Station Information Report

Solar and Meteorological Station

Pacific Power Association - Chuuk, FSM

Revision	Date	Author	Checked	Approved	Comments
Rev 0	17 Mar 2020	M. de Jager	J. van Jaarsveldt	M. de Jager	First Issue
Rev 1					
Rev 2					

Contents

1 Introduction

The World Bank initiated the Sustainable Energy Industry Development Project (SEIDP) to, amongst others, support the Pacific Power Association (PPA) in doing renewable energy resource assessments. The focus for this particular section of the project is to get high quality bankable wind as well as irradiance measurements supported by high quality meteorological measurements and to promote the awareness of the resource potential of wind and solar energy.

GeoSUN Africa is to execute the on-site measurement related aspects of the solar section of the project. The assignment for GeoSUN Africa is the following:

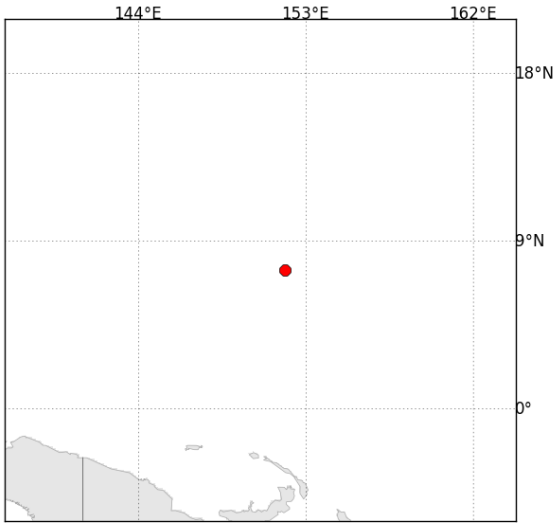
- An inception mission which involves visiting the proposed site locations and selecting the optimal location for the measurement equipment. The outcome of this inception mission is this implementation plan where sites and stations tiers are proposed;
- Providing high quality measuring equipment for each site, in line with the technical specifications;
- Installation of measurement equipment as well as subsequent Site Installation Report and photographs for each site;
- Hosting and providing two years of high quality, 'bankable' meteorological data relevant for solar resource assessment and project development;
- Ensuring maintenance, security, local cleaning/caretaking, and mitigation against extreme weather events and corrosion;
- Ensuring strong local involvement and capacity building at all stages of the measurement campaign;
- Decommissioning of all sites at the end of the measurement campaign, unless separate arrangements are made with one or more host institutions to continue with measurements outside of this assignment/contract.

This document acts as the Site Installation Report which follows the commissioning of the site, outlining the site location, site characteristics, technical specifications, calibration procedures, and all other relevant information to allow data users to fully understand the site and ensure the bankability of the measurement data. The Site Installation Report contains photographs of the site and the surrounding terrain.

The measurement data from the site will be continuously transferred to GeoSUN's central data repository, and shall then be transferred to the PPA on a monthly basis in both raw and quality-controlled formats according to the specifications developed by ESMAP. This data will be delivered via an online file sharing platform one month in arears. Site Measurement Reports will accompany the delivery of monthly data, and shall detail any issues with the site or equipment, field calibration procedure, and any notable conclusions or results.

The assignment shall be deemed completed once two years of concurrent data is delivered in compliance with the minimum data recovery rates specified. At this point the vendor shall decommission each site and remove the solar measurement equipment, unless alternative arrangements outside the scope of this assignment/contract are made and endorsed by the relevant client/host agency.

2 Station Summary

Work performed	Installation and commissioning of solar and meteorological measurement station
Commissioning date	16 March 2020
Planned decommissioning date	16 March 2022
Client	Pacific Power Association
Client contact person and contact details	Name: Wairarapa J. Young Email: rapa@ppa.org.fj Telephone: (679) 330 6022
Site location	North East corner of Runway on Chuuk. 
Access	Enter one of the main access gates to the runway. Head north east on paved road along the inside of the perimeter fence until the end of the runway is reached.
Coordinates	07° 28' 03.1" N, 151° 50' 59.4" E (7.467517, 151.849834)
Elevation	4 m AMSL
Time zone (local and data logger)	GMT +10 local time zone
Name and contact details of on-site contact person(s)	Name: Albert Francis Phone: 691 932 9091

3 Map of area

Figure 1: Map of the surrounding area (Source: Google Earth)

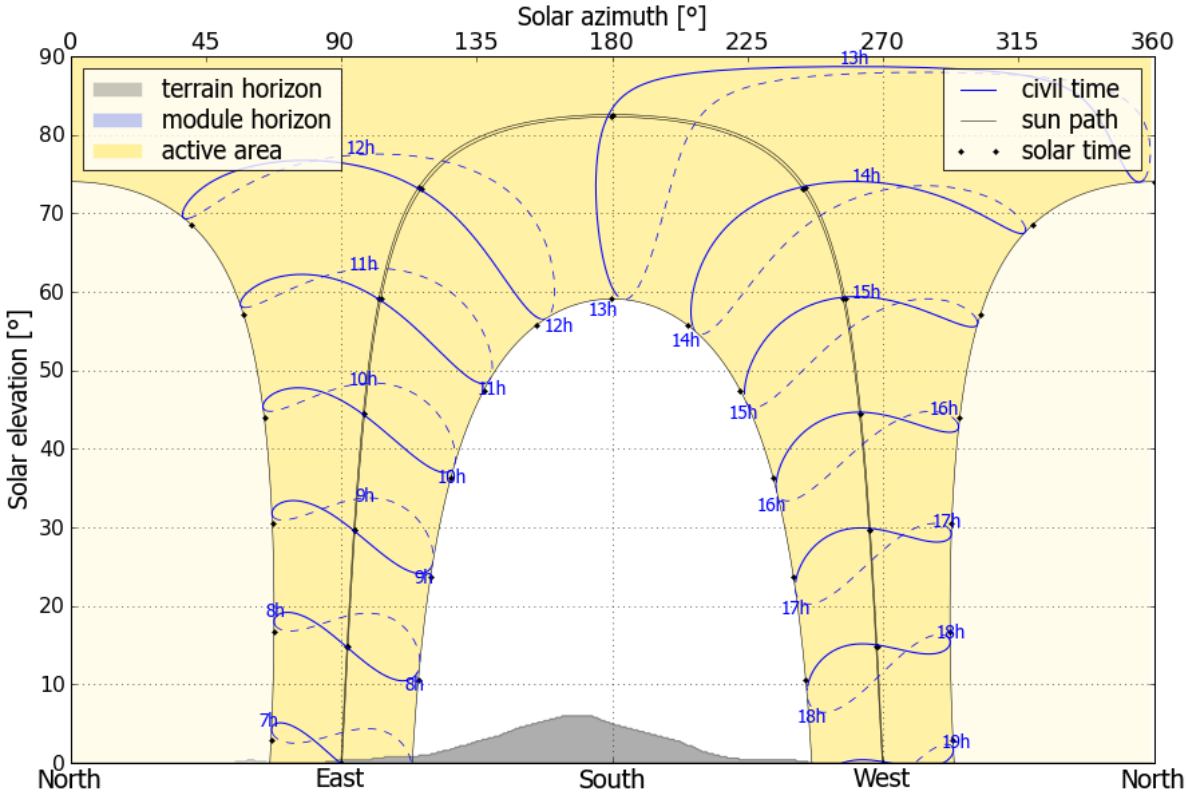


Figure 2: Terrain horizon and day length (Source: Solargis)

4 Site layout

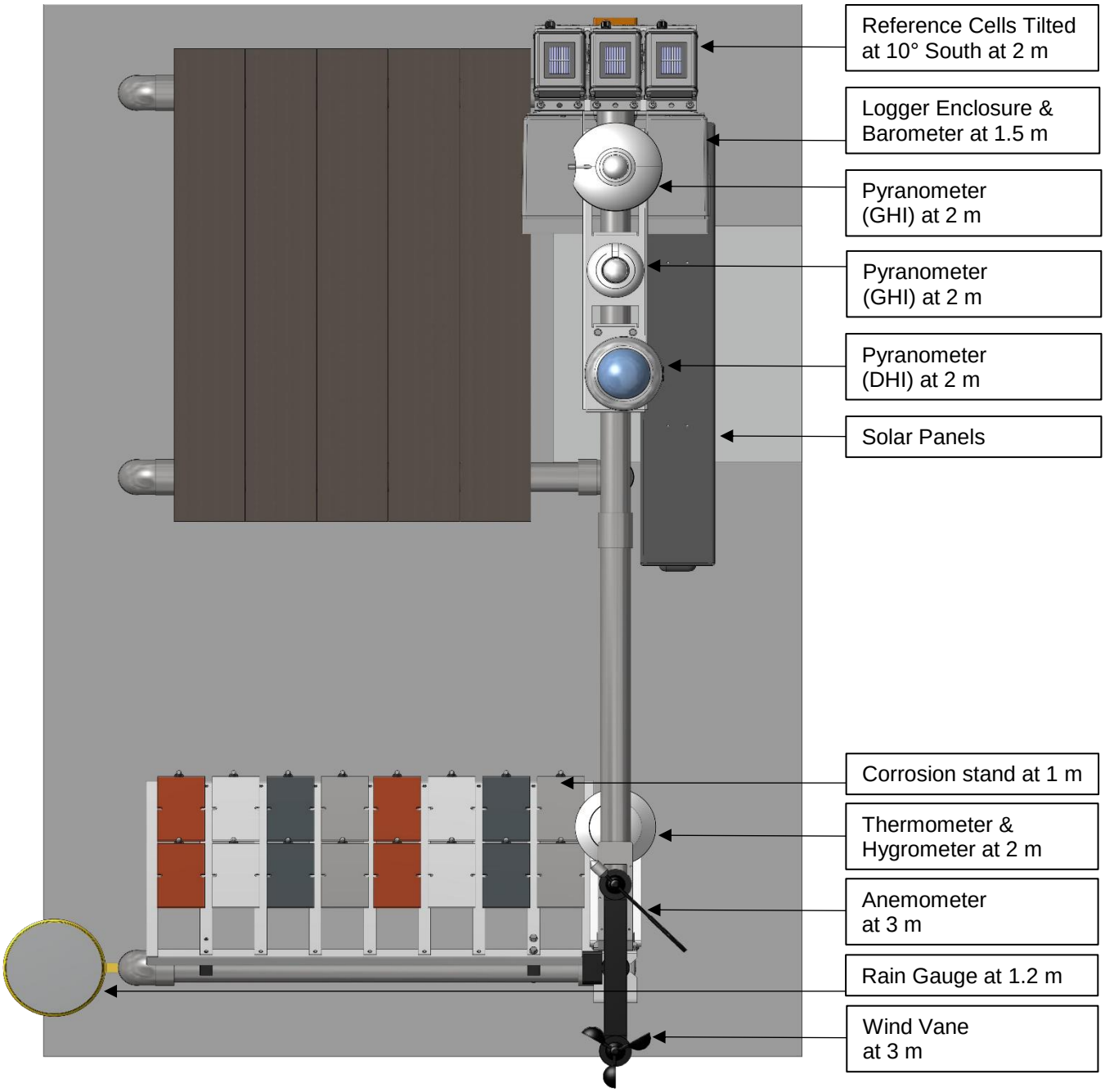


Figure 3: Site Layout (plan view)

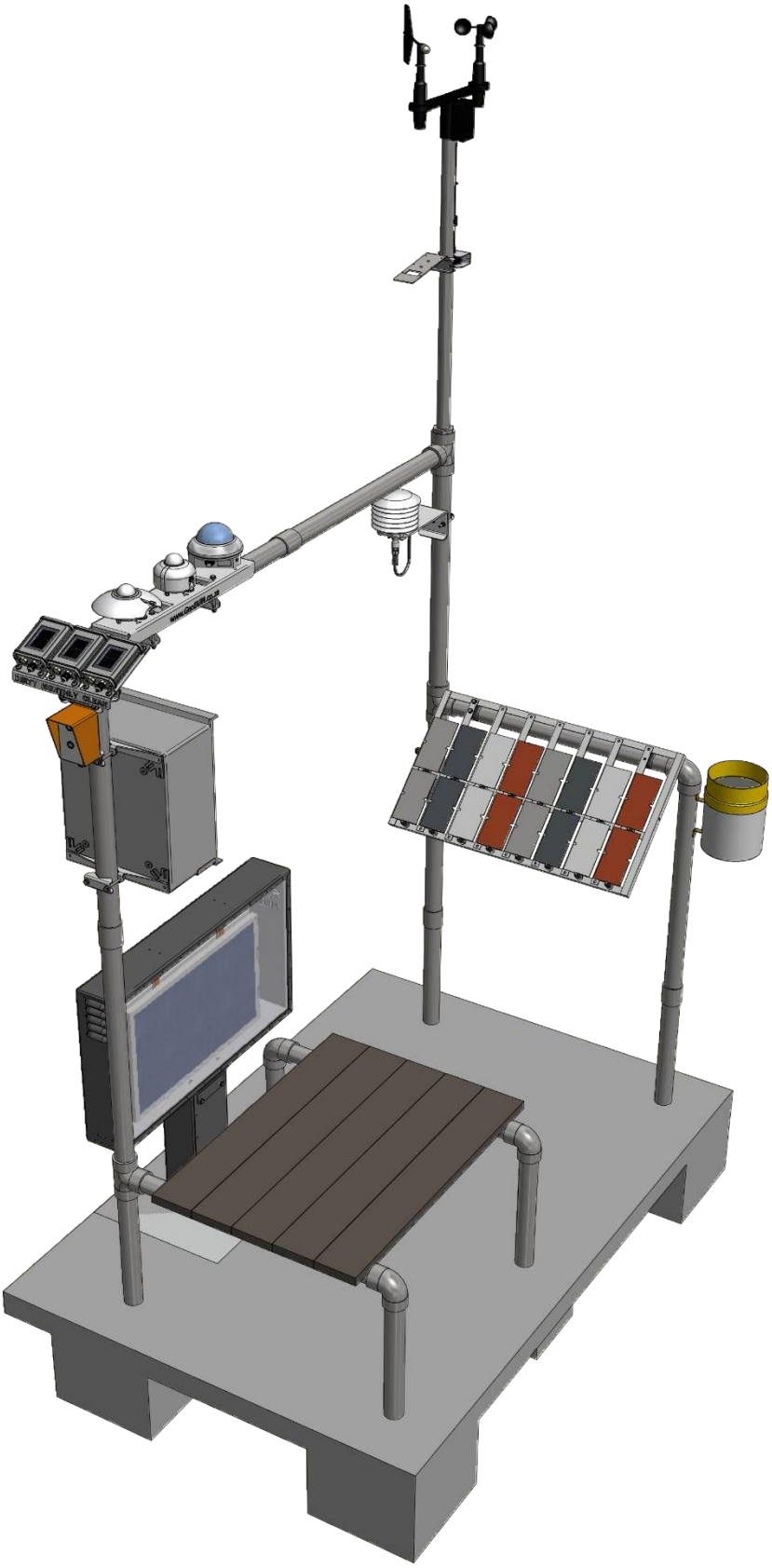


Figure 4: Site Layout (perspective view)

5 Instrument list, serial numbers and multipliers

Instrument (Measurement)	Make and Model	Serial Number	Variable Name (Program)	Multiplier
Pyranometer (GHI)	Hukseflux SR30-D1	4263	GHI_1	10.35 µV/W/m^2
Pyranometer (GHI)	Hukseflux SR20-T2	10499	GHI_2	15.82 µV/W/m^2
Pyranometer (DHI)	Delta Electronics SPN 1	A2059	GHI_SPN1	1
Reference Cell Clean	Ingenieurbüro Si-mV-85-A	85-00205-17-19350082	RefCellClean	58.12 µV/W/m^2
Reference Cell Monthly	Ingenieurbüro Si-mV-85-A	85-00205-17-19350081	RefCellMonthly	58.04 µV/W/m^2
Reference Cell Dirty	Ingenieurbüro Si-mV-85-A	85-00205-17-19350080	RefCellDirty	58.13 µV/W/m^2
3-Cup Anemometer (Wind speed)	RM Young 03002	016942	WSpd	0.2 Offset 0.75 Slope
Wind Vane (Wind Direction)	RM Young 03002	016942	WDir	0 Offset 352 Slope
Temperature Sensor (Ambient Temperature)	Campbell Scientific CS215	E22432	Temp	1
Relative humidity Sensor (Relative Humidity)	Campbell Scientific CS215	E22432	RH	1
Barometer (Atmospheric Pressure)	Vaisala PTB110	R3331020	BP	500 offset 0.24 slope
Rain Gauge (Rain)	Texas Electronics TR-525I	81182-819	Rain	0.2 mm/tip
Corrosion Plate	**Make**	**Sample**	**Position (Column, Row)**	**Mass (g)**
Mild Steel plate (Corrosion Testing)	Orytech Mild Steel	J3	C1, R1	132.0529
		J4	C1, R2	140.6725
		J5	C5, R1	137.1439
		J6	C5, R2	132.6568
H.D. Galvanised (Zinc) plate (Corrosion Testing)	Orytech H.D. Galvanised (Zinc)	J3	C3, R1	79.7088
		J4	C3, R2	79.9810
		J5	C7, R1	79.4285
		J6	C7, R2	80.0016
Copper plate (Corrosion Testing)	Orytech Copper	J3	C4, R1	79.8236
		J4	C4, R2	82.5901
		J5	C8, R1	83.0332
		J6	C8, R2	82.1855
Aluminium plate (Corrosion Testing)	Orytech Aluminium	J3	C2, R1	36.8349
		J4	C2, R2	37.5653
		J5	C6, R1	37.7825
		J6	C6, R2	38.7440

6 Supporting hardware and communication peripherals

Data Logger	Campbell Scientific CR1000X (OS: Std.03.02)
Communication	RS232 (115200) TCP/IP
Pakbus Address	780
Password Set	None
Modem	Maestro M100 3G modem with Poynting antenna
Network Details	Service provider: FSMTC Phone number: 930 2989
Modem Power Control	SW12V
Data Logger Clock	GMT+10
Main Battery	2 x 12 V / 24 Ah
Solar Panel(s)	2 x 25 W
Charge Controller	2 x CPL Research (10 A)

7 Data logger wiring

PPA Wiring Diagram
November 2019- CR1000x

Logger Port	Accessories	Connection	Instrument Cable	Function	Reading	Instrument
		C7	Grey	A-		
		C8	White	B+		
		AGB	Shield	GND		
	250mA Fast-Blow	PB-Fused	Brown	12V	GHI1	SR30
		GB	Black	0V		
			Blue	NC		
		3H	White	Signal +		
		3L	Green	Signal -		
		AGB	Black	GND		
	SW12-2		Yellow	Heater +	GHI2	SR20
		G	Brown	Heater -		
VX1	10kΩ 0.1% Resistor	SE4	Red+Pink	Temp +		
		AG2	Blue+Grey	Temp -		
		5H	White	GHI +		
		6H	Brown	DHI +		
		5L	Green	Signal -		
		6L	Bridged with 5L/Signal -		DHI	SPN1
		GB	Grey	0 V		
		PB	Pink	12 V		

SW12-2		Red	Heater +		
	G	Blue	Heater -		
	AGB	Clear	GND		
	NC	Yellow	Sun		
	PB	Red	12 V	Temp & RH	CS215
	C1	Green	Signal +		
	GB	White	0 V		
	GB	Black	0 V		
	AGB	Clear	GND		
	SE13	Orange	Signal +	Clean	Ref cell
	AG6	Blue	Signal -		
	AGB	Black	GND		
	SE14	Orange	Signal +	Monthly	Ref cell
	AG7	Blue	Signal -		
	AGB	Black	GND		
	SE15	Orange	Signal +	Dirty	Ref cell
	AG7	Blue	Signal -		
	AGB	Black	GND		
	VX2	Blue	Excitation	Wind Speed & Direction	03002
	SE16	Green	Signal +		
	AG8	White	Signal -		
	AGB	Clear	GND		
	P1	Red	Signal +		
	AGB	Clear	GND		
	P2	Black	Signal +	Rain	TE525
	AG	White	Signal -		
	AGB	Clear	GND		
	C5	Red	Signal +	Clean	Clean Button
	C2	Green	Light +		
	C3	Blue	Signal -		
	AGB	Clear	GND		
	C4	Yellow	Signal +	Monthly	Monthly Button
	C2	Green	Light +		
	C3	Blue	Signal -		
	AGB	Clear	GND		
	C6	Red	Signal +	Gate	Switch
	G	Blue	Signal -		
	AGB	Clear	GND		
	SE7	Blue/Brown	Signal +	Pressure	PTB110
	12V	Red	12V		
	5V	Green	Signal +		
	G	Black	Signal -		
	AG	Yellow/White	GND		
	AG	Clear	GND		

8 Power circuit diagram

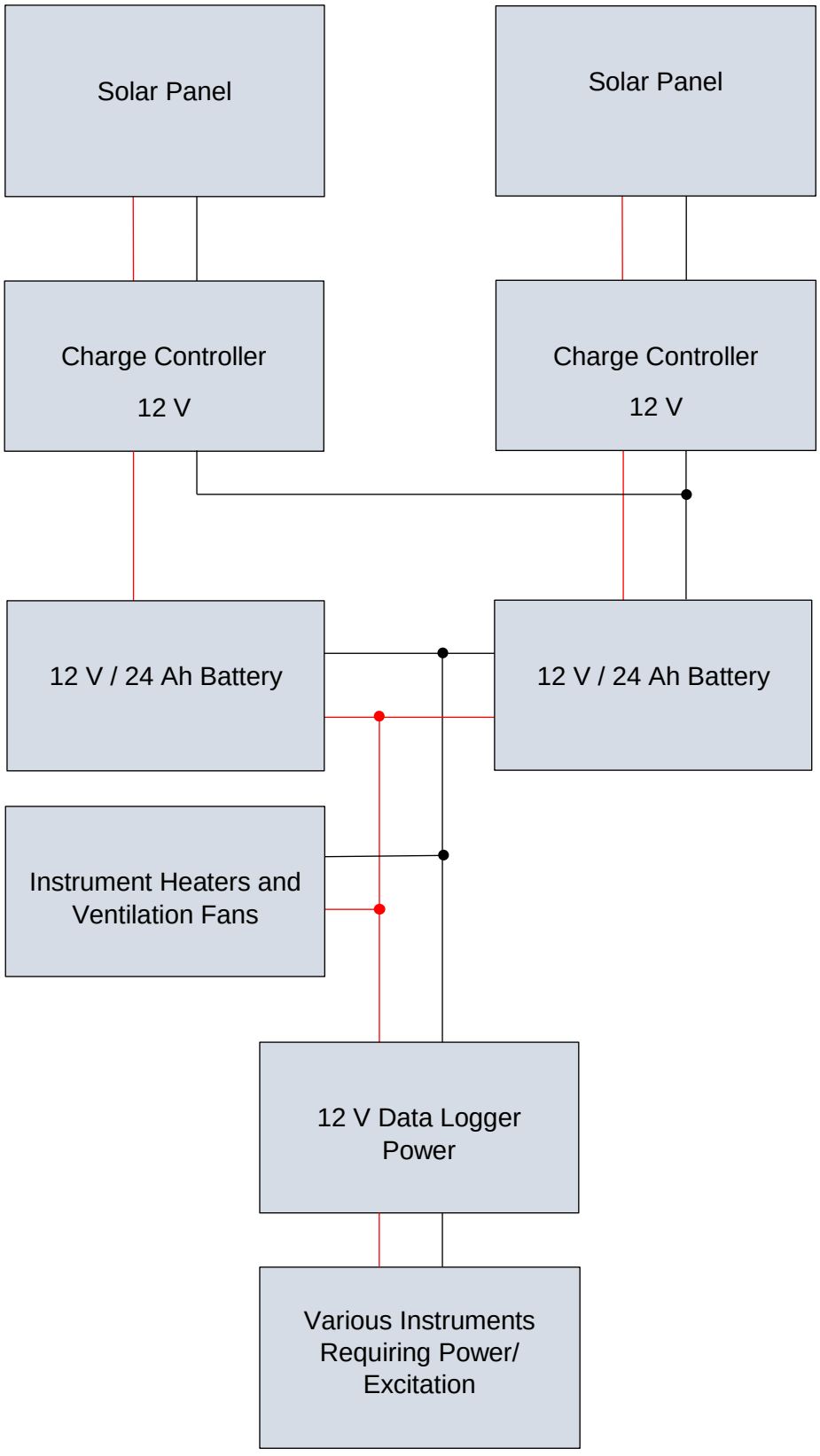


Figure 5: The DC power circuit

9 Detail Photographs

This section showcases details of the installation, including the main station components. Records are shown of instrument makes, models and serial numbers, as well as the installation levels and orientation where applicable.

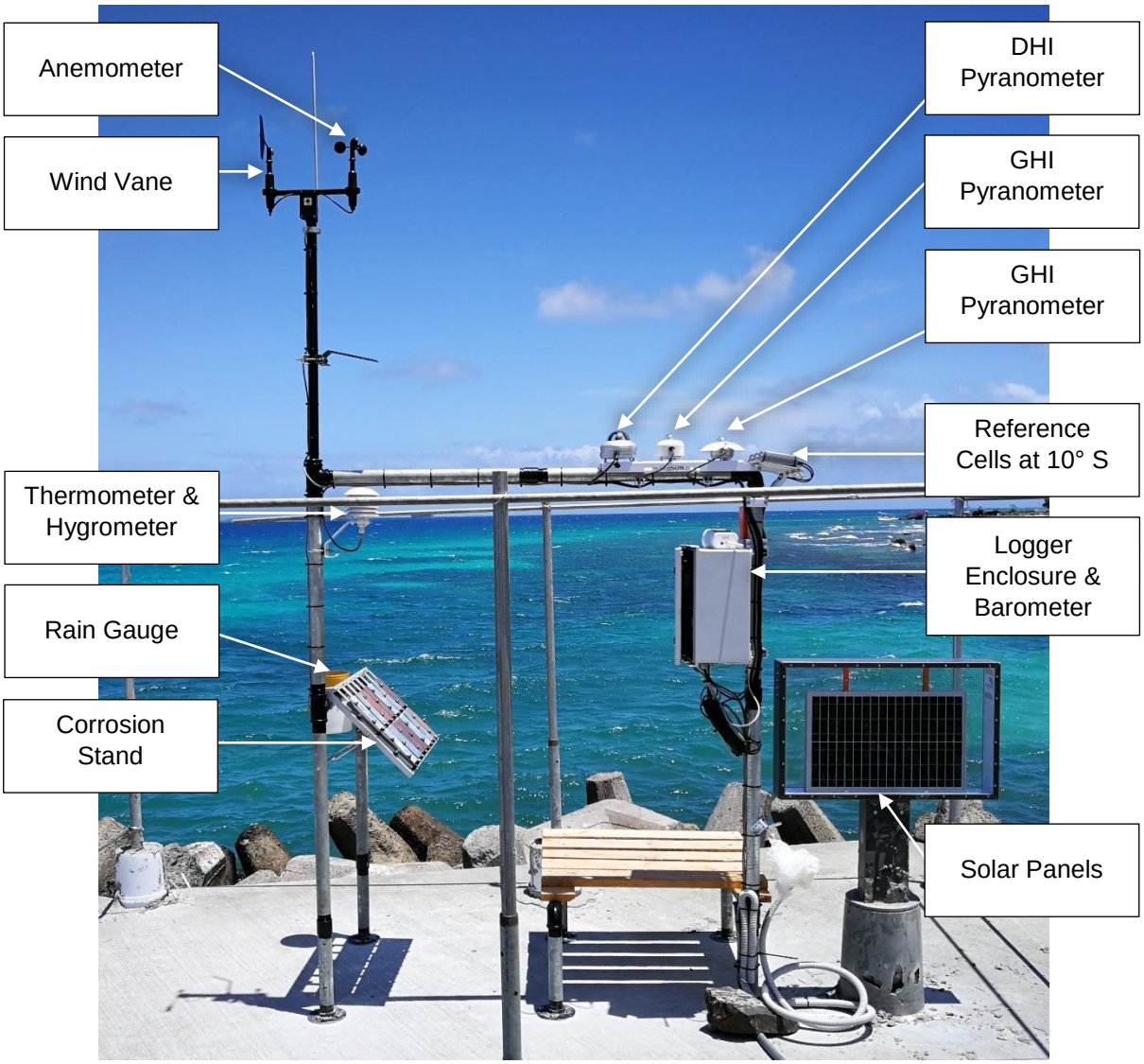


Figure 6: Station Summary

Figure 7: GHI (1) Pyranometer Installation

Figure 8: GHI (2) Pyranometer Installation

Figure 9: DHI Pyranometer Installation

Figure 10: Wind instruments at 3 m

Figure 11: Thermometer and Hygrometer at 2 m

Figure 12: Corrosion Test Stand

Figure 13: Rain Gauge

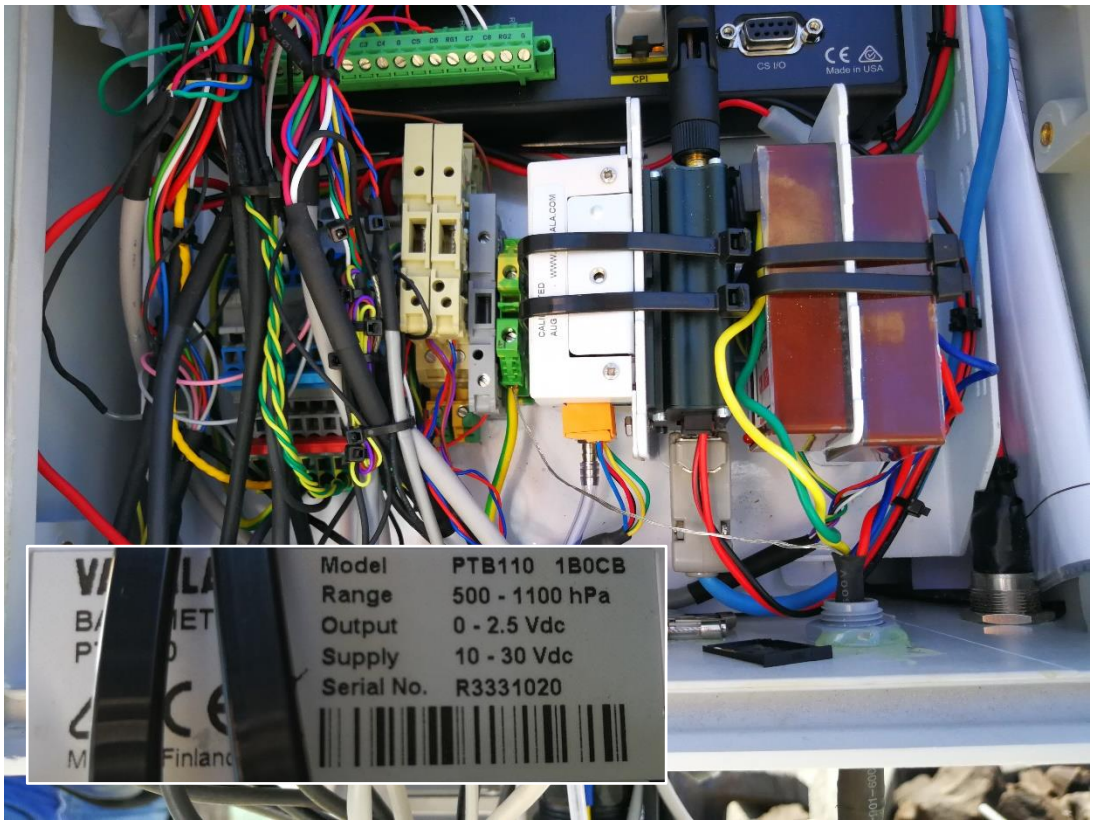


Figure 14: Barometer

Figure 15: Reference Cells at 10° South

Figure 16: Solar Panel

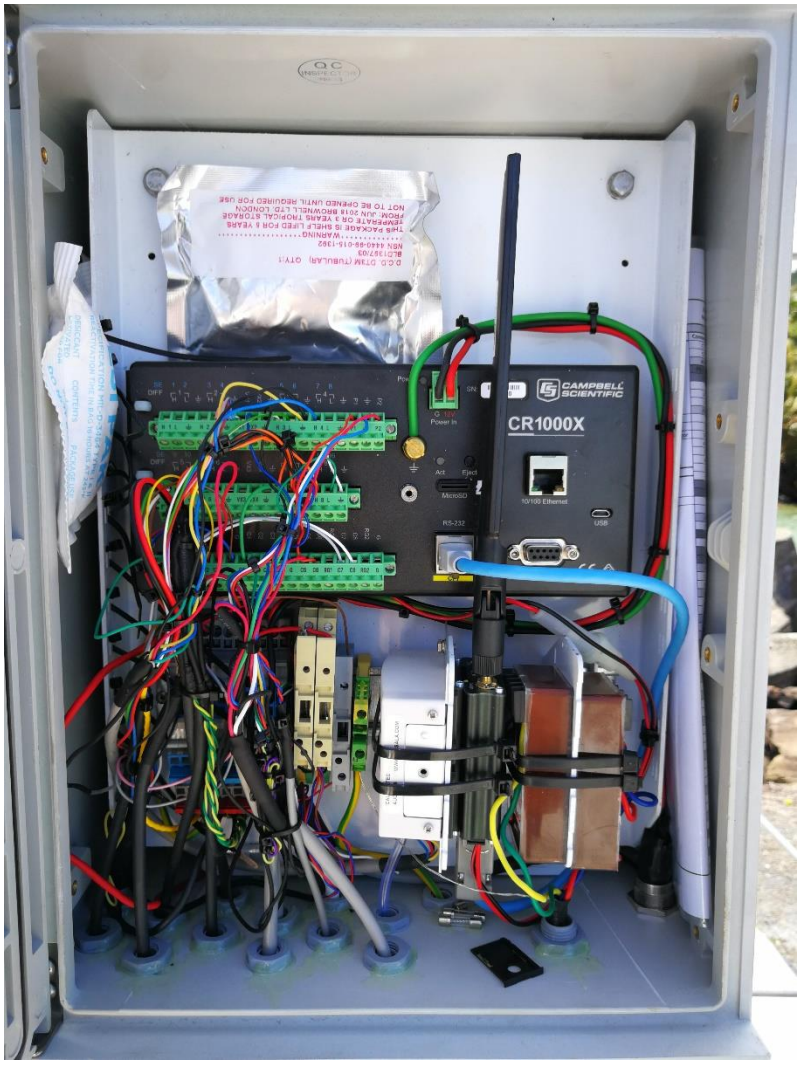


Figure 17: Logger Enclosure

10 Terrain Photographs

Obstacles protruding higher than the horizon as viewed from the solar instruments will affect lower solar elevation readings if they fall within the sun path as depicted in Figure 2. The pictures in this section shows the terrain surrounding the station at the time of installation, giving an indication of near or far shading influences on the station.

Figure 18: 0/360 Degrees (North)

Figure 19: 30 Degrees

Figure 20: 60 Degrees

Figure 21: 90 Degrees (East)

Figure 22: 120 Degrees

Figure 23: 150 Degrees

Figure 24: 180 Degrees (South)

Figure 25: 210 Degrees

Figure 26: 240 Degrees

Figure 27: 270 Degrees (West)

Figure 28: 300 Degrees

Figure 29: 330 Degrees

11 Station Photographs

This section indicates the station within the surrounding terrain to give an overall view thereof, as well as provide additional context to the possible near and far shading influences.

Figure 30: 0/360 Degrees (From North)

Figure 31: 30 Degrees

Figure 32: 60 Degrees

Figure 33: 90 Degrees (From East)

Figure 34: 120 Degrees

Figure 35: 150 Degrees

Figure 36: 180 Degrees (From South)

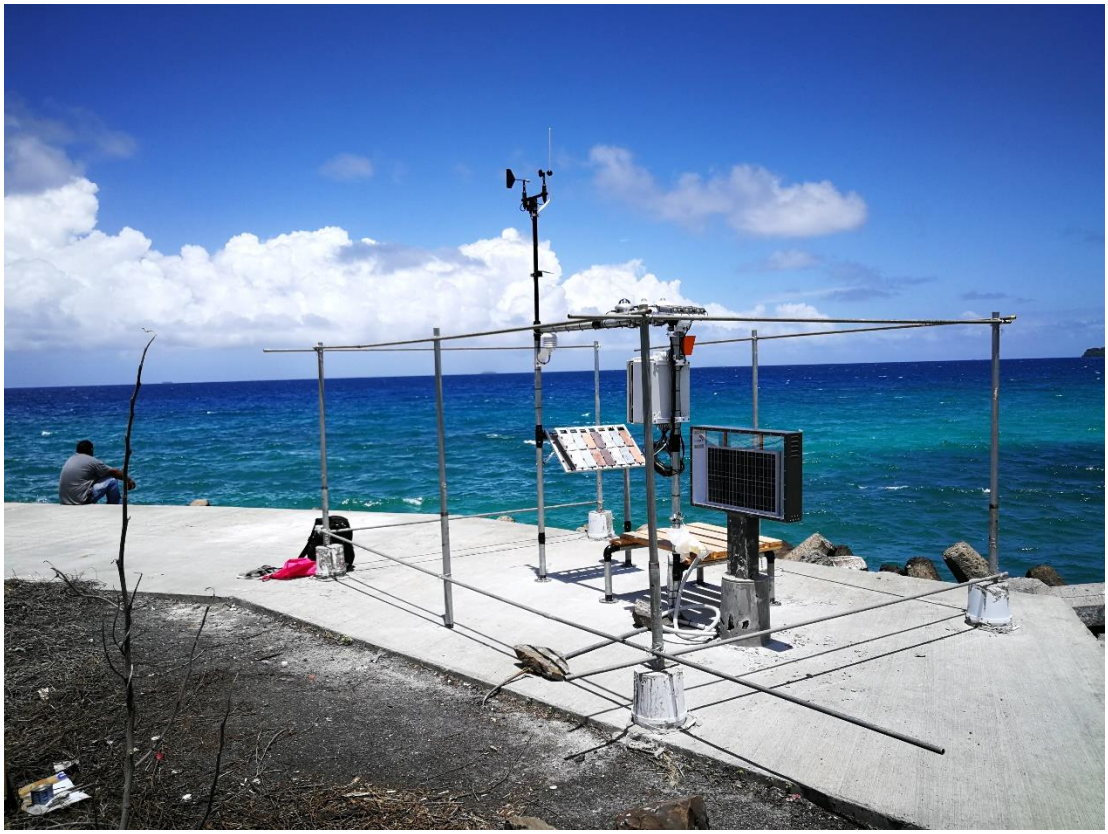


Figure 37: 210 Degrees

Figure 38: 240 Degrees

Figure 39: 270 Degrees (From West)

Figure 40: 300 Degrees

Figure 41: 330 Degrees

12 Calibration Certificates

Hukseflux
Thermal Sensors

Hukseflux Thermal Sensors B.V.
www.hukseflux.com
info@hukseflux.com

Calibration certificate

Pages 1
Release date: 24 SEP, 2019

Product code	**SR30-D1**
Product identification	**serial number 4263**
Product type	pyranometer
Measurand	hemispherical solar radiation
Calibration result	
Sensitivity	**S = 10.35 x 10^{-6} V/(W/m^2)**
Calibration uncertainty	**± 0.10 x 10^{-6} V/(W/m^2)**
	the number following the ± symbol is the expanded uncertainty with a coverage factor k = 2, and defines an interval estimated to have a level of confidence of 95 percent
Reference conditions	20 °C, normal incidence solar radiation, horizontal mounting, irradiance level 1000 W/m^2
Measurement process	
Metrological characteristic	S in [V/(W/m^2)]: sensitivity to irradiance in the 300 to 3000 x 10^{-9} m range, with 180° field of view angle, valid for reference conditions
Calibration method	indoor calibration according to ISO 9847, type IIc
Measurement equipment	Hukseflux Solar Radiation Calibration
Metrological traceability	
Calibration traceability	to WRR (World Radiometric Reference)
Calibration hierarchy	from WRR through ISO 9846 and ISO 9847
Working standard	pyranometer type SR30-D1, serial number 2484
Calibration institute	PMOD World Radiation Center, Davos, Switzerland
Standard sensitivity	9.94 x 10^{-6} V/(W/m^2)
Evaluation of the uncertainty of the calibration result	
Uncertainty calculation	the calibration uncertainty calculated as the square root of the sum of the squares of the calibration uncertainty of the working standard, the uncertainty of the method and the uncertainty due to deviations from the reference conditions is ± 1.0 %.

Person performing calibration:
N.E. Handayani

Calibration Date:
20 SEP, 2019

Person authorising calibration result of product:
M. Rietveld

Date:
24 SEP, 2019

Certificate identification: 201909.SR30-D1.4263.01

page 1/1

Hukseflux Thermal Sensors

Hukseflux Thermal Sensors B.V.
www.hukseflux.com
info@hukseflux.com

Product certificate

Pages: 4
Release date: 24 SEP, 2019

Product code	**SR30-D1**
Product identification	**serial number 4263**
Product type	pyranometer
Measurand	hemispherical solar radiation
Classification	secondary standard (ISO 9060), high quality (WMO-No. 8)

Calibration result	
Sensitivity	**S = 10.35 x 10^{-6} V/(W/m^2)**
Calibration uncertainty	**± 0.10 x 10^{-6} V/(W/m^2)**
	the number following the ± symbol is the expanded uncertainty with a coverage factor k = 2, and defines an interval estimated to have a level of confidence of 95 percent

Product specifications and conformity		
1:	ISO 9060 secondary standard	**verified**
2:	resistance	**16.9 Ω**
3:	insulation resistance	**> 100 x 10^6 Ω**
4:	response time (95 %)	**3.2 s**
5:	temperature response	**verified**
6:	directional response	**verified**
7:	tilt measurement uncertainty	**± 1 ° (0 to 90 °)**

Table 0.1 *connections*

PIN	WIRE	
1	Brown	VDC [+]
4	Black	VDC [−]
3	Blue	not connected
2	White	RS-485 B / B' [+]
5	Grey	RS-485 A / A' [−]
	Yellow	shield

Calibration procedure according to ISO 9847. Traceability of calibration is to the WRR (World Radiometric Reference) maintained at the World Radiation Center in Davos, Switzerland.

Please consult the user manual for set up, operation and maintenance instructions, and information on measurement uncertainty during actual use.

Person authorising acceptance and release of product:
M. Rietveld

Date:
24 SEP, 2019

Hukseflux Thermal Sensors

Hukseflux Thermal Sensors B.V.
www.hukseflux.com
info@hukseflux.com

Directional response

Pages: 4
Release date: 24 SEP, 2019

Product code	**SR30-D1**
Product identification	**serial number 4263**
Product type	pyranometer
Measurand	hemispherical solar radiation
Classification	secondary standard (ISO 9060), high quality (WMO-No. 8)
Characterisation result	
Directional response	**≤ ± 3.1 W/m²**
Measurement process	
Characterised parameter	dependence of sensitivity resulting from the direction of irradiance (a measure of the deviations from an ideal cosine response and its azimuthal variation)
Measurement functions	$C_{rel} = S(\theta)/(S(0)\cdot\cos(\theta) - 1)\cdot 100$ % with C_{rel} the deviation from an ideal cosine response at zenith angle θ in [%], S(θ) the sensitivity to beam irradiance at zenith angle θ in [V/(W/m²)], S(0) the sensitivity to beam irradiance at normal incidence, θ the incoming angle from zenith in [°] $C_{abs} = (S(\theta)/(S(0)\cdot\cos(\theta) - 1))\cdot\cos(\theta)\cdot 1000$ with C_{abs} the directional response as defined below in [W/m²]
Measurement equipment	Hukseflux Directional Response Characterisation
Conformity assessment	
Definition of measurand	The directional response is the error caused by assuming that the reported sensitivity is valid when measuring from any direction a beam whose normal incidence is 1000 W/m²
Acceptance interval	ISO 9060 specifies a limit on the directional response for a secondary standard pyranometer of ± 10 W/m²
Conclusion	Conformity verified

Table 0.2 *directional response test result*

DIRECTIONAL RESPONSE TEST								
azimuth	North		East		South		West	
zenith	C_{abs} [W/m²]	C_{rel} [%]	C_{abs} [W/m²]	C_{rel} [%]	C_{abs} [W/m²]	C_{rel} [%]	C_{abs} [W/m²]	C_{rel} [%]
40 °	-0.4	-0.1	-1.5	-0.2	-0.5	-0.1	+0.3	+0.0
60 °	-1.0	-0.2	-1.1	-0.2	-1.7	-0.3	-1.8	-0.4
70 °	-0.7	-0.2	-0.7	-0.2	-2.3	-0.7	-2.6	-0.8
80 °	+1.9	+1.1	+3.1	+1.8	+0.2	+0.1	-0.3	-0.2

Person performing characterisation:
K. Ismail

Date:
18 SEP, 2019

Hukseflux Thermal Sensors

Hukseflux Thermal Sensors B.V.
www.hukseflux.com
info@hukseflux.com

Temperature response

Pages: 4
Release date: 24 SEP, 2019

Product code	**SR30-D1**
Product identification	**serial number 4263**
Product type	pyranometer
Measurand	hemispherical solar radiation
Classification	secondary standard (ISO 9060), high quality (WMO-No. 8)

Characterisation result	
Temperature response	**< ± 0.02 % (-30 to +50 °C)**
Temperature coefficients*	**a = -18.4251 x 10^{-6} °C^{-2}**
	b = 5.7674 x 10^{-4} °C^{-1}
	c = 0.9958

* These temperature coefficients are applied internally in the instrument

Measurement process	
Characterised parameter	dependence of sensitivity to ambient temperature
Measurement function	$S(T) = S_0 \cdot (a \cdot T^2 + b \cdot T + c)$ with S(T) sensitivity in [V/(W/m²)] at an instrument body temperature T, S_0 sensitivity at 20 °C instrument body temperature, T the instrument body temperature in [°C], a, b and c the temperature coefficients determined from a second order polynomial fit
Measurement equipment	Hukseflux Temperature Response Characterisation

Conformity assessment	
Definition of measurand*	Temperature response is the remaining percentage deviation in sensitivity due to change in ambient temperature within a temperature interval after the temperature coefficients are applied
Temperature interval	-30 to +50 °C
Acceptance interval	Hukseflux specifies a limit on the temperature response for a SR30-D1 of ± 0.4 %
Conclusion	Conformity verified

* This is an adaptation of the definition in ISO 9060, which specifies a limit on the temperature response for a secondary standard pyranometer of 2 % within a temperature interval of 50 K.

Table 0.3 *temperature dependence test result*

TEMPERATURE DEPENDENCE TEST					
T [°C]	-30	-10	10	30	50
remaining deviation	+0.01 %	-0.02 %	+0.01 %	+0.00 %	+0.00 %

Person performing characterisation:
L. Asaa

Date:
17 SEP, 2019

Hukseflux Thermal Sensors

Hukseflux Thermal Sensors B.V.
www.hukseflux.com
info@hukseflux.com

Tilt sensor characterisation

Pages: 4
Release date: 24 SEP, 2019

Product code	**SR30-D1**
Product identification	**serial number 4263**
Product type	pyranometer
Measurand	hemispherical solar radiation
Classification	secondary standard (ISO 9060), high quality (WMO-No. 8)

Characterisation result*	x-axis	y-axis	z-axis
gain	0.9885	1.0155	1.0062
offset	-461	501	-203
temperature coefficient a_0	0.9019×10^{-12}	2.5189×10^{-12}	-0.0195×10^{-12}
temperature coefficient a_1	-0.3491	0.8310	-2.5872
temperature coefficient a_2	0.9612×10^{-2}	0.5910×10^{-2}	2.0124×10^{-2}
temperature coefficient a_3	-1.1818×10^{-4}	3.1193×10^{-4}	2.3242×10^{-4}

* These gains, offsets and temperature coefficients are applied internally in the instrument

Measurement process

Characterised parameters: tilt sensor gains and offsets

Measurement equation:

$$\theta = 360/2\pi \cdot \text{atan}((x^2 + y^2)^{1/2}/z)$$

$$x,y,z = \text{gain}_{x,y,z} \cdot \text{raw}_{x,y,z} + \text{offset}_{x,y,z} + d_{x,y,z}(T)$$

$$d_{x,y,z}(T) = a_{0x,0y,0z} + a_{1x,1y,1z} \cdot T + a_{2x,2y,2z} \cdot T^2 + a_{3x,3y,3z} \cdot T^3$$

with θ the sensor tilt angle with respect to the horizontal in [°], atan the arctangent function, x, y and z the corrected accelerometer counts, $\text{gain}_{x,y,z}$ the tilt sensor gains, $\text{raw}_{x,y,z}$ the raw accelerometer counts, $\text{offset}_{x,y,z}$ the tilt sensor offsets, $d_{x,y,z}(T)$ the correction for temperature dependence of the tilt measurement at an instrument body temperature T, a_0, a_1, a_2 and a_3 the temperature coefficients determined from a third order polynomial fit. Labels x, y and z refer to the three accelerometer axes.

Measurement process: Alignment with the bubble level is attained in horizontal position by introducing gains and offsets.
Gains and offsets are determined in horizontal position and at a tilt angle of 90 °. Temperature dependence of the tilt measurement is determined at a tilt angle of 90 ° between -30 and + 50 °C.

Measurement method: Hukseflux Tilt Sensor Characterisation

Conformity assessment

Description of assessment: The tilt measurement uncertainty is verified in horizontal position and at a tilt angle of 90 °

Acceptance interval: The tilt measurement uncertainty is specified at ± 1° (0 to 90 °)

Conclusion: Conformity verified

Person performing tilt sensor characterisation:
L. Asaa

Date:
24 SEP, 2019

Hukseflux Thermal Sensors

Hukseflux Thermal Sensors B.V.
www.hukseflux.com
info@hukseflux.com

Calibration certificate

Pages 1
Release date: 24 SEP, 2019

Product code	**SR20-T2**
Product identification	**serial number 10499**
Product type	pyranometer
Measurand	hemispherical solar radiation

Calibration result

Sensitivity	**S = 15.82 x 10^{-6} V/(W/m^2)**
Calibration uncertainty	**± 0.16 x 10^{-6} V/(W/m^2)**
	the number following the ± symbol is the expanded uncertainty with a coverage factor k = 2, and defines an interval estimated to have a level of confidence of 95 percent
Reference conditions	20 °C, normal incidence solar radiation, horizontal mounting, irradiance level 1000 W/m^2

Measurement process

Metrological characteristic	S in [V/(W/m^2)]: sensitivity to irradiance in the 300 to 3000 x 10^{-9} m range, with 180° field of view angle, valid for reference conditions
Calibration method	indoor calibration according to ISO 9847, type IIc
Measurement equipment	Hukseflux Solar Radiation Calibration

Metrological traceability

Calibration traceability	to WRR (World Radiometric Reference)
Calibration hierarchy	from WRR through ISO 9846 and ISO 9847
Working standard	pyranometer type SR20, serial number 5039
Calibration institute	PMOD World Radiation Center, Davos, Switzerland
Standard sensitivity	14.60 x 10^{-6} V/(W/m^2)

Evaluation of the uncertainty of the calibration result

Uncertainty calculation	the calibration uncertainty calculated as the square root of the sum of the squares of the calibration uncertainty of the working standard, the uncertainty of the method and the uncertainty due to deviations from the reference conditions is ± 1.0 %.

Person performing calibration:
D. Bemelman

Calibration Date:
24 SEP, 2019

Person authorising calibration result of product:
H.E. Brouwer

Date:
24 SEP, 2019

Certificate identification: 201909.SR20-T2.10499.01

page 1/1

Hukseflux Thermal Sensors

Hukseflux Thermal Sensors B.V.
www.hukseflux.com
info@hukseflux.com

Product certificate

Pages: 3
Release date: 24 SEP, 2019

Product code	**SR20-T2**
Product identification	**serial number 10499**
Product type	pyranometer
Measurand	hemispherical solar radiation
Classification	secondary standard (ISO 9060), high quality (WMO-No. 8)

Calibration result

Sensitivity	**S = 15.82 x 10^{-6} V/(W/m^2)**
Calibration uncertainty	**± 0.16 x 10^{-6} V/(W/m^2)**
	the number following the ± symbol is the expanded uncertainty with a coverage factor k = 2, and defines an interval estimated to have a level of confidence of 95 percent
Measurement function	E = U/S with E irradiance in [W/m^2], U voltage output in [V]

Product specifications and conformity

1:	ISO 9060 secondary standard	**verified**
2:	resistance	**65.6 Ω**
3:	insulation resistance	**> 100 x 10^6 Ω**
4:	response time (95 %)	**3.9 s**
5:	temperature response*	**verified**
6:	directional response	**verified**

*see separate certificate; result may be used to improve measurement quality

Table 0.1 *connections*

PIN	WIRE	
2	Red	10 kΩ thermistor [+]
3	Pink	10 kΩ thermistor [+]
6	Blue	10 kΩ thermistor [−]
8	Grey	10 kΩ thermistor [−]
1	Brown	heater
4	Yellow	heater
9	Black	ground
7	White	signal [+]
5	Green	signal [−]

The 10 kΩ thermistor is a single four-wire thermistor measuring instrument body temperature.

Calibration procedure according to ISO 9847. Traceability of calibration is to the WRR (World Radiometric Reference) maintained at the World Radiation Center in Davos, Switzerland.

Please consult the user manual for set up, operation and maintenance instructions, and information on measurement uncertainty during actual use.

Person authorising acceptance and release of product:
H.E. Brouwer

Date:
24 SEP, 2019

Hukseflux Thermal Sensors

Hukseflux Thermal Sensors B.V.
www.hukseflux.com
info@hukseflux.com

Directional response

Pages: 3
Release date: 24 SEP, 2019

Product code	**SR20-T2**
Product identification	**serial number 10499**
Product type	pyranometer
Measurand	hemispherical solar radiation
Classification	secondary standard (ISO 9060), high quality (WMO-No. 8)
Characterisation result	
Directional response	**≤ ± 8.3 W/m²**
Measurement process	
Characterised parameter	dependence of sensitivity resulting from the direction of irradiance (a measure of the deviations from an ideal cosine response and its azimuthal variation)
Measurement functions	$C_{rel} = S(\theta)/(S(0)\cdot\cos(\theta) - 1)\cdot 100$ % with C_{rel} the deviation from an ideal cosine response at zenith angle θ in [%], S(θ) the sensitivity to beam irradiance at zenith angle θ in [V/(W/m²)], S(0) the sensitivity to beam irradiance at normal incidence, θ the incoming angle from zenith in [°] $C_{abs} = (S(\theta)/(S(0)\cdot\cos(\theta) - 1))\cdot\cos(\theta)\cdot 1000$ with C_{abs} the directional response as defined below in [W/m²]
Measurement equipment	Hukseflux Directional Response Characterisation
Conformity assessment	
Definition of measurand	The directional response is the error caused by assuming that the reported sensitivity is valid when measuring from any direction a beam whose normal incidence is 1000 W/m²
Acceptance interval	ISO 9060 specifies a limit on the directional response for a secondary standard pyranometer of ± 10 W/m²
Conclusion	Conformity verified

Table 0.2 *directional response test result*

DIRECTIONAL RESPONSE TEST								
azimuth	North		East		South		West	
zenith	C_{abs} [W/m²]	C_{rel} [%]	C_{abs} [W/m²]	C_{rel} [%]	C_{abs} [W/m²]	C_{rel} [%]	C_{abs} [W/m²]	C_{rel} [%]
40 °	-0.6	-0.1	+0.1	+0.0	-1.4	-0.2	-2.6	-0.3
60 °	-4.3	-0.9	-3.5	-0.7	-5.7	-1.1	-5.4	-1.1
70 °	-7.4	-2.2	-7.1	-2.1	-8.3	-2.4	-8.3	-2.4
80 °	-7.0	-4.0	-5.7	-3.3	-6.6	-3.8	-6.8	-3.9

Person performing characterisation:
K. Ismail

Date:
20 SEP, 2019

Hukseflux Thermal Sensors

Hukseflux Thermal Sensors B.V.
www.hukseflux.com
info@hukseflux.com

Temperature response

Pages: 3
Release date: 24 SEP, 2019

Product code	**SR20-T2**
Product identification	**serial number 10499**
Product type	pyranometer
Measurand	hemispherical solar radiation
Classification	secondary standard (ISO 9060), high quality (WMO-No. 8)

Characterisation result

Temperature response	**± 0.3 %**
Temperature coefficients	**a = -6.5052 x 10^{-6} °C^{-2}** **b = 2.4231 x 10^{-4} °C^{-1}** **c = 0.9978**

Measurement process

Characterised parameter	dependence of sensitivity to ambient temperature
Measurement function	$S(T) = S_0 \cdot (a \cdot T^2 + b \cdot T + c)$ with S(T) sensitivity in [V/(W/m²)] at an instrument body temperature T, S_0 sensitivity at 20 °C instrument body temperature, T the instrument body temperature in [°C], a, b and c the temperature coefficients determined from a second order polynomial fit
Measurement equipment	Hukseflux Temperature Response Characterisation

Conformity assessment

Definition of measurand	Temperature response is the percentage deviation in sensitivity due to change in ambient temperature within an interval of 50 K
Temperature interval	-10 to +40 °C
Acceptance interval	ISO 9060 specifies a limit on the temperature response for a secondary standard pyranometer of 2 %
Conclusion	Conformity verified

Table 0.3 *temperature dependence test result*

TEMPERATURE DEPENDENCE TEST									
T [°C]	-30	-20	-10	0	10	20	30	40	50
$\frac{S(T) - S_0}{S_0}$	-1.5 %	-1.0 %	-0.5 %	-0.2 %	+0.0 %	+0.0 %	-0.1 %	-0.3 %	-0.6 %

Person performing characterisation:
H.A. Kanij

Date:
19 SEP, 2019

Delta-T Devices Ltd

SPN1 Sunshine Pyranometer

Calibration Certificate

This is to certify that the Sunshine Pyranometer type SPN1 identified below has been calibrated in accordance with Delta-T Devices Ltd standard production procedures and conforms to the specifications as detailed.

Serial Number	SPN1 – A2059
Date	24/09/19
Authorised Signature	

We recommend that this instrument is recalibrated every 2 years.

Traceability

The SPN1 is calibrated under a uniform light source which simulates the solar spectrum, against a transfer standard SPN1. The transfer standard is calibrated outdoors against a Kipp & Zonen CM21 secondary standard pyranometer (calibration traceable to the World Radiometric Reference), with solar tracker and shading disk for diffuse measurement.

Accuracy, Total (Global) and Diffuse radiation

When correctly calibrated, the expected accuracy is given in the table below. The figures give 95% confidence limits, i.e. 95% of individual readings will be within the stated limits under normal climatic conditions.

Overall accuracy:	±5% daily integrals ±5% ±10 $W.m^{-2}$ hourly averages ±8% ±10 $W.m^{-2}$ individual readings
Range	0 to >2000 $W.m^{-2}$
Analogue output sensitivity	1mV = 1 $W.m^{-2}$

Delta-T Devices Ltd
130 Low Road, Burwell, Cambridge, CB25 0EJ, UK
Tel: +44 1638 742922 Fax: +44 1638 743155
email: sales@delta-t.co.uk web: www.delta-t.co.uk

INGENIEURBÜRO
Mencke & Tegtmeyer GmbH
Meßgeräte für die Solartechnik
Schwarzer Weg 43A
31789 Hameln, Germany
www.ib-mut.de

Calibration Certificate Silicon Irradiance Sensor

Sensor Type: **Si-mV-85-A**
Serial No.: **85-00205-17-19350080**
Comment:

Irradiance Calibration with Artificial Light in Comparison to a Reference Cell

Calibrated by: **Huhnstock-Breuer**
Date / Time: **28.08.2019** **13:46**

	Type	Calibration µV/W/m²	Temperature Coefficient 1/°C	Output mV	Temperature °C	**Irradiance[1] W/m²**
Reference Cell	Si-Ref mono PTB-1	56,51	0,00067	56,953	30,76	**1004,0**
	Type	**Irradiance W/m²**	**Correction Factor [3]**	**Output mV**	**Temperature °C**	**Calibration µV/W/m²**
Test Object	Si-mV-85-A	1004,0	0,995818	58,606	31	**58,13**

Test Equipment Irradiance Calibration

Manufacturer	Type	Serial No.	Calibration Certificate	Trace
Ingenieurbüro Mencke & Tegtmeyer GmbH	Si-Ref mono PTB-1	02-20002-05-15309999	47109-PTB-18	PTB
Gantner Instruments	IDL100	191667	098220-02 D-K-15019-01-00	DKD
	ISM111	078743	098221-02 D-K-15019-01-00	DKD
OMEGA Engineering	IN510	9894	./.	./.

[1] $Irradiance = \frac{Output * 1000}{Calibration * (1 + Temperature\ Coefficient * (Temperature - 25))}$

[2] $Calibration = \frac{Output * 1000 * Correction\ Factor}{Irradiance}$

[3] Individual calculated for each Calibration Process, must not be used for Outdoor Application.

INGENIEURBÜRO
Mencke & Tegtmeyer GmbH
Meßgeräte für die Solartechnik
Schwarzer Weg 43A
31789 Hameln, Germany
www.ib-mut.de

Calibration Certificate Silicon Irradiance Sensor

Sensor Type: **Si-mV-85-A**
Serial No.: **85-00205-17-19350081**
Comment:

Irradiance Calibration with Artificial Light in Comparison to a Reference Cell

Calibrated by: **Huhnstock-Breuer**
Date / Time: **28.08.2019** **13:46**

	Type	Calibration µV/W/m²	Temperature Coefficient 1/°C	Output mV	Temperature °C	**Irradiance[1] W/m²**
Reference Cell	Si-Ref mono PTB-1	56,51	0,00067	56,953	30,76	**1004,0**
	Type	**Irradiance W/m²**	**Correction Factor [3]**	**Output mV**	**Temperature °C**	**Calibration µV/W/m²**
Test Object	Si-mV-85-A	1004,0	0,995915	58,512	30,86	**58,04**

Test Equipment Irradiance Calibration

Manufacturer	Type	Serial No.	Calibration Certificate	Trace
Ingenieurbüro Mencke & Tegtmeyer GmbH	Si-Ref mono PTB-1	02-20002-05-15309999	47109-PTB-18	PTB
Gantner Instruments	IDL100	191667	098220-02 D-K-15019-01-00	DKD
	ISM111	078743	098221-02 D-K-15019-01-00	DKD
OMEGA Engineering	IN510	9894	./.	./.

[1] $Irradiance = \frac{Output * 1000}{Calibration * (1 + Temperature\ Coefficient * (Temperature - 25))}$

[2] $Calibration = \frac{Output * 1000 * Correction\ Factor}{Irradiance}$

[3] Individual calculated for each Calibration Process, must not be used for Outdoor Application.

INGENIEURBÜRO
Mencke & Tegtmeyer GmbH
Meßgeräte für die Solartechnik
Schwarzer Weg 43A
31789 Hameln, Germany
www.ib-mut.de

Calibration Certificate Silicon Irradiance Sensor

Sensor Type: **Si-mV-85-A**
Serial No.: **85-00205-17-19350082**
Comment:

Irradiance Calibration with Artificial Light in Comparison to a Reference Cell

Calibrated by: **Huhnstock-Breuer**
Date / Time: **28.08.2019** **13:46**

	Type	Calibration µV/W/m²	Temperature Coefficient 1/°C	Output mV	Temperature °C	**Irradiance[1] W/m²**
Reference Cell	Si-Ref mono PTB-1	56,51	0,00067	56,953	30,76	**1004,0**

	Type	Irradiance W/m²	Correction Factor [3]	Output mV	Temperature °C	Calibration µV/W/m²
Test Object	Si-mV-85-A	1004,0	0,995707	58,600	31,16	**58,12**

Test Equipment Irradiance Calibration

Manufacturer	Type	Serial No.	Calibration Certificate	Trace
Ingenieurbüro Mencke & Tegtmeyer GmbH	Si-Ref mono PTB-1	02-20002-05-15309999	47109-PTB-18	PTB
Gantner Instruments	IDL100	191667	098220-02 D-K-15019-01-00	DKD
	ISM111	078743	098221-02 D-K-15019-01-00	DKD
OMEGA Engineering	IN510	9894	./.	./.

[1] $Irradiance = \frac{Output * 1000}{Calibration * (1 + Temperature\ Coefficient * (Temperature - 25))}$

[2] $Calibration = \frac{Output * 1000 * Correction\ Factor}{Irradiance}$

[3] Individual calculated for each Calibration Process, must not be used for Outdoor Application.

Model 525 Series Certification/Calibration Information

(form PR-TRL-AL-02.docx)

The sensors go through the certified calibration process to document for record with +- 1% accuracy.

The recorded error readings for this sensor was: .11 .06

Calibration Date: 7-24-19 S/N: 81182-819

BY: VR

NOTICE!!!

During Shipment the tipping assembly has been secured to avoid possible damage to the pivot assembly. Lift off collection and remove rubber band from inside to release tipping mechanism before installation.

VAISALA

Certificate report no. H47-19330040

CALIBRATION CERTIFICATE

Instrument	PTB110 Barometer
Serial number	R3331020
Manufacturer	Vaisala Oyj, Finland
Calibration date	14th August 2019

This instrument has been calibrated against a Vaisala PTB220 factory working standard. The Vaisala PTB220 is traceable to the National Institute of Standards and Technology (NIST, USA) via Vaisala Measurement Standards Laboratory (MSL). Vaisala MSL has been accredited by FINAS according to ISO/IEC 17025 standard.

At the time of shipment, the instrument described above was within its operating specifications.

Calibration results

Reference pressure hPa	Calculated pressure hPa	Observed voltage Vdc	Correction* hPa	Uncertainty** hPa
510.3	510.2	0.043	0.1	± 0.15
610.0	610.0	0.459	0.0	± 0.15
700.0	700.0	0.833	0.0	± 0.15
809.8	809.8	1.291	0.0	± 0.15
900.0	900.0	1.666	0.0	± 0.15
999.9	999.9	2.083	0.0	± 0.15
1060.1	1060.1	2.334	0.0	± 0.15
1099.9	1099.9	2.500	0.0	± 0.15

*To obtain the true pressure, add the correction to the barometer reading. Interpolated corrections may be used at intermediate readings of the scale of the barometer.
**The calibration uncertainty given at 95 % confidence level, k = 2

Equipment used in calibration

Type	Serial number	Calibration date	Certificate number
HP34970A	17403	2019-06-12	1250-307103583
PTB220	PA 14018	2019-03-21	K008-C00955

Ambient conditions
Humidity: 37 ± 5 %RH Temperature: 22 ± 2 °C Pressure: 1004 ± 20 hPa

Technician

Vaisala Oyj | PO Box 26, FI-00421 Helsinki, Finland
Phone +358 9 894 91 | Fax +358 9 8949 2227
Email firstname.lastname@vaisala.com | www.vaisala.com
Domicile Vantaa, Finland | VAT FI01244162 | Business ID 0124416-2

Calibration Certification – **Digital Humidity- and Temperature Sensors**

SENSIRION
THE SENSOR COMPANY

Calibration Certification

Name and address of the manufacturer: **Sensirion AG**
Laubisruetistrasse 50
CH-8712 Switzerland

Description: Digital Humidity- and Temperature Sensors

- SHT1x
- SHT2x
- SHT3x
- SHT7x
- SHTC1
- SHTW1
- STS21
- STSC1

The above mentioned products are calibrated to meet the specifications according to the corresponding Sensirion data sheet. Each device is individually tested after its calibration.

Sensirion uses transfer standards for the calibration. These transfer standards are themselves subject to a scheduled calibration procedure. The calibration of the reference itself used for the calibration of the transfer standards is performed by an ISO/IEC 17025 accredited laboratory.

The accreditation body is full member of the International Laboratory Accreditation Cooperation (www.ilac.org). Calibration certificates issued by facilities accredited by a signatory to the ILAC Mutual Recognition Arrangement (MRA) are accepted by all signatories to the ILAC MRA.

This provides traceability of measurement to recognized national standards and to units of measurement realized at the "National Physical Laboratory" (NPL) or other recognized national standards laboratories like "Physikalisch-Technische Bundesanstalt" (PTB) or "National Institute of Standards and Technology" (NIST).

Staefa, November 2015

Stephan Weber,
Director,
Head of Quality Management, Sensirion AG

Volker Born
Manager,
Head of Quality Engineering, SensirionAG

YOUNG

CERTIFICATE OF CALIBRATION AND TESTING

SERIAL NUMBER:	**WS00016942**
CUSTOMER:	INTELTRONICS INSTRUMENT
P.O. NUMBER:	2295
INV NUMBER:	150956
MODEL:	03002 WIND SENTRY ANEM & VANE W/J-BOX

We hereby certify that the sensor serial number specified above has been inspected, tested, and found to comply with all process and material specifications established for the purpose of quality assurance of R. M. Young Company products. Engineering drawings, procedures, and specifications are maintained on file at our premises.

Standards established by R. M. Young Company for calibrating the measuring and test equipment used in controlling product quality are traceable to the National Institute of Standards and Technology (NIST).

Date of Certification: 11 Apr 2019

R. M. Young Company

Ed Chemosky
Quality Assurance

R. M. YOUNG COMPANY 2801 Aero Park Drive, Traverse City Michigan 49686-9171 USA
TEL: (231) 946-3980 FAX: (231) 946-4772 Email: met.sales@youngusa.com