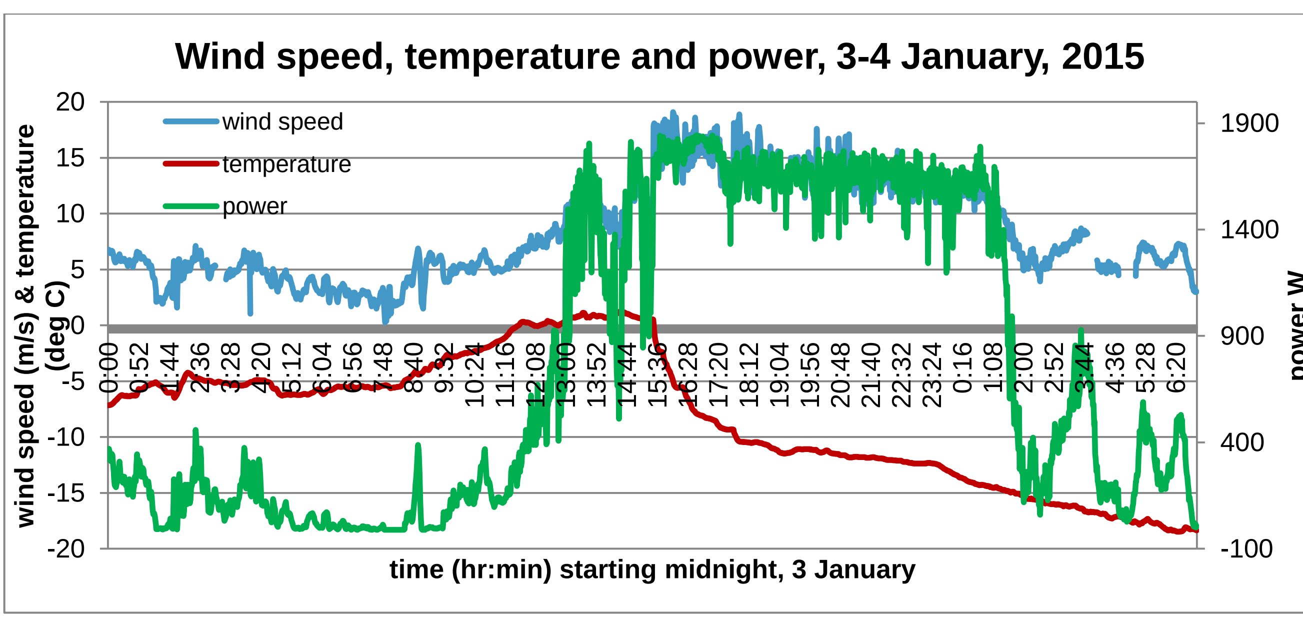


Figure 15. Strip chart of Pika T701 power, wind speed and temperature, 3-4 January, 2015. Gaps in the wind speed trace are where the primary anemometer froze, likely due to icing; zeroes deleted.

High-wind behavior: Figures 16 and 17 plot one-minute average rpm vs. wind speed and vs. transducer-measured power, over the same period as the cold temperature data above; during this period the highest recorded one-second wind speed was 22m/s. The turbine controller regulates rpm so that it does not exceed 400. The maximum one-second recorded rpm was 392.32.

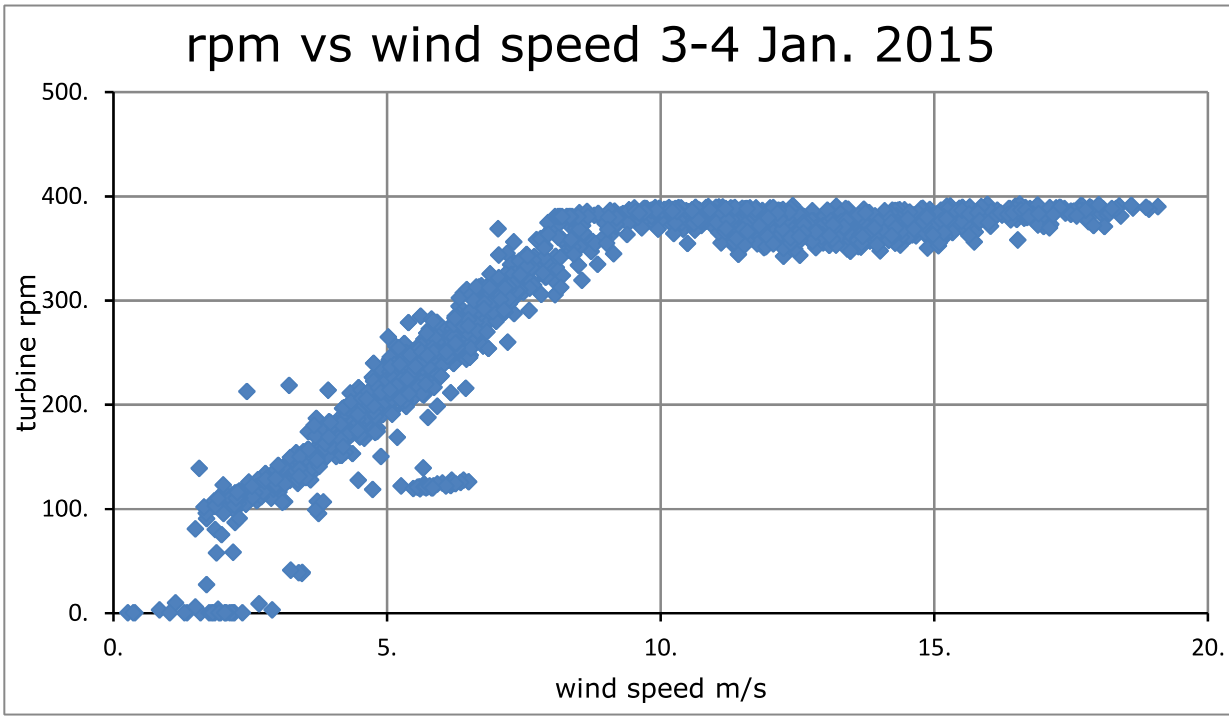


Figure 16. Turbine RPM vs. wind speed, 3-4 January, 2015. One-minute average data.

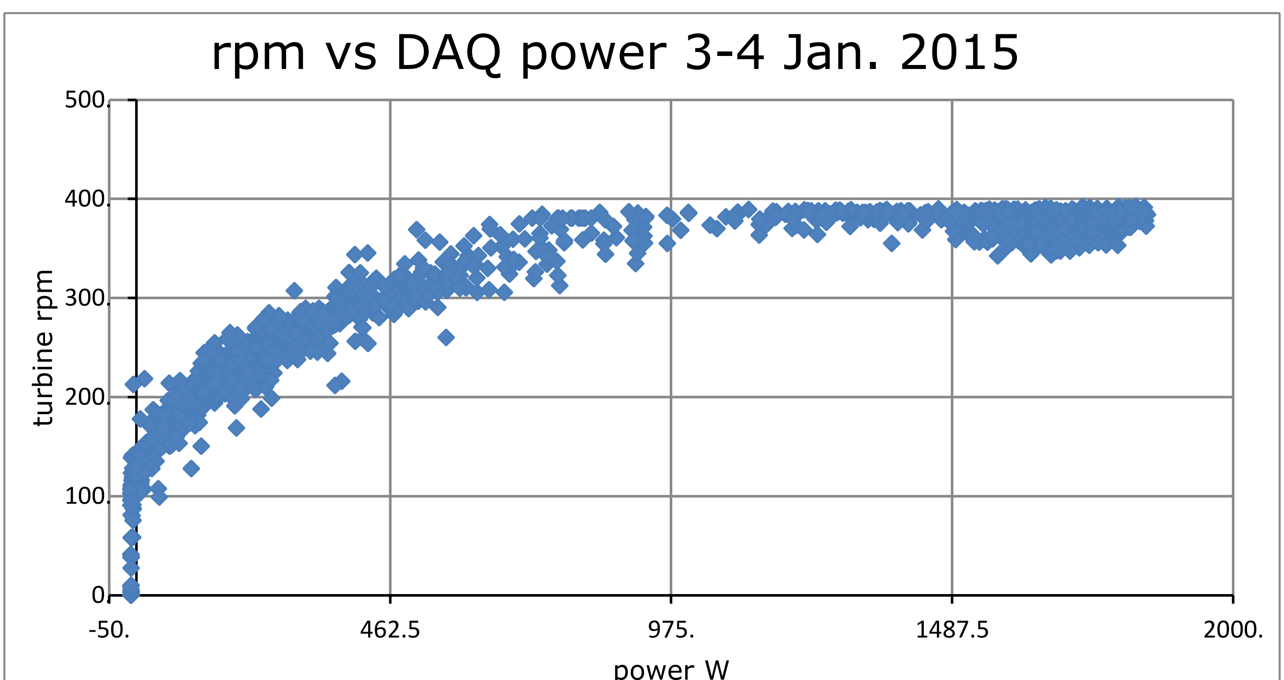


Figure 17. Pika T701 RPM vs. output power, 3-4 January 2015, one-minute average data.

Manual shut-down during high wind: While the turbine was shut down and restarted many times during certification testing, a formal test was conducted on 14 April, with Pika recording RPM and with the site manager making a video of the turbine at the same time. The videos are available on the High Plains Small Wind Test Center website (http://wac.ece.ksu.edu/?q=node/28). Graphs in Figures 18 and 19 show RPM, power and wind speed vs time during this test. Note that power and wind speed are averaged over one minute, while RPM numbers are instantaneous. Wind speed was over 12 m/s most of this time, gusting to 15.7 m/s maximum.

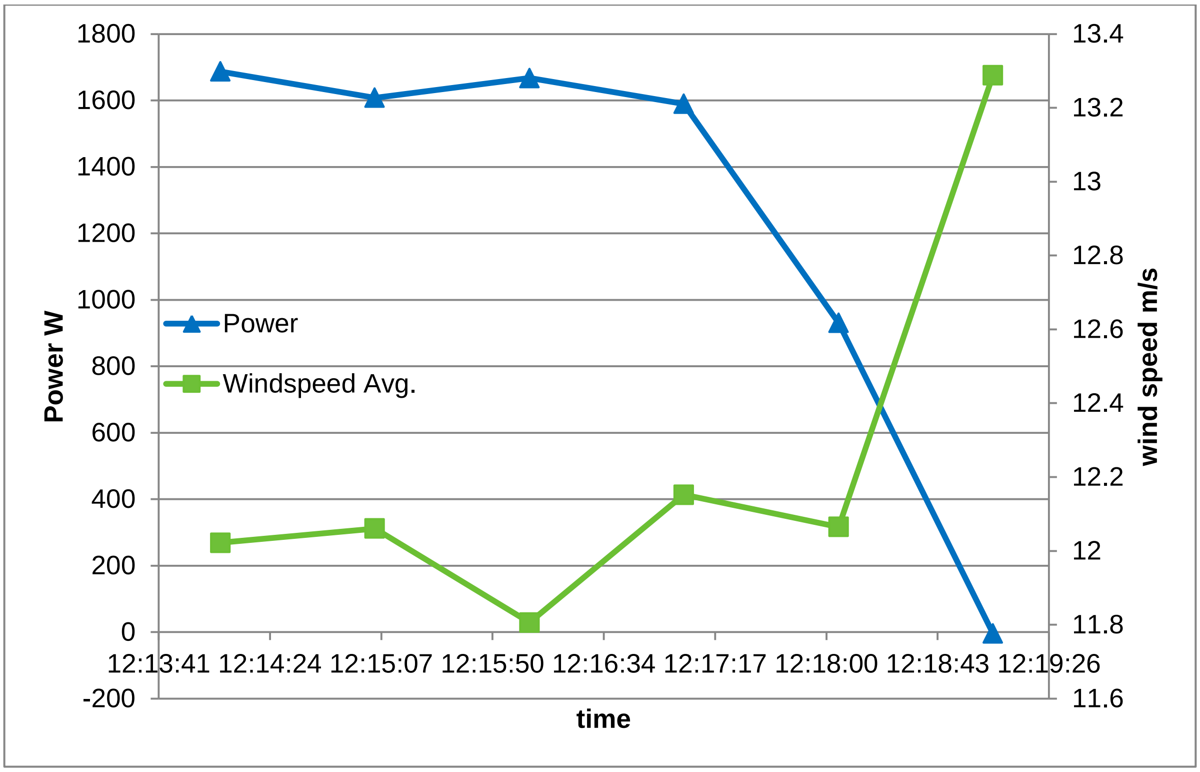


Figure 18. Wind speed (green squares, right axis) and power (blue triangles, left axis) vs time during 14 April, 2015 manual shutdown test during high wind. Time in fractions of a second.

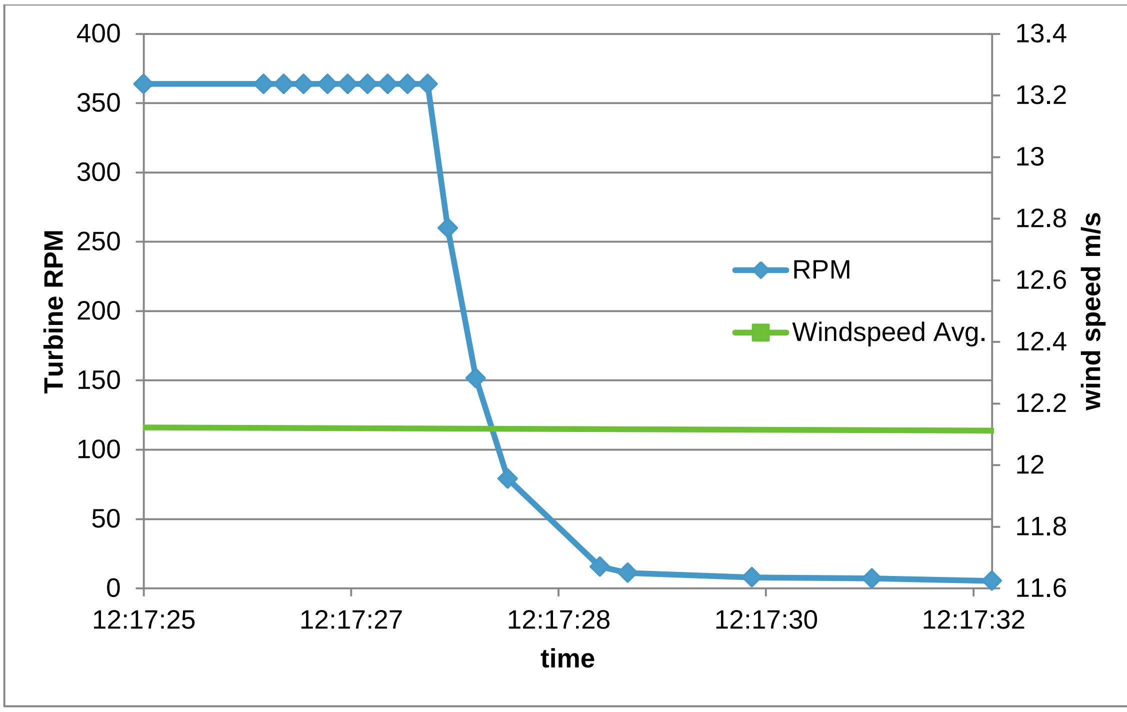


Figure 19. One-minute average wind speed (green, right axis) and one-second instantaneous turbine RPM (blue diamonds, left axis) vs time during 14 April, 2015 manual shutdown test during high wind. Time in fractions of a second. No one-second wind data are available in this time window. The recorded one-second maximum in this time window was 14.9m/s, minimum 11.1m/s.

Emergency shutdown: Pika includes a single-use centripetal brake on each turbine. If it must be used, it must be replaced by the manufacturer afterwards; we therefore did not try to test it at High Plains. This brake is tested on each turbine prior to turbine shipping. Pika will submit a video of this test.

Maintenance and component replacement provisions: The manual recommends visual and auditory inspection of the turbine annually for vibration and changes in behavior. Such inspections were carried out daily, and over the course of one year are certainly adequate for a turbine owner. No parts should or did need replacement.

Personal safety provisions: The Pika inverter is sealed and labeled that no user-servicable parts are inside. The control panel is a touch screen; inverter software does not permit changing of safety set points from the control panel. The inverter installation manual gives directions for installation that allow for cooling and warn that the heatsink may get hot, so install it where it won't be accidentally touched. It also gives warnings about checking line voltages with a meter; the warnings are sufficient to advise to a non-skilled person that an electrician should probably complete the installation. A warning is included that DC voltage will remain at the inverter DC terminals when disconnected, and time should be allowed for discharge; this is not different from other consumer electronics such as televisions. The manual does explicitly say that connection to the utility grid should be done by a licensed electrician; however the writing overall does not demand that.

The turbine installation manual is written in a manner suggesting that the owner might complete all installation; however it has plenty of warnings scattered throughout that would lead an insecure or non-skilled person to obtain expert help. We at High Plains are familiar with users who might follow these instructions themselves without difficulty (farmers, for example) and given the size of the Pika T701, feel that the directions are sufficient.

Special note on vibration and maintenance: prior to the beginning of the testing described in this report, a different Pika T701 turbine was installed at the test site, at the same hub height, on an experimental fibreglass monopole tower. During strong winds it was observed that this tower would oscillate significantly, though the turbine operation and energy production seemed unaffected. However, during a high-wind event (22-25 m/s) at night when no one was present, the tower snapped at about 2/3 of its height above ground, leaving the turbine and tower top hanging by the power wires from the tower 'stub'. The test site DAS recorded all instrumentation as well as all data from the inverter through the tower break. The turbine did stop producing power. The inverter remained awake for a while but its data stream froze, as it is programmed to do when data packets are not received. Unfortunately we cannot verify from the data collected that the controller stopped the turbine due to this extreme event, but the turbine certainly did stop and did not attempt to continue to operate, even while powered. We feel that this is worthy of mention even though we do not have solid data to verify that the turbine's control system functioned as designed. The turbine was replaced at the test site to ensure that no possible damage would interfere with continuing testing; however no damage to the turbine itself was noted after the tower failure: this is in extreme agreement with manual recommendations for part replacement.

8. Deviations and Exceptions

Exceptions to the Standard were taken during this test as explained below.

The height of the temperature probe on the met tower is specified in two places in the IEC 61400-12-1 Ed. 1 standard. In section 6.4 it specifies that "The air temperature sensor… shall be mounted within 10 m of hub height to represent the air temperature at the wind turbine rotor centre." In Annex H Power performance testing of small wind turbines, item j reads in part "the air temperature sensor… shall be mounted so that [it is] at least 1,5 rotor diameters below hub height even if such mounting results in a location less than 10 m above ground level." For the Pika T701 test unit, hub height is 16.94m, and the diameter is 3m. To be in compliance with Annex H, the sensor would need to be at least 4.5m below hub height. The temperature probe was placed approximately 1.5m above ground, at the DAQ box, in order to keep it out of direct sunlight. Previous experience has indicated that no sunshield is adequate against high summer Kansas sun. The uncertainty associated with this move is included in the uncertainty calculations; it comes to 0.2° C.

The center does not have a calibration report for the temperature sensor prior to start of test. The sensor will be calibrated at end of test. All other instruments were within two years of calibration and will be recalibrated at end of test.

The pressure sensor is located on the met mast also at the instrument box, about 1.5m above ground. The air pressure was adjusted for elevation according to the Standard.

The distance between turbine and met tower mast is 12.3m; with a turbine diameter of 3m this is 0.3m outside the Standard-specified 2-4D distance between turbine and met tower. The turbine and met tower foundations had been installed for a slightly larger turbine. We placed the primary anemometer on the leg of the tower closest to the turbine, so the exact distance between primary anemometer and turbine hub is 12.17m = 4.05 D.

The Ohio Semitronics power transducer does not have documents showing that it meets the IEC 60688 class 0.5 requirements. However documents from OSI show that the power transducer is substantially equivalent to units sold in Europe as the Camille Bauer M563/DME which does meet the IEC 60688 requirements.

Tests of emergency shutdown due to high temperature, excessive vibration and high wind (over 30 m/s) were not conducted because these conditions did not occur during the test period. See the special note on vibration above. The highest 10-minute average and instantaneous maximum temperatures recorded on site during the test were both 42°C, and the turbine operated normally through those intervals.

Appendix A - Calibration Data Sheets for Pika T701 Test Instruments

Primary Anemometer – Pre-Test Calibration

Svend Ole Hansen ApS

SCT. JØRGENS ALLÉ 7 · DK-1615 KØBENHAVN V · DENMARK
TEL: (+45) 33 25 38 38 · FAX: (+45) 33 25 38 39 · WWW.SOHANSEN.DK

WIND ENGINEERING FLUID DYNAMICS

CERTIFICATE FOR CALIBRATION OF CUP ANEMOMETER

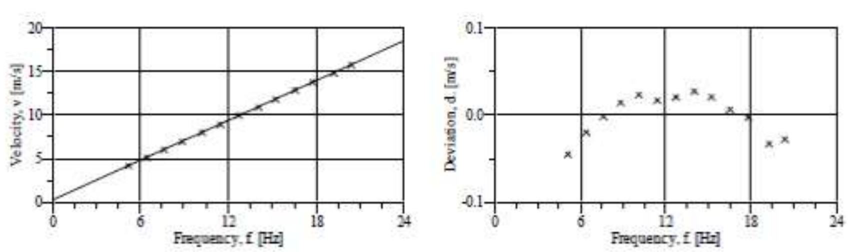
Certificate number: 13.02.06054 | **Date of issue:** November 5, 2013
Type: NRG Class 1 | **Serial number:** 596700001838
Manufacturer: Renewable NRG Systems, Inc., 110 Riggs Road, Hinesburg, VT 05461, USA
Client: Renewable NRG Systems, Inc., 110 Riggs Road, Hinesburg, VT 05461, USA

Anemometer received: October 17, 2013 | **Anemometer calibrated:** November 1, 2013
Calibrated by: ke | **Procedure:** MEASNET, referring to IEC 61400-12-1
Certificate prepared by: cea | **Approved by:** Calibration engineer, jtr

Calibration equation obtained: $v\,[m/s] = 0.76384 \cdot f\,[Hz] + 0.23751$
Standard uncertainty, slope: 0.00193 | **Standard uncertainty, offset:** 0.08439
Covariance: -0.0000277 $(m/s)^2/Hz$ | **Coefficient of correlation:** $\rho = 0.999980$
Absolute maximum deviation: -0.045 m/s at 4.149 m/s

Barometric pressure: 1007.0 hPa | **Relative humidity:** 30.1%

Succession	Velocity pressure, q. [Pa]	Temperature in wind tunnel [°C]	Temperature in control room [°C]	Wind velocity, v. [m/s]	Frequency, f [Hz]	Deviation, d [m/s]	Uncertainty u_c (k=2) [m/s]
2	9.94	29.3	22.7	4.149	5.1799	-0.045	0.021
4	15.08	29.2	22.7	5.109	6.4036	-0.020	0.025
6	21.29	29.0	22.7	6.071	7.6380	-0.001	0.029
8	28.45	28.9	22.7	7.015	8.8548	0.014	0.033
10	37.25	28.8	22.7	8.027	10.1669	0.023	0.037
12	46.84	28.8	22.7	8.999	11.4478	0.018	0.042
13-last	57.49	28.7	22.7	9.969	12.7121	0.021	0.046
11	69.56	28.8	22.7	10.967	14.0119	0.027	0.051
9	81.96	28.9	22.7	11.906	15.2498	0.021	0.055
7	95.75	29.0	22.7	12.872	16.5320	0.006	0.059
5	110.02	29.1	22.7	13.800	17.7598	-0.003	0.064
3	127.82	29.2	22.7	14.877	19.2092	-0.033	0.068
1-first	144.08	29.5	22.7	15.803	20.4146	-0.028	0.073



ilac-MRA | DANAK CAL Reg nr. 452 | measnet

Accreditation to ISO 17025 | Page 1 of 2

Figure A1. Primary anemometer manufacturer calibration sheet pg 1 of 2.

EQUIPMENT USED

Serial number	Description
-	Boundary layer wind tunnel.
1256	Control cup anemometer.
-	Mounting tube, D = 25 mm
t3	PT100 temperature sensor, wind tunnel.
t4	PT100 temperature sensor, control room.
950610	PPC500 Furness pressure manometer
Z0420014	HMW71U Humidity transmitter
U4220037	PTB100AVaisala analogue barometer.
PS1	Pitot tube
HB2835279	Computer Board. 16 bit A/D data acquisition board.
-	PC dedicated to data acquisition.

Traceable calibrations of the equipment are carried out by external accredited institutions: Furness (PPC500) and Exova Metech. A real-time analysis module within the data acquisition software detects pulse frequency.

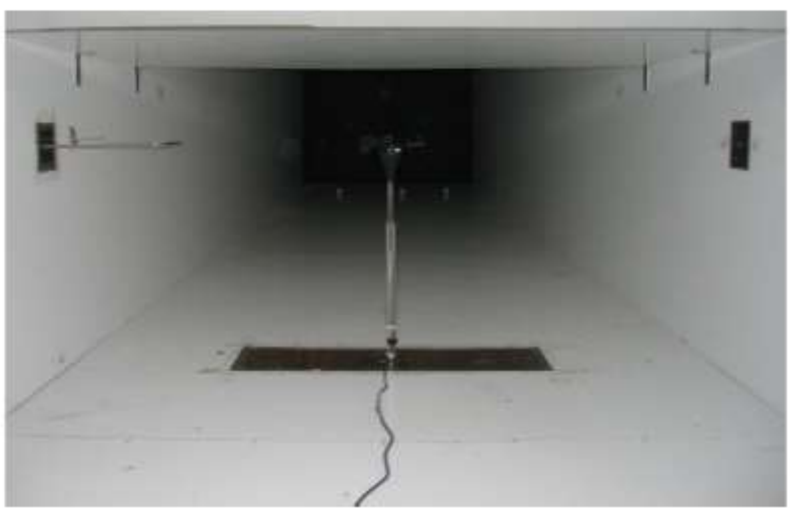


Photo of the wind tunnel setup (hxb = 0.85x1.75 m). The shown anemometer is of the same type as the calibrated one.

UNCERTAINTIES

The documented uncertainty is the total combined uncertainty at 95% confidence level (k=2) in accordance with EA-4/02. The uncertainty at 10 m/s comply with the requirements in the MEASNET procedure that prescribes an absolute uncertainty less than 0.1 m/s at a mean wind velocity of 10 m/s, that is 1%. See Document 97.00.004 "MEASNET - Test report on the calibration campaign" for further details.

Certificate number: 13.02.06054

 Page 2 of 2

Figure A2. Primary anemometer manufacturer calibration sheet pg 2 of 2.

Secondary Anemometer

2nd ANEMOMETER

SOH Wind Engineering LLC

141 Leroy Road · Williston, VT 05495 · USA

Tel 802.999.3309 · Fax 802.735.9106 · www.sohwind.com

CERTIFICATE FOR CALIBRATION OF CUP ANEMOMETER

Certificate number: 13.US1.08710 | **Date of issue:** October 31, 2013

Type: NRG #40HC | **Serial number:** 179700000907

Manufacturer: Renewable NRG Systems Inc, 110 Riggs Road, Hinesburg, VT 05461, USA

Client: Renewable NRG Systems Inc, 110 Riggs Road, Hinesburg, VT 05461, USA

Anemometer received: October 25, 2013 | **Anemometer calibrated:** 11:55 October 31, 2013

Calibrated by: mej | **Calibration procedure:** IEC 61400-12-1:2005(E) Annex F Modified for 4-26 m/s

Certificate prepared by: Software Revision 4 | **Approved by:** Calibration engineer, rds

Calibration equation obtained: $v\,[m/s] = 0.75452 \cdot f\,[Hz] + 0.41550$

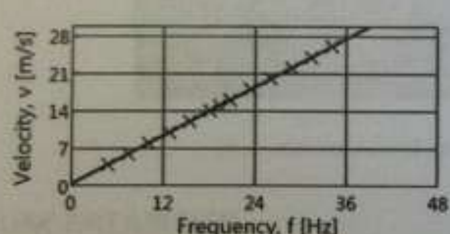
Standard uncertainty, slope: 0.00172 | **Standard uncertainty, offset:** 0.06682

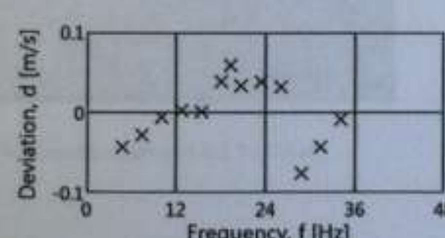
Covariance: -0.0000329 $(m/s)^2/Hz$ | **Coefficient of correlation:** $\rho = 0.999984$

Absolute maximum deviation: 0.076 m/s at 22.092 m/s

Barometric pressure: 1001.7 hPa | **Relative humidity:** 25.6%

Succession	Velocity pressure, q. [Pa]	Temperature in wind tunnel [°C]	Temperature in d.p. box [°C]	Wind velocity, v. [m/s]	Frequency, f. [Hz]	Deviation, d. [m/s]	Uncertainty u_c (k=2) [m/s]
1-first	9.44	25.9	26.5	4.026	4.8424	-0.043	0.069
12	20.96	26.6	26.5	6.008	7.4498	-0.028	0.047
2	37.67	25.7	26.5	8.043	10.1166	-0.006	0.036
11	58.77	26.7	26.5	10.065	12.7862	0.002	0.031
3	84.99	25.6	26.5	12.079	15.4575	0.001	0.028
10	115.32	26.9	26.5	14.105	18.0924	0.038	0.028
13-last	131.64	26.5	26.6	15.061	19.3330	0.059	0.028
4	150.50	25.7	26.5	16.079	20.7153	0.033	0.027
9	189.95	27.0	26.5	18.110	23.4005	0.038	0.029
5	235.13	25.9	26.5	20.110	26.0603	0.032	0.030
8	282.52	27.1	26.5	22.092	28.8291	-0.076	0.032
6	336.17	26.3	26.5	24.070	31.4068	-0.043	0.034
7	395.53	26.8	26.5	26.136	34.1003	-0.009	0.037





ilac-MRA

ACLASS ACCREDITED CALIBRATION

AC-1746

Standard: ISO/IEC 17025

Figure A4. Secondary anemometer 3rd-party calibration sheet pg 1 of 1.

Wind Direction Vane

Date: 4/10/2012

Product Specifications
Product #: 1904
http://www.nrgsystems.com/sitecore/content/Products/1904.aspx

NRG #200P Wind Direction Vane, 10K, With Boot

The industry standard wind direction vane used worldwide. Thermoplastic and stainless steel components resist corrosion and contribute to a high strength-to-weight ratio.

SPECIFICATIONS

	Description
Sensor type	continuous rotation potentiometric wind direction vane
Applications	• wind resource assessment • meteorological studies • environmental monitoring
Sensor range	360° mechanical, continuous rotation
Instrument compatibility	all NRG loggers
	Output signal
Signal type	Analog DC voltage from conductive plastic potentiometer, 10K ohms
Transfer function	Output signal is a ratiometric voltage
Accuracy	potentiometer linearity within 1%
Dead band	8° Maximum, 4° Typical
Output signal range	0 V to excitation voltage (excluding deadband)
	Response characteristics
Threshold	1 m/s (2.2 miles per hour)
	Power requirements
Supply voltage	Regulated potentiometer excitation of 1 V to 15 V DC
	Installation
Mounting	onto a 13 mm (0.5 inch) diameter mast with cotter pin and set screw
Tools required	0.25 inch nut driver, petroleum jelly, electrical tape
	Environmental
Operating temperature range	-55 °C to 60 °C (-67 °F to 140 °F)
Operating humidity range	0 to 100% RH
Lifespan	50 million revolutions (2 to 6 years normal operation)
	Physical
Connections	4-40 brass hex nut/post terminals
Weight	0.14 kg (0.3 pounds)
Dimensions	• 21 cm (8.3 inches) length x 12 cm (4.3 inches) height • 27 cm (10.5 inches) swept diameter
	Materials

Figure A5. Wind direction vane manufacturer specification sheet pg 1 of 2.

Wing	black UV stabilized injection molded plastic
Body	black UV stabilized static-dissipating plastic
Shaft	stainless steel
Bearing	stainless steel
Boot	protective PVC sensor terminal boot included
Terminals	brass

110 Riggs Road - Hinesburg - VT 05461 USA - TEL (802) 482-2255 - FAX (802) 482-2272 - EMAIL sales@nrgsystems.com

Figure A6. Wind direction vane manufacturer specification sheet pg 2 of 2.

Temperature Probe

Date: 4/10/2012

Product Specifications
Product #: 1906
http://www.nrgsystems.com/sitecore/content/Products/1906.aspx

NRG #110S Temperature Sensor with Radiation Shield

Durable integrated circuit temperature sensor provides a high level voltage output signal. Ideal for collecting temperature data for energy density calculations and monitoring air temperature at remote sites.

SPECIFICATIONS

Description

Sensor type	integrated circuit temperature sensor with six plate radiation shield
Applications	• wind resource assessment • meteorological studies • environmental monitoring
Sensor range	-40 °C to 52.5 °C (-40 °F to 126.5 °F)
Instrument compatibility	all NRG loggers

Output signal

'gnal type	linear analog voltage
Transfer function	Temp = (Voltage x 55.55) - 86.38 °C [Temp = (Voltage x 100) - 123.5 °F]
Accuracy	• offset is +/- 0.8 °C (1.4 °F) maximum • nonlinearity is +/- 0.33 °C (+/- 0.6 °F) maximum • total error +/- 1.1 °C (2 °F) maximum
Electrical time constant	250 µs
Output signal range	0 V to 2.5 V DC

Response characteristics

Thermal time constant	10 minutes

Power requirements

Supply voltage	4 V to 35 V DC
Supply current	300 µA max. (no load on output)

Installation

Mounting	attaches to tower with included hose clamps
Tools required	• 8mm (5/16 inch) nut driver or flat blade (-) screwdriver (to install hose clamps) • sheet metal shears or similar (for trimming hose clamps)

Environmental

Operating temperature range	-40 °C to 52.5 °C (-40 °F to 126.5 °F)
Operating humidity range	0 to 100% RH
Lifespan	10 years +

Physical

onnections	wire leads: • signal (clear wire) • ground (black wire) • excitation (red wire) • shield wire for earth ground

Figure A7. Temperature probe manufacturer specification sheet pg 1 of 2.

Cable length	5 m (16 feet)
Weight	0.47 kg (1.04 pounds)
Dimensions	• sensor only: 30.5 mm (1.2 inches) height x 12.7 mm (0.5 inch) diameter • sensor with radiation shield: 127 mm (5 inches) diameter x 127 mm (5 inches) height
	Materials
Cable	3 conductor 22 AWG, with overall foil shield and drain wire, chrome PVC jacket
Probe	aluminum, epoxy filled
Shield	UV-stabilized thermoplastic solar radiation shield

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Figure A8. Temperature probe manufacturer specification sheet pg 2 of 2.

Pressure Transducer

Calibration Report

NRG BP20 Barometric Pressure Sensor

NRG BP-20 Serial Number	1805 12465
Calibration Date	2010.11.15 10:38:44
Calibration performed by	PPC
NRG Reference BP Instrument No.	1044
NRG Digital Volt Meter (DVM) Instrument No.	102908
Uncertainty of Voltage Measurement	+/- 5 mV

Calibration of this BP-20 Absolute Pressure Sensor was performed against Reference Absolute Pressure Sensor, NRG Instrument #1044. Output voltage measured with B&K Model 391A, NRG Instrument #102908. Uncertainty of the voltage measurement is +/- 5 millivolts. Calibration of these instruments is traceable to the National Institute for Standards and Technology (NIST).

The output (in kPa) for this BP-20 sensor is defined by: P = (21.79 x Vout) + 10.53

BP-20 Slope	21.79	kPa / Volt
BP-20 Offset	10.53	kPa

BP-20 Slope and Offset Conversion Chart for
NRG Symphonie Data Retriever, MicroSite, and BaseStation software

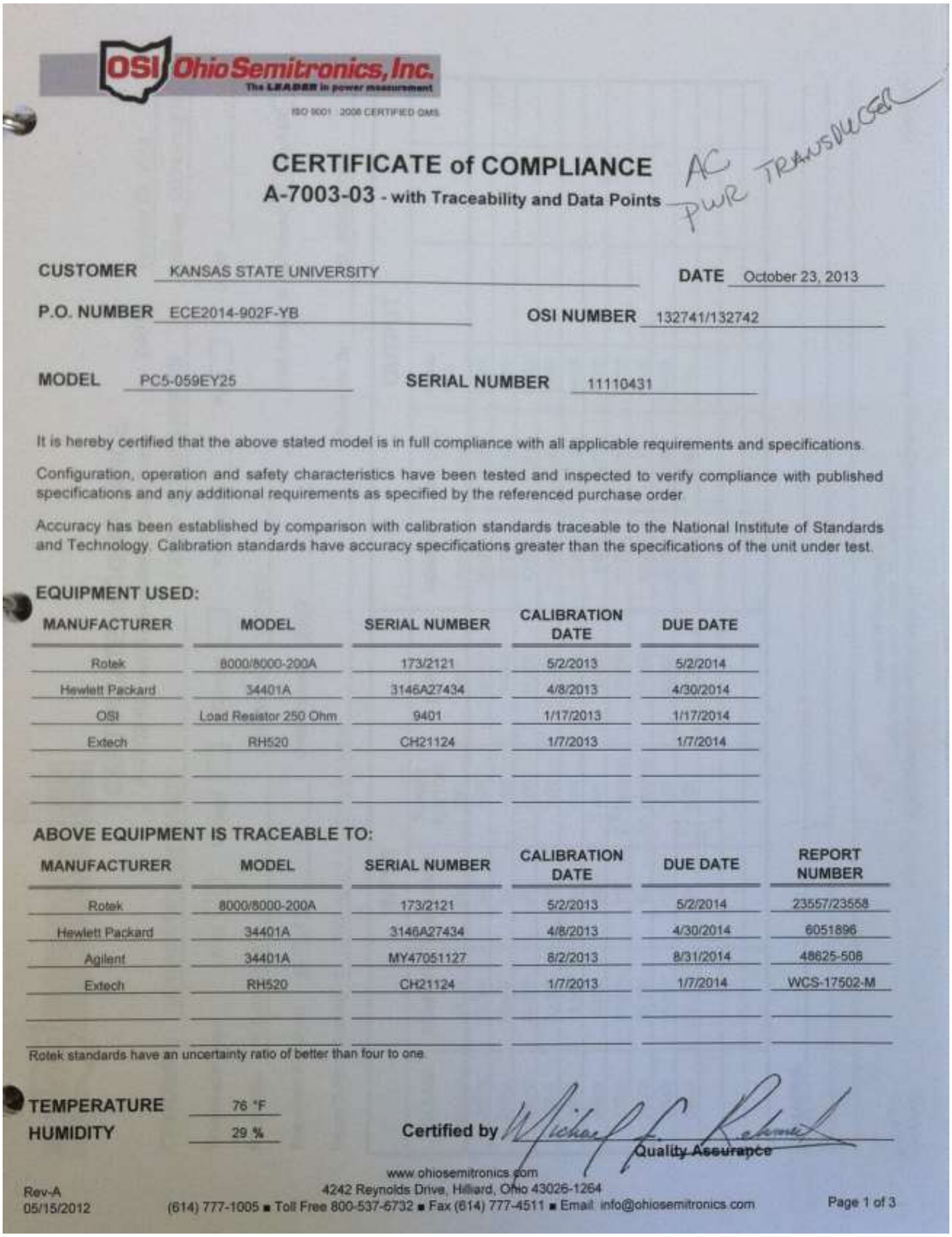
To Scale to...	enter slope (scale factor)	and enter offset
mB	0.4255	650.029
kPa	0.04255	65.003
inches of mercury	0.01257	19.195

Global leaders in wind assessment technology NRG SYSTEMS

110 Riggs Road Hinesburg VT 05461 USA · TEL (802) 482-2255 · FAX (802) 482-2272 · EMAIL sales@nrgsystems.com

Figure A9. Pressure transducer manufacturer calibration sheet pg 1 of 1.

Power Transducer



OSI Ohio Semitronics, Inc.
The LEADER in power measurement
ISO 9001 : 2008 CERTIFIED QMS

CERTIFICATE of COMPLIANCE

A-7003-03 - with Traceability and Data Points

AC PWR TRANSDUCER

CUSTOMER KANSAS STATE UNIVERSITY **DATE** October 23, 2013

P.O. NUMBER ECE2014-902F-YB **OSI NUMBER** 132741/132742

MODEL PC5-059EY25 **SERIAL NUMBER** 11110431

It is hereby certified that the above stated model is in full compliance with all applicable requirements and specifications.

Configuration, operation and safety characteristics have been tested and inspected to verify compliance with published specifications and any additional requirements as specified by the referenced purchase order.

Accuracy has been established by comparison with calibration standards traceable to the National Institute of Standards and Technology. Calibration standards have accuracy specifications greater than the specifications of the unit under test.

EQUIPMENT USED:

MANUFACTURER	MODEL	SERIAL NUMBER	CALIBRATION DATE	DUE DATE
Rotek	8000/8000-200A	173/2121	5/2/2013	5/2/2014
Hewlett Packard	34401A	3146A27434	4/8/2013	4/30/2014
OSI	Load Resistor 250 Ohm	9401	1/17/2013	1/17/2014
Extech	RH520	CH21124	1/7/2013	1/7/2014

ABOVE EQUIPMENT IS TRACEABLE TO:

MANUFACTURER	MODEL	SERIAL NUMBER	CALIBRATION DATE	DUE DATE	REPORT NUMBER
Rotek	8000/8000-200A	173/2121	5/2/2013	5/2/2014	23557/23558
Hewlett Packard	34401A	3146A27434	4/8/2013	4/30/2014	6051896
Agilent	34401A	MY47051127	8/2/2013	8/31/2014	48625-508
Extech	RH520	CH21124	1/7/2013	1/7/2014	WCS-17502-M

Rotek standards have an uncertainty ratio of better than four to one.

TEMPERATURE 76 °F

HUMIDITY 29 %

Certified by Quality Assurance

www.ohiosemitronics.com
4242 Reynolds Drive, Hilliard, Ohio 43026-1264
(614) 777-1005 ■ Toll Free 800-537-6732 ■ Fax (614) 777-4511 ■ Email: info@ohiosemitronics.com

Rev-A 05/15/2012

Page 1 of 3

Figure A10. Power transducer manufacturer calibration sheet pg 1 of 3.

OSI Ohio Semitronics, Inc.
The LEADER in power measurement

CERTIFICATE of COMPLIANCE

A-7003-03 - with Traceability and Data Points

DATE October 23, 2013

CUSTOMER KANSAS STATE UNIVERSITY **P.O. No.** ECE2014-902F-YB **OSI No.** 132741/132742

Transducer Type **Watt** [X] **Voltage** [ ] **Current** [ ] **Frequency** [ ] **PF** [ ] **Other** ______

Model No. PC5-059EY25 **Serial No.** 11110431

Specified Accuracy ±0.5% F.S. **Output Load** 250Ω

Data Status is As Found [X] **As Left** [ ]

Input/Output Scaling 0 - 20kW Input = 4 - 20mAdc Output **Recorded by** D. BORBRIDGE

INPUT					OUTPUT					
VOLTAGE (V L1-N)	CURRENT (A L1)	FREQUENCY (Hz)	POWER FACTOR (PF)	POWER (kW)	NOMINAL (mAdc)	ACTUAL (mAdc)	PASS/ FAIL			
240.0	83.333	60	1.00	20.000	20.000	19.988	PASS			
240.0	66.667	60	1.00	16.000	16.800	16.820	PASS			
240.0	50.000	60	1.00	12.000	13.600	13.616	PASS			
240.0	33.333	60	1.00	8.000	10.400	10.404	PASS			
240.0	16.667	60	1.00	4.000	7.200	7.188	PASS			
240.0	0.000	60	N/A	0.000	4.000	4.008	PASS			
240.0	83.333	60	0.5 Lagging	10.000	12.000	12.000	PASS			
240.0	83.333	60	0.5 Leading	10.000	12.000	12.000	PASS			
300.0	66.667	60	1.00	20.000	20.000	19.984	PASS			
200.0	100.000	60	1.00	20.000	20.000	19.900	FAIL			

REMARKS:

Rev-A
05/15/2012

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4242 Reynolds Drive, Hilliard, Ohio 43026-1264
(614) 777-1005 ■ Toll Free 800-537-6732 ■ Fax (614) 777-4511 ■ Email: info@ohiosemitronics.com

Page 2 of 3

Figure A11. Power transducer manufacturer calibration sheet pg 2 of 3.

OSI Ohio Semitronics, Inc. The LEADER in power measurement

CERTIFICATE of COMPLIANCE

A-7003-03 - with Traceability and Data Points

DATE October 23, 2013

CUSTOMER KANSAS STATE UNIVERSITY **P.O. No.** ECE2014-902F-YB **OSI No.** 132741/132742

Transducer Type **Watt** [X] **Voltage** [ ] **Current** [ ] **Frequency** [ ] **PF** [ ] **Other** ______

Model No. PC5-059EY25 **Serial No.** 11110431

Specified Accuracy ±0.5% F.S. **Output Load** 250Ω

Data Status is As Found [ ] **As Left** [X]

Input/Output Scaling 0 - 20kW Input = 4 - 20mAdc Output **Recorded by** D. BORBRIDGE

INPUT					OUTPUT					
VOLTAGE (V L1-N)	CURRENT (A L1)	FREQUENCY (Hz)	POWER FACTOR (PF)	POWER (kW)	NOMINAL (mAdc)	ACTUAL (mAdc)	PASS/ FAIL			
240.0	83.333	60	1.00	20.000	20.000	20.000	PASS			
240.0	66.667	60	1.00	16.000	16.800	16.820	PASS			
240.0	50.000	60	1.00	12.000	13.600	13.616	PASS			
240.0	33.333	60	1.00	8.000	10.400	10.400	PASS			
240.0	16.667	60	1.00	4.000	7.200	7.184	PASS			
240.0	0.000	60	N/A	0.000	4.000	4.000	PASS			
240.0	83.333	60	0.5 Lagging	10.000	12.000	11.988	PASS			
240.0	83.333	60	0.5 Leading	10.000	12.000	12.004	PASS			
300.0	66.667	60	1.00	20.000	20.000	20.004	PASS			
200.0	100.000	60	1.00	20.000	20.000	19.944	PASS			

REMARKS:

Rev-A
05/15/2012

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4242 Reynolds Drive, Hilliard, Ohio 43026-1264
(614) 777-1005 ■ Toll Free 800-537-6732 ■ Fax (614) 777-4511 ■ Email: info@ohiosemitronics.com

Page 3 of 3

Figure A12. Power transducer manufacturer calibration sheet pg 3 of 3.

DAS Boards

Trescal

Certificate #: *2622240001* *T*

17025 Accredited Certificate of Calibration

ilac-MRA ACCREDITED Calibration Laboratory

Acct #:	123790
Customer:	Advanced Manufacturing Institute
Shipper #:	2074961
Address:	510 McCall Rd Manhattan, KS, 66502
Contact:	NI RMA
PO #:	

Manufacturer:	National Instruments
Model:	9205
Description:	32 Channel Analog Input Module
Serial Number:	154153B
Asset Number:	154153B
Barcode:	

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 X
Damaged	N/A	Repaired
N/A		Charted
		Returned As Is

Cal Date:	10/28/2013
Due Date:	10/28/2015
Temperature:	71.10 deg. F
Humidity:	64.80 %
Baro. Press.:	
Procedure:	DCN 09381
Reference:	manufacturer's manual

Incoming Remarks:

ndo

Domestic Accredited Calibration w/esd bags

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
2528850168	Fluke	5700A	Multifunction Calibrator	10/24/2013	01/24/2014

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

This report applies only to the item(s) identified above and shall not be reproduced, except in full, without the written approval of Trescal. This unit has been calibrated utilizing standards with a Test Uncertainty Ratio (TUR) of greater than 4:1 approximating a 95 % confidence level with a coverage factor of k=2 unless otherwise stated above or as stated on the Report of Calibration. The calibration was performed using references traceable to the SI through NIST or other recognized national laboratory, accepted fundamental or natural physical constants, ratio type of calibration, or by comparison to consensus standards. Trescal's calibration program is in compliance with:

ISO/IEC 17025:2005, ANSI/NCSL Z540-1:1994, ANSI/NCSL Z540.3:2006, MIL STD 45662A, QD-4000 2010

Trescal warrants all material and labor performed for ninety (90) days unless covered under a separate policy

* Any number of factors may cause the calibrated item to drift out of tolerance before the interval has expired

Technician Name/Date: James Nimri, 10/28/2013 Signatory: [signature] QA Approved: [stamp]

3201 West Royal Lane, Suite 150, Irving, TX 75063 (214) 723-5600 FAX (214) 723-5601

Page 1 of 1

Figure A13. Voltage module (for temperature & pressure), manufacturer calibration certificate pg 1 of 1.

Trescal

Certificate #: 2622240002 T

17025 Accredited Certificate of Calibration

Calibration Laboratory Certificate #: 2516.01

Acct #:	123790	**Manufacturer:**	National Instruments
Customer:	Advanced Manufacturing Institute	**Model:**	9203
Shipper #:	2074961	**Description:**	8 Channel Analog Current Input Modu
Address:	510 McCall Rd Manhattan, KS, 66502	**Serial Number:**	153E128
Contact:	NI RMA	**Asset Number:**	153E128
PO #:		**Barcode:**	

As Received		As Returned		Action Taken			
In Tolerance	X	In Tolerance	X	Full Calibration	X	**Cal Date:**	10/28/2013
Out of Tolerance		Out of Tolerance		Special Calibration		**Due Date:**	10/28/2014
Malfunctioning		Malfunctioning		Oper. Verification		**Temperature:**	71.10 deg. F
Operational		Operational		Adjusted		**Humidity:**	69.80 %
Damaged		N/A		Repaired		**Baro. Press.:**	
N/A				Charted		**Procedure:**	DCN 09374
				Returned As Is		**Reference:**	manufacacturers' manual

Incoming Remarks:

ndo

Domestic Accredited Calibration w/esd bags

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
2528850168	Fluke	5700A	Multifunction Calibrator	10/24/2013	01/24/2014

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

This report applies only to the item(s) identified above and shall not be reproduced, except in full, without the written approval of Trescal. This unit has been calibrated utilizing standards with a Test Uncertainty Ratio (TUR) of greater than 4:1 approximating a 95 % confidence level with a coverage factor of k=2 unless otherwise stated above or as stated on the Report of Calibration. The calibration was performed using references traceable to the SI through NIST or other recognized national laboratory, accepted fundamental or natural physical constants, ratio type of calibration, or by comparison to consensus standards. Trescal's calibration program is in compliance with:

ISO/IEC 17025:2005, ANSI/NCSL Z540-1-1994, ANSI/NCSL Z540.3-2006, MIL STD 45662A, QD-4000:2010

Trescal warrants all material and labor performed for ninety (90) days unless covered under a separate policy.

* Any number of factors may cause the calibrated item to drift out of tolerance before the interval has expired.

Technician Name/Date: James Nimri, 10/28/2013 Signatory: Will Tyler QA Approved:

3201 West Royal Lane, Suite 150, Irving, TX 75063 (214) 723-5600 FAX (214) 723-5601

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Figure A14. Current module (for power transducer) manufacturer calibration certificate pg 1 of 1.

NATIONAL INSTRUMENTS

Technical Sales

(866) 531-6285
orders@ni.com

Ordering Information | Detailed Specifications | Pinouts/Front Panel Connections

For user manuals and dimensional drawings, visit the product page resources tab on ni.com.

Last Revised: 2014-11-06 07:14:33.0

NI 9421

24 V, Sinking Digital Input, 8 Ch Module

- 8 channels, 100 μs digital input
- 24 V logic, sinking digital input
- Compatibility with NI CompactDAQ counters
- 60 VDC, CAT I (D-SUB), or 250 Vrms, CAT II (screw-terminal) isolation
- 25-pin D-SUB or 10-position screw-terminal connectors available
- -40 °C to 70 °C operating, 5 g vibration, 50 g shock

Overview

The NI 9421 is an 8-channel, 100 μs sinking digital input module for any NI CompactDAQ or CompactRIO chassis. Each channel is compatible with 24 V signals and features transient overvoltage protection of 2,300 Vrms between the input channels and earth ground. Each channel also has an LED that indicates the state of that channel. The NI 9421 works with industrial logic levels and signals for direct connection to a wide array of industrial switches, transducers, and devices.

You can choose from two connector options for the NI 9421: a 10-position screw-terminal connector and a 25-position D-SUB connector. This industry-standard 25-position D-SUB connector provides for low-cost cabling to a wide variety of accessories from NI or other vendors. A number of vendors with custom D-SUB cable fabrication services can deliver cables with a pinout that matches your exact application needs.

Recommended Accessories
-NI 9924 or other 25-pin D-SUB connector (for D-SUB variant)
-NI 9927 strain relief and operator protection (for screw-terminal variant)

Optional Accessories
-NI 9936 extra screw-terminal block (quantity 10)
-NI 9980 extra spring-terminal block (quantity 10)
Note: The NI 9980 is not compatible with the NI 9927 and must be used with low or nonhazardous voltages or installed in a properly rated enclosure.

Box Contents
-1 NI 9421 C Series module
-1 NI 9421 Operating Instructions and Specifications manual
-1 NI 9936 10-position connector (for screw-terminal variant)

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Comparison Tables

Product Name	Signal Levels	Direction	Channels	Update Rate	Isolation	Connectivity
NI 9375	24 V	Sinking Input, Sourcing Output	16 In, 16 Out	7 μs In, 500 μs Out	60 VDC Ch-Earth	Spring Terminal, 37-Pin D-SUB
NI 9411	±5, 24 V	Sinking/Sourcing Diff/SE Input	6	500 ns	60 VDC Ch-Earth	15-Pin D-SUB
NI 9421	24 V	Sinking Input	8	100 μs	60 VDC (D-SUB), 250 Vrms (ST)	Screw Terminal, 25-Pin D-SUB
NI 9422	24, 48, 60 V	Sinking/Sourcing Input	8	250 μs	250 Vrms Ch-Ch	Screw Terminal
NI 9423	24 V	Sinking Input	8	1 μs	250 Vrms Ch-Earth	Screw Terminal
NI 9425	24 V	Sinking Input	32	7 μs	60 VDC Ch-Earth	37-Pin D-SUB
NI 9426	24 V	Sourcing Input	32	7 μs	60 VDC Ch-Earth	37-Pin D-SUB

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Figure A15. NI 9421 digital input module (for both anemometers) manufacturer data sheet pg 1 of 9. Remaining pages available on request.