National Renewable Energy Laboratory

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Wind Turbine Safety and Function Test Report for the ARE 442 Wind Turbine

J. van Dam, D. Baker, and D. Jager

Technical Report
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J. van Dam, D. Baker, and D. Jager

Prepared under Task No. WE10.2211

Technical Report
NREL/TP-xxx-xxxxx
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Background

This test was conducted as part of the U.S. Department of Energy's (DOE) Independent Testing project. This project was established to help reduce the barriers of wind energy expansion by providing independent testing results for small turbines. In total, four turbines were tested at the National Wind Technology Center (NWTC) as a part of this project. Safety and function testing is one of up to five tests that were performed on the turbines, including power performance, duration, noise, and power quality tests. Test results provide manufacturers with reports that can be used for small wind turbine certification.

The test equipment includes an ARE 442 wind turbine mounted on a 100-ft free-standing lattice tower. The system was installed by the NWTC Site Operations group with guidance and assistance from Abundant Renewable Energy.

Test Objective

The objective of this test is to:

- verify that the test turbine displays the behavior predicted in the design
- determine if provisions relating to personnel safety are properly implemented
- characterize the dynamic behavior of the wind turbine at rated wind speed and above.

NREL does not limit the safety and function test to features described in the wind turbine documentation. NREL also inspects, possibly tests, and reports on features that are required by IEC 61400-2 that may not be described in the wind turbine documentation.

NREL conducted this test in accordance with Section 9.6 of the International Electrotechnical Commission (IEC) standard, Wind Turbines – Part 2: Design requirements for small wind turbines, IEC 61400-2, Second edition, 2006-03.

Description of Test Turbine and Setup

The test turbine was an ARE 442 wind turbine. This turbine is an upwind three-bladed side furling turbine with a rated power of 10kW. Table 1 provides the key descriptive information of the test turbine.

The ARE 442 wind turbine was installed at site 3.3a at the National Wind Technology Center located eight miles south of Boulder, Colorado (Figure 1). The location primarily consists of mostly flat terrain with short vegetation. The test site has prevailing wind, bearing 292 degrees, relative to true north (292°T). For measurements where it is important to accurately measure wind speed, NREL used data obtained when wind direction is between 214°T and 72°T. In this measurement sector, which was established in accordance with IEC 61400-12-1, the influence of terrain and obstructions on the anemometer and turbine is small.

A one line diagram of the turbine system is provided in Figure 2.

Table 1. Test Turbine Configuration

Turbine manufacturer and address	Abundant Renewable Energy 22700 NE Mountain Top Road Newberg OR 97132
Model name	ARE 442
Serial number	Y08-001C
Production date	January 2008
Design nominal voltage at terminals (VAC)	240
Maximum current at terminals (A)	55
Design frequency at terminals (Hz)	60
SWT class	II
Design 50-year extreme wind speed, V_{e50} (m/s)	59.5
Rotor Diameter (m)	7.2
Hub Height (vertical center of rotor) (m)	30.9
Tower Type	Freestanding Lattice Valmont U4.5 x 100'
Rated Electrical Power (kW)	10
Rated Wind Speed (m/s) (lowest wind speed at which turbine produces rated power)	11
Rated rotor speed (rpm) (lowest rotor speed at which turbine produces rated power)	140
Rotor speed range (rpm)	0-160
Fixed or variable pitch	Fixed
Number of Blades	3
Blade Tip Pitch Angle (deg)	0, blade root flat on alternator
Blade make, type, serial number	Aero Energy 089-028, 089-029, 089-030
Description of control system (device & software version)	Combination of side furling with gravity return, VCL 442-HV voltage clamp and Windyboy US6000 inverter software.

Figure 1. ARE 442 wind turbine at the NWTC test site

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Instrumentation

The following parameters were measured in this test: wind speed, electrical power, rotor speed, and grid voltage. NREL calculated the rotor speed by measuring the frequency of the wild AC (variable voltage, variable frequency) coming from the alternator.

An indication of turbine status was obtained by measuring the status of the relays that activate the brake resistors up in the yaw head. The signal is zero when the generator is shorted, and five when it is not.

The instruments that were used for these measurements are listed in Table 2. The calibration sheets for the instruments used for this safety and function test are included in Appendix A.

Table 2. Equipment List for Safety and Function Test

Instrument	Make, Model	Serial Number	Calibration Due Date
Power transducer	Secondwind Phaser 5FM-4A20	02663	April 28, 2009
Current transducers	OSI 12974	001235408 001235411	Calibrated with Power transducer, April 28, 2009
Primary anemometer	Thies, First Class	0707886	Feb. 28, 2009
Reference anemometer	NRG, Max 40	179500049022	In situ
Rotor speed	OSI Voltage Transducer VT7-010E-11	08010700	April 28, 2009
Data acquisition system	Compact DAQ w/LabView based data acquisition cDAQ-9172 NI 9229 NI 9217 NI 9205	12EAE14 12A2037 12C73B4 12ECB77	May 31, 2008 Aug. 3, 2008 Oct. 9, 2008 Modules calibrated post-test on May 6, 2009, found in compliance

Procedure

Safety and function testing may involve some risk to personnel and to equipment. NREL endeavors to accomplish its tasks with minimal risk by incorporating appropriate controls into testing procedures. This test report documents these controls where they may have had an influence on results obtained.

Control and Protection System Functions

The first part of the test procedure is to assess the control and protection system functions listed below. For each function, NREL provided an input to the existing control and protection system or simulated the external condition. NREL then recorded the response of the turbine.

In the list below, turbine response was observed for each major response category (startup, normal shutdown, emergency shutdown). If faults or other actions caused one of these major responses, NREL simulates the appropriate input and verifies that the control and protection system appropriately a) sensed the condition, and b) provided indication of an appropriate response. This procedure enables, for example, all the E-stop functions to be checked without exposing the turbine to multiple, potentially-damaging stops. These checks are designated by the term “behavior” in the list below.

1. Power control
2. Rotor speed control
3. Yaw orientation
4. Startup
 - a. Normal operation – winds rising above cut-in
 - b. After maintenance or fault clearance at design wind speed or above
 - c. Maintenance of fault conditions at design wind speed or above
5. Normal shutdown
6. Emergency shutdown during operation
7. Behavior upon excessive vibration
8. Behavior upon loss of load
9. Turbine specific checks
 - a. Behavior upon over-temperature
 - b. Behavior upon loss of load brake or diversion load connection

Personnel Safety Provisions

The second part of the test procedure is to evaluate provisions for personnel safety. For this turbine, the following issues were reviewed.

- Safety instructions
- Climbing
- Fire resistance and control
- Fire extinguisher
- Emergency stop buttons
- Lock-out / tag-out provisions
- Interlock on electrical cabinets
- Safety signs
- Unauthorized changing of control settings
- Lightning protection
- Presence and functioning of rotor and yaw lock

Dynamic Behavior

NREL observed the turbine over a wide range of wind speeds. Observations were written in the logbook and are reported in the results section. No direct measurement of accelerations was done for this turbine.

Results

Test results reported here are based on test conducted from June 12, 2008 when the turbine was commissioned through October 2, 2009.

Control and Protection System Functions

The only significant finding is that the rotor speed NREL measured is well above what the manufacturer specified.

NREL limits testing to investigate single-fault failures and has not investigated failures of “safe life” components. If a second fault were to occur during a critical event, severe results can be expected. NREL does not make judgments on whether such failures are likely or whether additional features in the control and protection system are needed to protect against such consequences.

The following is a list of tests that NREL conducted on the ARE 442:

Power control

Figure 3 shows that the power output of the turbine system is limited. This is mainly due to the power output limitations of the inverters. It does not necessarily mean that the turbine itself is limiting power correctly. The measured power curve does not deviate significantly from the published power curve.

Rotor speed control

Rotor speed measurements taken during the test period do not conclusively indicate that the turbine system exhibits control over rotor speed in response to high winds. Figure 4 shows both 10-minute average rotor speed data and maximum and minimum value in each 10 minute period. The maximum and minimum values are based on data samples at 40Hz. The averages appear to be leveling off quite well. However, there is quite a bit of variation in the maxima with no clear trend. Most of the high maxima were measured during periods where the turbine came back online from a faulted condition during high wind conditions. An example of such a high rotor speed event is given in Figure 5.

The manufacturer's expected maximum rotor speed was "above 200 rpm."

Yaw orientation

NREL observed yaw behavior frequently during the test period and compared yaw position with the nearby wind-vane indication of wind direction. We observed normal behavior under all wind conditions. At low wind speeds, the rotor operates at about 40° offset from the prevailing wind direction. This yaw error decreases as the wind speed increases until the turbine furls.

This turbine uses slip rings to transmit power to and from the nacelle to the tower cable. Therefore, droop cable over-twist is not an issue.

Startup

NREL observed that the turbine rotor starts spinning whenever winds increase to about 2 m/s. The turbine controller responds after a wait period during which it checks brake functionality. This is followed by a period during which the controller keeps the rotor speed at a low value until the inverters come on-line. When the inverters are online, the controller releases the rotor to normal operating speed. NREL has observed the turbine starting up over a wide range of wind speeds. NREL has not observed any abnormal behavior during any of the startups. NREL observed similar smooth cut-ins when the turbine was returned to service after shutdown.

Normal Shutdown

When winds drop below cut-in, the rotor gradually slows and stops producing power with no significant change in sound or behavior. This turbine does not have a cut-out wind speed, so normally it does not shut down in high winds.

Emergency shutdown during operation from any operating condition

Physically the emergency shutdown is the same as an automatic shutdown due to a fault.

The turbine safely brings the rotor down to an idling speed under any wind condition. This behavior is consistent with the manual's statement that the system can be shut down at any wind speed.

In addition to the automatic shutdown the controller performed, NREL also performed shutdowns by pushing the stop button on the voltage clamp. The turbine safely brought the rotor down to an idling speed any time this was performed.

Behavior upon excessive vibration

The turbine has no means to sense excessive vibration or to shut down should excessive vibration occur. The IEC turbine design standards require such sensors on large turbines but not on turbines smaller than 200^m².

Behavior upon loss of load

When the inverters sense a grid fault, they disconnect from the grid. The voltage clamp then applies the brake. NREL tested for this by opening the disconnect switch between the ARE subpanel and panel 3-3L. This test took place on November 5, 2008 in winds of about 12 m/s.

The turbine shut down but then never came back online. It was found that the Insulated Gate Bipolar Transistors IGBT's in the voltage clamp had failed. Figure 6 shows the time traces of the event.

A similar event during which the IGBT's failed happened during a real grid outage on June 13th. Both failures happened during winds in which the inverters were producing maximum power and the diversion loads were likely already active.

On July 20, 2009, the loss of load simulation was repeated in low winds (6m/s). The turbine did not sustain any damage from this test. (Figure 7)

Turbine specific checks

Over temperature

This turbine system has provisions to monitor temperature in the voltage clamp and in the diversion loads. Should those components become too hot, the turbine shuts down, initiates a 5-minute cool down period, and waits until all temperatures are below their set point. On December 5, 2008, independent temperature readings were taken during high winds. At the time, an over-temperature fault occurred. NREL measured the temperature at the top of one of the diversion loads to be 72.7°C. The temperature in the voltage clamp enclosure was 41.2°. At that time, the ambient temperature in the data shed was 34.4°C.

Load brake resistor failure simulation

Upon startup of the turbine, the voltage clamp checks to see if the diversion loads and brake resistors are properly installed. To test this function, NREL disconnected the DL2+ wire inside the voltage clamp. The turbine went through the startup sequence, allowing the rotor to rotate slowly. It then faulted to a Load/Brake Resistor test fault as indicated by the red and green LED both being steady on.

Personnel Safety Provisions

Safety Instructions

The turbine operator's manual provides few safety instructions for installation, operation, and maintenance. The turbine does not require trained personnel for maintenance or servicing so no warning of this nature is required on the manual's cover.

The Owners manual covers assembly of the turbine but not the actual installation of the turbine system. NREL asked and received a separate document describing the installation procedure including hoisting and rigging information.

NREL checked the manual to determine if the safety instructions addressed requirements in the IEC small turbine design standard and found the following:

1. Disengage the load and/or energy sources: The voltage clamp has instructions indicating that it should only be opened after the stop button has been pushed. The inverter manuals describe how to disconnect the inverters from both the DC and AC connections.
2. Stop and secure the rotor: NREL found an explanation on how to slow down the rotor but no provision was found on how to stop it completely.
3. Stop and secure the yaw mechanism: The turbine has no provisions for securing the yaw mechanism.
4. Stop and secure the furling system: The turbine has no provisions for securing the furl mechanism.
5. Climb tower: The tower came with a TUF TUG safety climb system. It included a manual with instructions for safe climbing.

Climbing

NREL personnel climbed the turbine using the supplied TUF TUG fall protection system. On one side of the tower, additional horizontal braces are installed to form a ladder. Climbing the tower was found to be fairly easy. The main issue was getting to a working position at the top of the climbing system. There are no recommendations in the owner's manual about transferring from the fall protection cable to a working position on the turbine and the climbing system ends before reaching a position high enough to work on the turbine. There are no obvious or clearly identified tie off points other than the tab on top of the turbine behind the rotor, which is difficult to reach when still holding on to the side of the ladder. Another issue is preventing the turbine from yawing while in the process of getting into a working position. NREL recommends inserting some language into the manual describing how to safely tie off a blade to the tower to prevent rotor rotation and yaw movement.

Fire resistance and control

The Windyboy inverters are designed to resist “normal internal temperatures” and according to the manual will de-rate to maintain safe internal temperatures. NREL did not evaluate this since the inverter is UL listed as compliant with UL 1741.

The voltage clamp has a temperature sensor which will shut the turbine down once the temperature exceeds a threshold. The dump load is enclosed in a fire-resistant, metal enclosure. It has temperature sensors installed in the top of the enclosures. If the temperature exceeds the limits, the turbine will shut down.

The turbine Owner’s Manual describes the clearance required around each of the system’s components.

Fire extinguisher

NREL provided a fire extinguisher in the building that housed the voltage clamp, diversion loads, and inverters. The manufacturer does not provide fire extinguishers or recommend that they be installed.

Emergency Stop Button

The turbine has an emergency stop button on the voltage clamp (Figure 8) for use in manual turbine shutdown.

Lock-out / tag-out provisions

NREL provided a lockable switch between the grid and the subpanel that was connected to the voltage clamp and the inverters (Figure 9). The manufacturer does not provide this equipment or recommend that this type of equipment be installed. Nor does the manufacturer provide procedures for de-energization of the turbine system.

Interlock on electrical cabinets

The voltage clamp does not have an interlock on the cabinet. However, there is a warning label and instructions on the door. A hex key is needed to open the cabinet.

Safety signs

1. The voltage clamp has a label warning of high voltage and instructions on how to safely open the enclosure. (Figure 10)
2. The diversion loads did not have any warning signs. NREL added a sign stating “Caution hot surface do not touch.”
3. The TUF TUG safety system has a tag on the cable at the base of the tower. (Figure 11)
4. NREL added labels indicating the voltage levels on all enclosures, electrical panels, and disconnects.

Unauthorized changing of control settings

There are no readily accessible ways to alter any settings in the voltage clamp. The inverter settings can be changed if the directions in the manual are followed. The inverter must be opened to do so.

Lighting Protection

The turbine was purchased with the lightning protection package. This is normally an add-on that has to be purchased separately. It consists of three surge suppressors. One at the tower base, one on the voltage clamp, and one on the sub-panel as indicated in Figure 2. During the test period, no direct or nearby lightning strikes were observed.

In addition to the surge suppressors, the turbine base is grounded and a ground wire runs in the trench back to the data shed to a second ground rod. No Ufer ground was specified for the foundation itself.

Presence of rotor and yaw lock

There is no rotor lock or yaw lock present on the turbine.

Dynamic Behavior

NREL observed operation throughout the test period in wind speeds ranging from dead calm to winds in excess of 25 m/s. The total observation time exceeded the required one hour. NREL did not measure accelerations directly. NREL noted that the turbine displayed no excessive vibrations. The turbine did not produce any significant differences in noise levels. Tail movement and yaw behavior appeared normal under all conditions.

Figure 3. Power response to wind speed (red- maxima, green - minima, blue -average)

Figure 4. Rotor speed response to wind speed (red- maxima, green - minima, blue -average)

Figure 5. Time series of a high rpm event (datafile ARE081230_001156)

Figure 6. Turbine response during a simulated grid outage -- the IGBT's failed. (datafile ARE081105_144425)

Figure 7. Simulated grid outage in low winds (data file ARE090720_115146)

Figure 8. ARE442 Voltage clamp with e-stop button

Figure 9. ARE 442 disconnect

Figure 10. Safety instructions on the voltage clamp

Figure 11. Safety instruction tag on the TUF TUG climbing system

Deviations and Exceptions

Deviations from the Standard

There were no known exceptions to the Standard for the test.

Exceptions to the NWTC Quality Assurance System

The data acquisition modules were used beyond the calibration due date. The modules were post-test calibrated and found to be in compliance within the specifications. Appendix A includes the post-test calibration sheets.

Appendix A – Instrument Calibration Sheets

Branch #: 5000

NREL METROLOGY LABORATORY

Test Report

Test Instrument: Phaser Power Transducer & 2-CTs

DOE #: 02824C

Model # : Phaser-5-F-5A

S/N : 02663

Calibration Date: 01/28/2008

Due Date: 01/28/2010

A. Set-Up for Total Real Power Calibration:
A.1. Voltage is applied to phases A&B = 120 V @ 60 Hz.
A.2. Current is applied to n = 5-TURNS through two current transformers that are connected to phases A&B.
A.3. Analog Output-1 is measured across precision resistor = 250 Ω .
A.4. Phaser Full Scale setting = -7.2KW to 7.2KW.

Input Current (AAC)	Input Power (KW)	Analog Output-1 (VDC)
28	6.72	4.790
21	5.04	4.341
14	3.36	3.892
7	1.68	3.444
0	0	2.995
-7	-1.68	2.547
-14	-3.36	2.099
-21	-5.04	1.651
-28	-6.72	1.203

B. Set-Up for Power Factor Calibration:
B.1. Voltage & Current are applied as A.1 & A.2.
B.2. Analog Output-2 is measured across precision resistor = 250 Ω .

Power (KW)	Power Factor	Analog Output-2 (VDC)
6.72	1.0	4.989
"	0.8	4.179
"	0.6	3.377
"	0.4	2.577
"	0.2	1.778

Page 1 of 2

Figure A.1. Power transducer calibration sheet

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Calibration laboratory for velocity of air flow

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PHYSIKALISCH-TECHNISCHEN BUNDESANSTALT (PTB)

Deutsche WindGuard
Wind Tunnel Services GmbH
Varel

Kalibrierschein *Calibration Certificate*

Kalibrierzeichen
Calibration label

DKD-K-
36801

07_2417

Gegenstand
Object Cup Anemometer

Hersteller
Manufacturer Thies Clima
D-37083 Göttingen

Typ
Type 4.3350.00.000

Fabrikat/Serien-Nr.
Serial number Body: 0707886
Cup: 0707886

Auftraggeber
Customer Thies Clima
D-37083 Göttingen

Auftragsnummer
Order No. VT07255

Anzahl der Seiten des Kalibrierscheines
Number of pages of the certificate 3

Datum der Kalibrierung
Date of calibration 24.07.2007

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).

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Figure A.2. Primary anemometer calibration sheet

**Certificate of
Calibration****Board Information:**

Serial Number: 12A2037
NI Part Number: 192580D-02
Description: NI 9229

Certificate Information:

Certificate Number: 733748
Date Printed: 05-JAN-09

Calibration Date: 31-MAY-07
Recommended Calibration Due Date: 31-MAY-08*

Ambient Temperature: 22 °C
Relative Humidity: 50 %

National Instruments certifies that at the time of manufacture, the above product was calibrated in accordance with applicable National Instruments procedures. These procedures are in compliance with relevant clauses of ISO 9001 and are designed to assure that the product listed above meets or exceeds National Instruments specifications.

National Instruments further certifies that the measurements standards and instruments used during the calibration of this product are traceable to National and/or International Standards administered by NIST or Euromet members or are derived from accepted values of natural physical constants.

The environment in which this product was calibrated is maintained within the operating specifications of the instrument and the standards.

The information shown on this certificate applies only to the instrument identified above and the certificate may not be reproduced, except in full, without prior written consent by National Instruments.

For questions or comments, please contact National Instruments Technical Support.

NI Hungary Software és
Hardware Gyártó Kft.
4031 Debrecen, Határ út
1/A.
HUNGARY

Signed,

Andrew Krupp
Quality Director

* Recommended calibration due date is based on a combination of calibration interval and, when applicable, calibration shelf life. This date may vary depending on your application requirements.

Figure A.4. NI 9229 data acquisition module calibration sheet I

**Certificate of
Calibration****Board Information:**

Serial Number: 12C73B4
NI Part Number: 192547D-01
Description: NI 9217

Certificate Information:

Certificate Number: 786529
Date Printed: 05-JAN-09

Calibration Date: 03-AUG-07
Recommended Calibration Due Date: 03-AUG-08*

Ambient Temperature: 23 °C
Relative Humidity: 46 %

National Instruments certifies that at the time of manufacture, the above product was calibrated in accordance with applicable National Instruments procedures. These procedures are in compliance with relevant clauses of ISO 9001 and are designed to assure that the product listed above meets or exceeds National Instruments specifications.

National Instruments further certifies that the measurements standards and instruments used during the calibration of this product are traceable to National and/or International Standards administered by NIST or Euromet members or are derived from accepted values of natural physical constants.

The environment in which this product was calibrated is maintained within the operating specifications of the instrument and the standards.

The information shown on this certificate applies only to the instrument identified above and the certificate may not be reproduced, except in full, without prior written consent by National Instruments.

For questions or comments, please contact National Instruments Technical Support.

NI Hungary Software és
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4031 Debrecen, Határ út
1/A.
HUNGARY

Signed,

Andrew Krupp
Quality Director

* Recommended calibration due date is based on a combination of calibration interval and, when applicable, calibration shelf life. This date may vary depending on your application requirements.

Figure A.5. NI 9217 data acquisition module calibration sheet I

**Certificate of
Calibration****Board Information:**

Serial Number: 12ECB77

NI Part Number: 193299F-01

Description: NI-9205

Certificate Information:

Certificate Number: 837236

Date Printed: 05-JAN-09

Calibration Date: 09-OCT-07

Recommended Calibration Due Date: 09-OCT-08*

Ambient Temperature: 23 °C

Relative Humidity: 37 %

National Instruments certifies that at the time of manufacture, the above product was calibrated in accordance with applicable National Instruments procedures. These procedures are in compliance with relevant clauses of ISO 9001 and are designed to assure that the product listed above meets or exceeds National Instruments specifications.

National Instruments further certifies that the measurements standards and instruments used during the calibration of this product are traceable to National and/or International Standards administered by NIST or Euromet members or are derived from accepted values of natural physical constants.

The environment in which this product was calibrated is maintained within the operating specifications of the instrument and the standards.

The information shown on this certificate applies only to the instrument identified above and the certificate may not be reproduced, except in full, without prior written consent by National Instruments.

For questions or comments, please contact National Instruments Technical Support.

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4031 Debrecen, Határ út
1/A.
HUNGARY

Signed,

Andrew Krupp
Quality Director

* Recommended calibration due date is based on a combination of calibration interval and, when applicable, calibration shelf life. This date may vary depending on your application requirements.

Figure A.6. NI 9205 data acquisition module calibration sheet I

Certificate of Calibration

3214191

Certificate Page 1 of 1

Instrument Identification

Company ID: 229037
NATIONAL INSTRUMENTS

PO Number: 337683

11500 N. MOPAC EXPWY
ATTN. RMA DEPT.
AUSTIN, TX 78759

Instrument ID: **12A2037**

Model Number: NI 9229

Manufacturer: NATIONAL INSTRUMENTS

Serial Number: 12A2037

Description: 4-CHANNEL, ± 60 V, 24-BIT SIMULTANEOUS ANALOG INPUT

Accuracy: Mfr Specifications

Certificate Information

Reason For Service: CALIBRATION

Type of Cal: ACCREDITED 17025

As Found Condition: IN TOLERANCE

As Left Condition: LEFT AS FOUND

Procedure: NATIONAL INSTRUMENTS CAL EXECUTIVE REV 3.3.1

Remarks: Reference attached Data.

Technician: WAYNE GETCHELL

Cal Date: 06May2009

Cal Due Date: 06May2010

Interval: 12 MONTHS

Temperature: 23.0 C

Humidity: 44.0 %

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [$K=2$, approx. 95% Confidence Level] was maintained unless otherwise stated.

Davis Calibration Laboratory is certified to ISO 9001:2000 by Eagle Registrations (certificate # 3046). Lab Operations meet the requirements of ANSI/NCSL Z540-1-1994, ISO 10012:2003, 10CFR50 AppxB, and 10CFR21.

ISO/IEC 17025-2005 accredited calibrations are per ACLASS certificate # AC-1187 within the scope for which the lab is accredited.

All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.

This certificate shall not be reproduced except in full, without written consent of Davis Calibration Laboratory.

Approved By: VICTOR PENA
Service Representative

Calibration Standards

<u>NIST Traceable#</u>	<u>Inst. ID#</u>	<u>Description</u>	<u>Model</u>	<u>Cal Date</u>	<u>Date Due</u>
3143038	15-0271	MULTIFUNCTION CALIBRATOR	5700A	15Apr2009	14Jul2009

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Figure A.7. NI 9229 data acquisition module calibration sheet II

Certificate of Calibration

3214178

Certificate Page 1 of 1

Instrument Identification

Company ID: 229037
NATIONAL INSTRUMENTS

PO Number: 337683

11500 N. MOPAC EXPWY
ATTN: RMA DEPT.
AUSTIN, TX 78759

Instrument ID: **12C73B4**

Model Number: NI 9217

Manufacturer: NATIONAL INSTRUMENTS

Serial Number: 12C73B4

Description: 4-CH 100 OHM 24-BIT RTD ANALOG INPUT

Accuracy: Mfr. Specifications

Certificate Information

Reason For Service: CALIBRATION
Type of Cal: ACCREDITED 17025
As Found Condition: IN TOLERANCE
As Left Condition: LEFT AS FOUND
Procedure: CAL EXEC 3.3.1 CAL EXEC 3.3.1

Technician: WAYNE GETCHELL
Cal Date: 06May2009
Cal Due Date: 06May2010
Interval: 12 MONTHS
Temperature: 23.0 C
Humidity: 46.0 %

Remarks: Reference attached data.

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [K=2, approx. 95% Confidence Level] was maintained unless otherwise stated.

Davis Calibration Laboratory is certified to ISO 9001:2000 by Eagle Registrations (certificate # 3046). Lab Operations meet the requirements of ANSI/NCSL Z540-1-1994, ISO 10012:2003, 10CFR50 AppxB, and 10CFR21.

ISO/IEC 17025-2005 accredited calibrations are per ACLASS certificate # AC-1187 within the scope for which the lab is accredited. All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.

This certificate shall not be reproduced except in full, without written consent of Davis Calibration Laboratory.

Approved By: VICTOR PENA
Service Representative

Calibration Standards

NIST Traceable#	Inst. ID#	Description	Model	Cal Date	Date Due
3078982	15-0011	DECADE RESISTOR	DB52	24Mar2009	24Mar2010
3004176	15-0060	DIGITAL MULTIMETER (GOLDEN CAL)	3458A OPT 002	17Feb2009	17May2009

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Figure A.8. NI 9217 data acquisition module calibration sheet II

Certificate of Calibration

3214150

Certificate Page 1 of 1

Instrument Identification

Company ID: 229037
NATIONAL INSTRUMENTS

PO Number: 337683

11500 N. MOPAC EXPWY
ATTN: RMA DEPT.
AUSTIN, TX 78759

Instrument ID: **12ECB77**

Model Number: NI 9205

Manufacturer: NATIONAL INSTRUMENTS

Serial Number: 12ECB77

Description: 32-CH ± 200 MV TO ± 10 V, 16-BIT, 250 KS/S ANALOG INPUT MODULE

Accuracy: Mfr Specifications

Certificate Information

Reason For Service: CALIBRATION

Type of Cal: ACCREDITED 17025

As Found Condition: IN TOLERANCE

As Left Condition: LEFT AS FOUND

Procedure: NATIONAL INSTRUMENTS CAL EXECUTIVE REV 3.3.1

Remarks: Reference attached Data.

Technician: WAYNE GETCHELL

Cal Date: 06May2009

Cal Due Date: 06May2010

Interval: 12 MONTHS

Temperature: 23.0 C

Humidity: 47.0 %

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [$K=2$, approx. 95% Confidence Level] was maintained unless otherwise stated.

Davis Calibration Laboratory is certified to ISO 9001:2000 by Eagle Registrations (certificate # 3046). Lab Operations meet the requirements of ANSI/NCCL Z540-1-1994, ISO 10012:2003, 10CFR50 AppxB, and 10CFR21.

ISO/IEC 17025:2005 accredited calibrations are per ACLASS certificate # AC-1187 within the scope for which the lab is accredited. All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.

This certificate shall not be reproduced except in full, without written consent of Davis Calibration Laboratory.

Approved By: VICTOR PENA
Service Representative

Calibration Standards

<u>NIST Traceable#</u>	<u>Inst. ID#</u>	<u>Description</u>	<u>Model</u>	<u>Cal Date</u>	<u>Date Due</u>
3143038	15-0271	MULTIFUNCTION CALIBRATOR	5700A	15Apr2009	14Jul2009

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Figure A.9. NI 9205 data acquisition module calibration sheet II

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1. REPORT DATE (DD-MM-YYYY) February 2010			2. REPORT TYPE Technical Report		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE Wind Turbine Safety and Function Test Report for the ARE 442 Wind Turbine					5a. CONTRACT NUMBER DE-AC36-08-GO28308	
					5b. GRANT NUMBER	
					5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) J. van Dam, D. Baker, and D. Jager					5d. PROJECT NUMBER NREL/TP-500-47030	
					5e. TASK NUMBER WE102211	
					5f. WORK UNIT NUMBER	
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12. DISTRIBUTION AVAILABILITY STATEMENT National Technical Information Service U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161						
13. SUPPLEMENTARY NOTES						
14. ABSTRACT (Maximum 200 Words) This test was conducted as part of the U.S. Department of Energy's (DOE) Independent Testing project. This project was established to help reduce the barriers of wind energy expansion by providing independent testing results for small turbines. In total, four turbines were tested at the National Wind Technology Center (NWTC) as a part of this project. Safety and function testing is one of up to five tests that were performed on the turbines, including power performance, duration, noise, and power quality tests. Test results provide manufacturers with reports that can be used for small wind turbine certification. The test equipment includes an ARE 442 wind turbine mounted on a 100-ft free-standing lattice tower. The system was installed by the NWTC Site Operations group with guidance and assistance from Abundant Renewable Energy.						
15. SUBJECT TERMS ARE 442 wind turbine; safety and function test; independent testing project; small wind turbines						
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UL	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON	
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