INSTRUCTION MANUAL

CNR4 Net Radiometer

Revision: 9/13

WARRANTY AND ASSISTANCE

This equipment is warranted by CAMPBELL SCIENTIFIC (CANADA) CORP. ("CSC") to be free from defects in materials and workmanship under normal use and service for **twenty-four (24) months** from date of shipment unless specified otherwise. ***** **Batteries are not warranted.** ***** CSC's obligation under this warranty is limited to repairing or replacing (at CSC's option) defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to CSC. CSC will return such products by surface carrier prepaid. This warranty shall not apply to any CSC products which have been subjected to modification, misuse, neglect, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability or fitness for a particular purpose. CSC is not liable for special, indirect, incidental, or consequential damages.

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CAMPBELL SCIENTIFIC (CANADA) CORP. does not accept collect calls.

Non-warranty products returned for repair should be accompanied by a purchase order to cover repair costs.

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PLEASE READ FIRST

About this manual

Please note that this manual was originally produced by Campbell Scientific Inc. (CSI) primarily for the US market. Some spellings, weights and measures may reflect this origin.

Some useful conversion factors:

Area:	1 in^2 (square inch) = 645 mm^2
Length:	1 in. (inch) = 25.4 mm
	1 ft (foot) = 304.8 mm
	1 yard = 0.914 m
	1 mile = 1.609 km
Mass:	1 oz. (ounce) = 28.35 g
	1 lb (pound weight) = 0.454 kg
Pressure:	1 psi (lb/in2) = 68.95 mb
Volume:	1 US gallon = 3.785 litres

In addition, part ordering numbers may vary. For example, the CABLE5CBL is a CSI part number and known as a FIN5COND at Campbell Scientific Canada (CSC). CSC Technical Support will be pleased to assist with any questions.

About sensor wiring

Please note that certain sensor configurations may require a user supplied jumper wire. It is recommended to review the sensor configuration requirements for your application and supply the jumper wire is necessary.

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CNR4 Net Radiometer

1. Introduction

The CNR4 is a research-grade net radiometer that measures the energy balance between incoming and outgoing radiation. Our dataloggers measure the CNR4's output. This net radiometer offers a professional solution for scientific-grade energy balance studies.

Before using the CNR4, please study:

- Section 2, *Cautionary Statements*
- Section 3, *Initial Inspection*
- Section 4, *Quickstart*

2. Cautionary Statements

- Although the CNR4 is rugged, it is also a highly precise scientific instrument and should be handled as such.

- Care should be taken when opening the shipping package to not damage or cut the cable jacket. If damage to the cable is suspected, consult with a Campbell Scientific applications engineer.

- Do not attempt to rotate the instrument using the sensor heads, or you may damage the sensors; use the mounting rod only.

3. Initial Inspection

- Upon receipt of the CNR4, inspect the packaging and contents for damage. File damage claims with the shipping company.

- The model number and cable length are printed on a label at the connection end of the cable. Check this information against the shipping documents to ensure the correct product and cable length are received.

- Refer to the Ships With list to ensure that parts are included (see Section 3.1, *Ships With*).

3.1 Ships With

(2) 26006 Drying Cartridges
(1) WRR Traceable Calibration Certificate for the pyranometers
(1) WRR Traceable Calibration Certificate for the pyregeometers
(1) Mounting Arm from original manufacturer
(1) Extra Calibration Stickers from original manufacturer
(1) ResourceDVD

4. Quickstart

Please review Section 7, *Operation*, for wiring and CRBasic programming. Appendix B, *CNF4 Heater/Ventilator*, provides information about using the CNF4 heater/ventilator.

4.1 Siting Considerations

1. Mount the sensor so no shadow will be cast on it at any time of day from obstructions such as trees, buildings, or the mast or structure on which it is mounted. If the instrument is *h* meters above the surface, 99% of the input of the lower sensors comes from a circular area with a radius of 10*h*. Shadows or surface disturbances with a radius < 0.1*h* will affect the measurement by less than 1%.

2. To avoid shading effects and to promote spatial averaging, the CNR4 should be mounted at least 1.5 m above the ground surface. It is recommended that the CNR4 be mounted to a separate vertical pipe at least 25 ft from any other mounting structures.

3. Orient the sensor towards the nearest pole to avoid potential problems from shading.

4.2 Mounting

A mounting bracket kit, pn 26120, is used to mount the CNR4 directly to a vertical pipe, or to a CM202, CM203, CM204, or CM206 crossarm. Mount the sensor as follows:

1. Attach the mounting rod to the CNR4 (see FIGURE 4-1).

FIGURE 4-1. Attaching the mounting rod to the CNR4 body

2. Attach the 26120 mounting bracket to the vertical mounting pipe, or CM200-series crossarm using the provided U-bolt (see FIGURE 4-2).

FIGURE 4-2. Attaching the CNR4 onto the mounting rod (pn 26120) using vertical pole or horizontal crossarm

3. Insert the sensor's support arm into the mounting block of the mounting bracket kit. Make sure the sensor points in the direction of the arrows that appear after the word **SENSOR** on top of the bracket (see FIGURE 4-2).

CAUTION Do not attempt to rotate the instrument using the sensor heads, or you may damage the sensors; use the mounting rod only.

4. Perform a coarse leveling of the sensor using the sensor's bubble level.

5. Tighten the four screws on top of the mounting bracket to properly secure the support arm so that it does not rotate (see FIGURE 4-2).

6. Perform the fine leveling using the two spring-loaded leveling screws—one on the front and the other on the back of the bracket.

7. Route the sensor cable to the instrument enclosure.

8. Use the UV-resistant cable ties included with the tripod or tower to secure the cable to the vertical pipe or crossarm and tripod/tower.

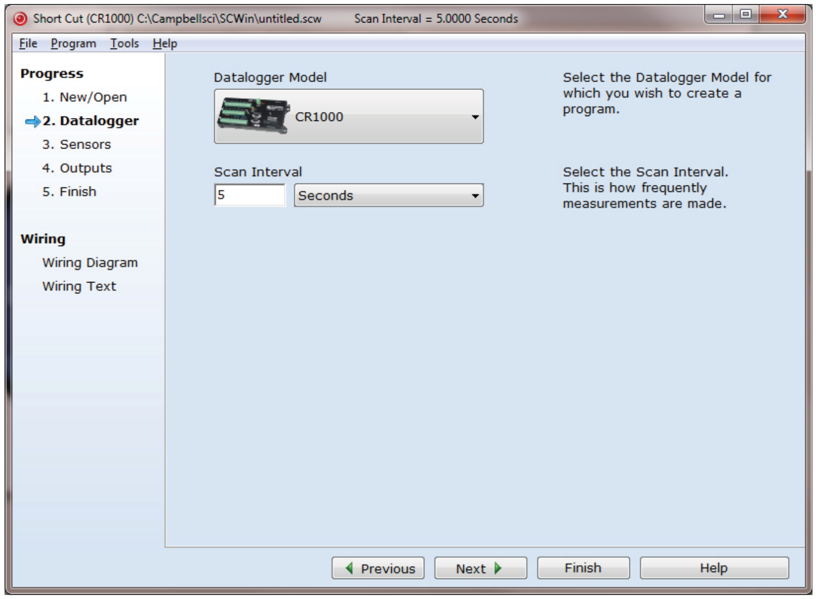
4.3 Use SCWin to Program Datalogger and Generate Wiring Diagram

The simplest method for programming the datalogger to measure the CNR4 is to use Campbell Scientific's SCWin Program Generator.

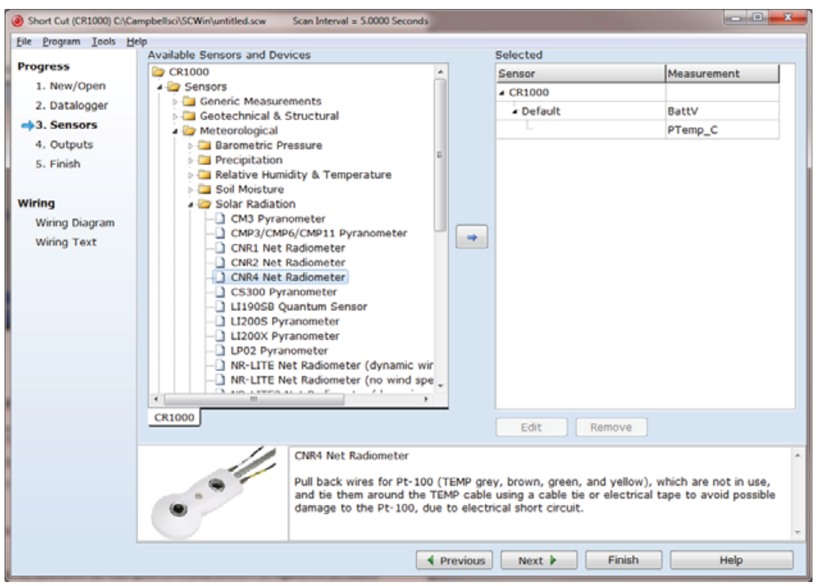
NOTE The SCWin example provided here uses the thermistor to provide the temperature correction.

1. Open Short Cut and click on **New Program**.

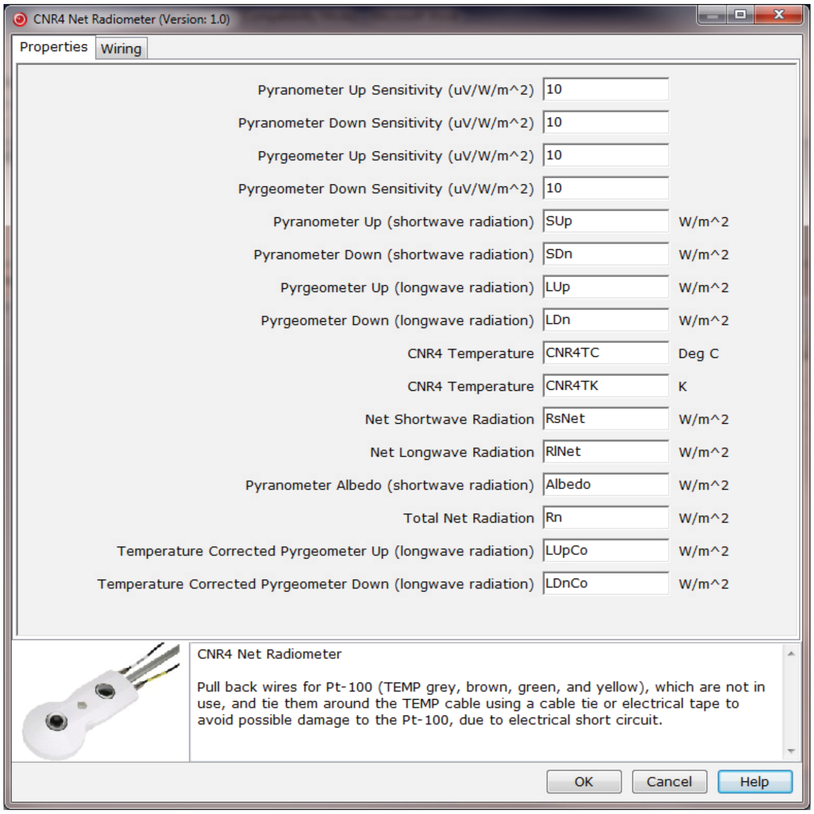
2. Select the datalogger and enter the scan interval.



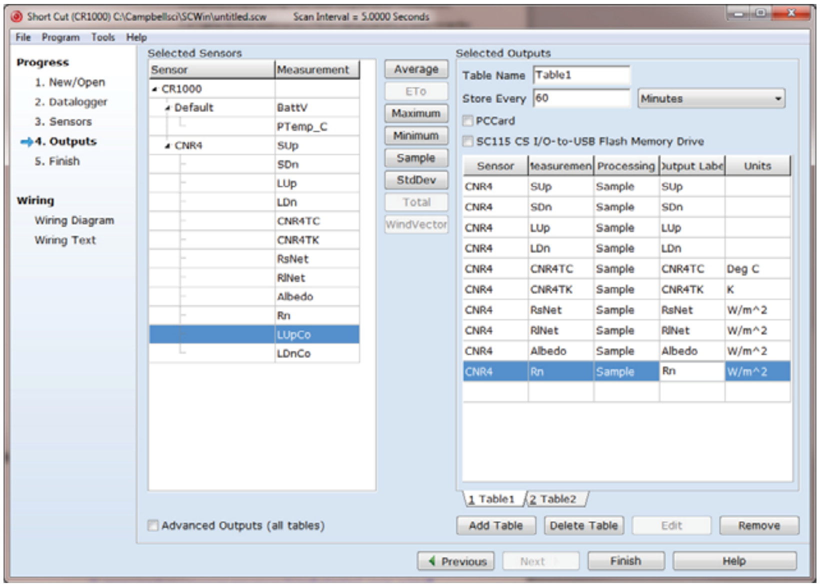
3. Select **CNR4 Net Radiometer,** and select the **right arrow** (in center of screen) to add it to the list of sensors to be measured, and then select **Next**.



4. Enter the sensitivity values supplied on the manufacturer's certificate of calibration; these sensitivity values are unique to each sensor. The public variables defaults can typically be used. After entering the information, click on OK, and then select **Next**.



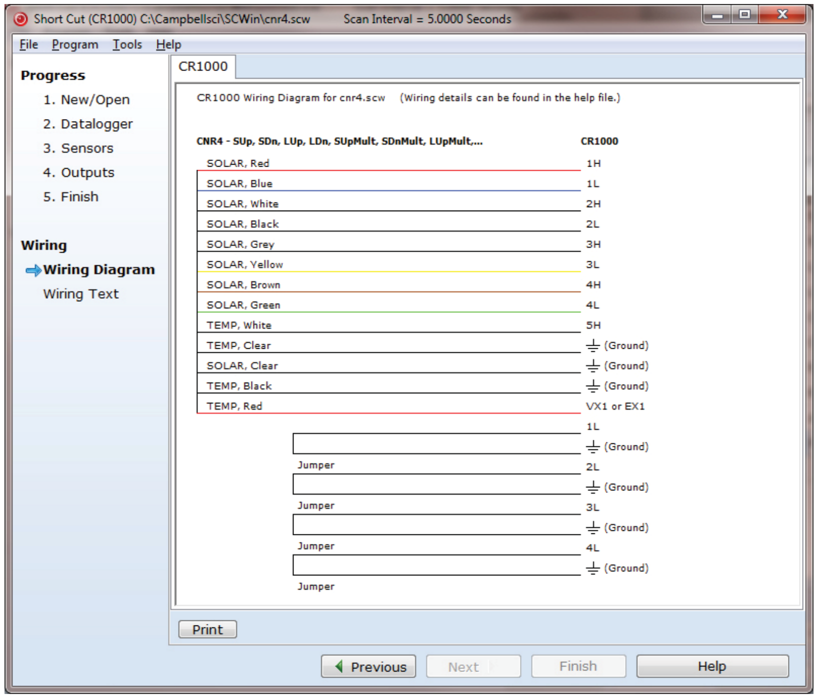
5. Choose the outputs and then select **Finish**.



6. In the Save As window, enter an appropriate file name and select **Save**.

7. In the Confirm window, click **Yes** to download the program to the datalogger.

8. Click on **Wiring Diagram** and wire according to the wiring diagram generated by Short Cut.



5. Overview

The CNR4 Net Radiometer consists of a pyranometer pair, one facing upward, the other facing downward, and a pyrgeometer pair in a similar configuration. The pyranometer pair measures short-wave solar radiation, and the pyrgeometer pair measures long-wave far infrared radiation. The upper long-wave detector of CNR4 has a meniscus dome to ensure that water droplets roll off easily while improving the field of view to nearly 180°, compared with a 150° for a flat window. All four sensors are integrated directly into the instrument body, instead of separate modules mounted onto the housing. Each sensor is calibrated individually for optimal accuracy.

Two temperature sensors, a thermistor and a Pt-100, are integrated with the CNR4 body. The temperature sensor is used to provide information to correct the infrared readings for the temperature of the instrument housing. Care has been taken to place the long-wave sensors close to each other and close to the temperature sensors. This ensures that the temperatures of the measurement surfaces are the same and accurately known, improving the quality of the long-wave measurements. A completion resistor is added in the pig tail end of the thermistor cable providing an easy interface with dataloggers for half-bridge measurement.

The CNR4 design is light weight and has an integrated solar shield that reduces thermal effects on both the short-wave and the long-wave measurements. The cables are made from Santoprene® jacket, which is intended for outdoor use, and is resistant to a variety of pollutants and UV-radiation. The mounting rod can be unscrewed for transport.

An optional ventilation unit with a heater, CNF4, is designed as an extension of the solar shield and can be fitted to the CNR4 or retrofitted later. The heater/ventilation unit is compact and provides efficient air-flow over the domes and windows to minimize the formation of dew and to reduce the frequency of cleaning. The integrated heater can be used to melt frost.

The CNR4 design is such that both the upward facing and the downward-facing instruments measure the energy that is received from the whole hemisphere (180° field of view). The output is expressed in W/m^2. The total spectral range that is measured is roughly from 0.3 to 42 µm. This spectral range covers both the short-wave solar radiation, 0.3 to 2.8 µm, and the long-wave far infrared radiation, 4.5 to 42 µm. The gap between these two produces negligible errors.

The CNR4 is manufactured by Kipp & Zonen, but cabled for use with Campbell Scientific dataloggers. Its cables can terminate in:

- Pigtails that connect directly to a Campbell Scientific datalogger (cable termination option –PT).
- Connector that attaches to a prewired enclosure (cable termination option –PW).

6. Specifications

Features:

- Research-grade performance
- Meniscus dome on upper long-wave detector allows water droplets to easily roll off of it and increases field of view to nearly 180°
- Internal temperature sensors provide temperature compensation of measurements
- Drying cartridge helps keep the electronics dry
- Compatible with the CNF4 ventilation unit with heater that reduces formation of dew and melts frost
- Separate outputs of short-wave and long-wave infrared radiation for better accuracy and more thorough quality assurance
- Solar shield reduces thermal effects on the sensors

Compatible Dataloggers: CR1000
CR3000
CR5000

The properties of the CNR4 are mainly determined by the properties of the individual probes. Generally the accuracy of the CNR4 will be higher than that of competitive net-radiometers, because the solar radiation measurement performed by the pyranometer is accurate, and offers a traceable calibration. Also the optionally integrated heater/ventilator unit improves the accuracy. Due to the fact that the net short-wave radiation can be very intense, 1000 W/m^2 compared to a typical –100 W/m^2 net long-wave radiation, the accuracy of the short-wave radiation measurement is critical. Wind corrections, as applied by less accurate competitive instruments are not necessary. The robust materials used imply that the CNR4 will not suffer damages inflicted by birds. FIGURE 6-1 and FIGURE 6-2 show the CNR4 with and without the CNF4 heater/ventilator. From a spectral point of view, the pyranometer and pyrgeometer are complementary, and together they cover the full spectral range.

FIGURE 6-1. The CNR4 net radiometer with cables and mounting rod, top view

FIGURE 6-2. The CNR4 net radiometer with CNF 4 heater/ventilator unit, top view

6.1 CNR4 Specifications

Sensor sensitivities:	Four probes with unique sensitivity values. Please refer to the calibration sheets or label on the bottom of the sensor for the sensitivity values.
Operating temperature:	–40 to +80°C (–40 to 176°F)
Operating humidity:	0 to 100% RH
Bubble level sensitivity:	< 0.5°
Sensor type:	Thermopile
Receiver paint:	Carbon Black
Desiccant:	Silica gel (replaceable)
Housing material:	Anodized aluminum body
Shock/vibration:	IEC 721-3-2-2m2
CE:	Complies with EC guideline 89/336/EEC 73/23/EEC
Environmental protection:	IP 67
Requirements for data acquisition	
Radiation components:	4 differential or 4 single-ended analog channels
Thermistor:	1 voltage excitation and 1 single-ended analog channel
Pt-100 temperature:	1 current excitation and 1 differential analog channel.
Cable length:	User defined
Weight	
Sensor:	0.85 kg (1.89 lb) without cables
Heater/ventilator, CNF4 (optional):	0.50 kg (1.11 lb) without cables
Mounting rod:	34.7 cm (13.67 in) length 1.6 cm (0.63 in) diameter

6.2 Pyranometer Specifications

* indicates ISO specifications.

Spectral range:	305 to 2800 nm (50% points)
Sensitivity:	10 to 20 μV/W/m^2
Response time*:	< 18 seconds (95% response)
Non-linearity*:	< 1% (0 to 1000 W m^{-2} irradiance)
Non-stability*:	< 1%
Temperature dependence of sensitivity*:	< 4% (–10° to +40°C)
Tilt response*:	< 1% at any angle with 1000 W/m^2

Directional error*:	< 20 W/m^2 at angle up to 80° with 1000 W/m^2
Zero offset due to 0 to -200 W/m^2 IR net irradiance*:	< 15 W/m^2
Zero offset due to temperature change*:	< 3 W/m^2 (5 K/hr temperature change) < 1 W/m^2 (with CNF4 installed)
Operating temperature:	–40°C to +80°C
Field of view	
Upper detector:	180°
Lower detector:	150° (due to lower solar shield to prevent illumination at low zenith angles)
Maximum solar irradiance:	2000 W/m^2
Expected accuracy for daily totals:	±10 %
Typical signal output for atmospheric application:	0 to 15 mV
Impedance:	20 to 200 Ω, typically 50 Ω
Detector:	Copper-constantan multi-junction thermopile
Level accuracy:	1 degree
Irradiance:	0 to 2000 W/m^2
Spectral selectivity:	< 3% (330 to 1500 nm spectral interval)
Uncertainty in daily total:	< 5% (95% confidence level)
Instrument calibration:	Indoors. Side by side against reference CMP3 pyranometer according to ISO 9847:1992 annex A.3.1

6.3 Pyrgeometer Specifications

Spectral range:	4.5 to 42 µm (50% points)
Sensitivity:	5 to 15 µV/W/m^2
Impedance:	20 to 200 Ω (typically 50 Ω)
Response time:	< 18 seconds (95% response)
Non-linearity:	< 1% (–250 to +250 W/m^2 irradiance)
Temperature dependence of sensitivity:	< 4% (–10° to +40°C)
Tilt error:	< 1% (deviation when tilted at any angle off horizontal)
Zero offset due to temperature change:	±4 W/m^2 (5 K/hr temperature change)

Field of view	
Upper:	180 degrees
Lower:	150 degrees
Net-irradiance:	–250 to +250 W/m^2
Non-stability:	< 1% (sensitivity change per year)
Window heating offset:	< 6 W/m^2 (1000 W/m^2 solar irradiance)
Uncertainty in daily total:	< 10% (95% confidence level) indoor calibration
Typical signal output for atmospheric application:	±5 mV
Temperature sensors	
Thermistor:	10k Ω
Pt-100:	DIN class A
Instrument calibration:	Indoors, side by side against reference CG(R) 3 pyrgeometer. On request outdoors, side by side against reference CG(R) 4 pyrgeometer

6.4 Optional CNF4 Heater/Ventilator

The purpose of the heater/ventilator is to prevent dew deposition on the pyrgeometer and pyrgeometer window, thus enhancing the measurement accuracy and reliability. Using the heater/ventilator will have negligible effect on the pyranometer reading.

Generally, the errors caused by the heater/ventilator will be small relative to the errors that would have been caused by water deposition.

6.4.1 CNF4 Specifications

Heater	
Power consumption:	10 W @ 12 Vdc (15 Ω)
Ventilator	
Power consumption:	5 W @ 12 Vdc
Supply voltage:	8 to 13.5 Vdc
Weight without cable:	0.5 kg (1.11 lb)
Operating temperature:	–40 to +80°C

7. Operation

7.1 Using the CNR4 in the Four Separate Components Mode

In the four separate components mode configuration (measuring two short-wave radiation signals and two long-wave signals), all signals are measured separately. Calculation of net-radiation and albedo can be done online by the datalogger, or offline by the user during post-processing, using the stored raw data.

The two pyranometers will measure the short-wave radiation, both incoming and reflected. The two pyrgeometers will measure the long-wave radiation. For proper analysis of the pyrgeometer measurement results, they must be temperature corrected using the temperature measurement performed by the onboard thermistor or Pt-100 sensor.

7.1.1 Measuring Short-wave Solar Radiation with Pyranometer

The pyranometer generates an mV signal that is simply proportional to the incoming short-wave radiation. The conversion factor between voltage, V, and W/m^2 of solar irradiance E, is the calibration constant C or sensitivity (Equation 7-1).

For each pyranometer,

$$E = V/C \qquad (7\text{-}1)$$

Measuring with a pyranometer can be done by connecting two pyranometer wires to a datalogger. Incidental light results in a positive signal. The pyranometer mounting plate and ambient air should be at the same temperature. Conversion of the voltage to irradiance can be done according to Equation 7-1, and is computed by the datalogger program.

With the upward-facing pyranometer, the global (solar) downwelling radiation is measured. The downward-facing pyranometer measures the reflected upwelling solar radiation. When calculating the net radiation, the upwelling radiation must be subtracted from the downwelling radiation. See Section 7.1.5, *Calculation of Net Short-wave Radiation*.

7.1.2 Measuring Long-wave Far Infrared Radiation with Pyrgeometer

When using the pyrgeometer, you should realize the signal generated by the pyrgeometer represents the exchange of long-wave far infrared (thermal) radiation between the pyrgeometer and the object that it is facing. This implies that the pyrgeometer will generate a positive voltage output, V, when it faces an object that is hotter than its own sensor housing, and that it will give a negative voltage signal when it faces an object that is colder. Therefore, when estimating the far infrared radiation that is generated by the object facing the pyrgeometer, usually the sky or the soil, you will have to take the pyrgeometer temperature, T, into account. This is why the temperature sensors are incorporated in the CNR4's body near the pyrgeometer sensing element, and has, therefore, the same temperature as the pyrgeometer sensor surface. The calculation of the long-wave far infrared irradiance, E, is done according to Equation 7-2.

For the pyrgeometer only

$$E = V/C + 5.67 \bullet 10^{-8} \bullet T^4 \qquad (7\text{-}2)$$

In this equation, C is the sensitivity of the sensor.

NOTE T is in Kelvin, and not in Celsius or Fahrenheit.

The downward-facing pyrgeometer measures the far infrared radiation that is emitted by the ground. The upward-facing pyrgeometer measures the far infrared radiation from the sky. As the sky is typically colder than the instrument, one can expect negative voltage signals from the upward-facing pyrgeometer. Equation 7-2 is used to calculate the far infrared irradiance of the sky and of the ground.

7.1.3 Measuring CNR4 Temperature with Thermistor

The CNR4 has two temperature sensors built inside: thermistor and Pt-100; both have identical accuracy. Using the thermistor is recommended when using Campbell Scientific dataloggers. The thermistor has a greater resistance (10 kΩ @ 25°C) than Pt-100 sensor (100 Ω @ 0°C), and the change in resistance with respect to temperature, in absolute terms, is greater. Therefore, the cable resistance can be neglected, and the thermistor can easily be measured using **Half-Bridge Measurement** instruction on Campbell Scientific dataloggers.

TABLE 7-1 shows the thermistor resistance values as a function of temperature.

TABLE 7-1. Resistance values versus CNR4's thermistor temperature in °C.

Temperature [°C]	Resistance [Ω]	Temperature [°C]	Resistance [Ω]	Temperature [°C]	Resistance [Ω]
–30	135200	0	29490	30	8194
–29	127900	1	28150	31	7880
–28	121100	2	26890	32	7579
–27	114600	3	25690	33	7291
–26	108600	4	24550	34	7016
–25	102900	5	23460	35	6752
–24	97490	6	22430	36	6500
–23	92430	7	21450	37	6258
–22	87660	8	20520	38	6026
–21	83160	9	19630	39	5805
–20	78910	10	18790	40	5592
–19	74910	11	17980	41	5389
–18	71130	12	17220	42	5193
–17	67570	13	16490	43	5006
–16	64200	14	15790	44	4827
–15	61020	15	15130	45	4655
–14	58010	16	14500	46	4489

TABLE 7-1. Resistance values versus CNR4's thermistor temperature in °C.					
Temperature [°C]	**Resistance [Ω]**	**Temperature [°C]**	**Resistance [Ω]**	**Temperature [°C]**	**Resistance [Ω]**
–13	55170	17	13900	47	4331
–12	52480	18	13330	48	4179
–11	49940	19	12790	49	4033
–10	47540	20	12260	50	3893
–9	45270	21	11770	51	3758
–8	43110	22	11290	52	3629
–7	41070	23	10840	53	3504
–6	39140	24	10410	54	3385
–5	37310	25	10000	55	3270
–4	35570	26	9605	56	3160
–3	33930	27	9227	57	3054
–2	32370	28	8867	58	2952
–1	30890	29	8523	59	2854

Relatively small errors occur when the CNR4 is not in thermal equilibrium. This happens for example when the heater is on, or when the sun is shining. When the heater and ventilator are on, the largest expected deviation between the real sensor temperature and the thermistor reading is 1 degree. This results in a worst case error for the pyrgeometer of 5 W/m^2. When the sun is shining, the largest expected deviation between the real sensor temperature and the thermistor reading is again 1 degree. This results in a worst case error for the pyrgeometer of 5 W/m^2.

The thermistor will not give a good indication of ambient air temperature; at 1000 W/m^2 solar radiation, and no wind, the instrument temperature will rise approximately 5 degrees above the ambient temperature.

The offsets of both the pyranometers and the pyrgeometers might be larger than 5 W/m^2 if large temperature gradients are forced on the instrument (larger than 5 K/hr); for example, when rain hits the instrument. This occurrence can be detected using the thermistor readout, and can be used for data filtering.

The thermistor measurement is calculated by the datalogger, using the **Half-Bridge Measurement** instruction, which requires one voltage excitation and one single-ended analog channel.

Alternatively, you can use the Pt-100 to make the temperature measurement. In order to make the temperature measurement, using the Pt-100 sensor, you will need one current excitation channel, and one differential analog channel. TABLE 7–2 shows the Pt-100 resistance values as a function of temperature. Please refer to Appendix C, *CR3000 Program for Measuring Pt-100 Temperature Sensor*, for a sample program to measure Pt-100.

TABLE 7–2. Resistance values versus CNR4's Pt–100 temperature in °C.

Temperature [°C]	Resistance [Ω]	Temperature [°C]	Resistance [Ω]	Temperature [°C]	Resistance [Ω]
–30	88.22	0	100.00	30	111.67
–29	88.62	1	100.39	31	112.06
–28	89.01	2	100.78	32	112.45
–27	89.40	3	101.17	33	112.83
–26	89.80	4	101.56	34	113.22
–25	90.19	5	101.95	35	113.61
–24	90.59	6	102.34	36	113.99
–23	90.98	7	102.73	37	114.38
–22	91.37	8	103.12	38	114.77
–21	91.77	9	103.51	39	115.15
–20	92.16	10	103.90	40	115.54
–19	92.55	11	104.29	41	115.93
–18	92.95	12	104.68	42	116.31
–17	93.34	13	105.07	43	116.70
–16	93.73	14	105.46	44	117.08
–15	94.12	15	105.85	45	117.47
–14	94.52	16	106.24	46	117.85
–13	94.91	17	106.63	47	118.24
–12	95.30	18	107.02	48	118.62
–11	95.69	19	107.40	49	119.01
–10	96.09	20	107.79	50	119.40
–9	96.48	21	108.18	51	119.78
–8	96.87	22	108.57	52	120.16
–7	97.26	23	108.96	53	120.55
–6	97.65	24	109.35	54	120.93
–5	98.04	25	109.73	55	121.32
–4	98.44	26	110.12	56	121.70
–3	98.83	27	110.51	57	122.09
–2	99.22	28	110.90	58	122.47
–1	99.61	29	111.28	59	122.86

7.1.4 Calculation of Albedo

Albedo is the ratio of reflected short-wave radiation to incoming short-wave radiation. This unitless value ranges between 0 and 1. Typical values are 0.9 for snow, and 0.3 for grassland. To determine the albedo, the measured values of the two pyranometers are used. Do not use the measured values when the solar elevation is lower than 10 degrees above the horizon. Errors in the measurements at these elevations are likely and yield unreliable results. This is due to deviations in the directional response of the pyranometers.

$$\text{Albedo} = (\text{E lower Pyranometer}) / (\text{E upper Pyranometer}) \qquad (7\text{-}3)$$

In the equation above, E is calculated according to the Equation 7-1.

Albedo will always be smaller than 1. Checking this can be used as a tool for quality assurance of your data. If you know the approximate albedo at your site, the calculation of albedo can also serve as a tool for quality control of your measured data at a specific site.

7.1.5 Calculation of Net Short-wave Radiation

The net short-wave solar radiation is equal to the incoming (downwelling) short-wave radiation minus the reflected (upwelling) short-wave radiation.

$$\text{Net Short-wave Radiation} = (\text{E upper Pyranometer}) - (\text{E lower Pyranometer}) \tag{7-4}$$

In the equation above, E is calculated according to Equation 7-1.

Net short-wave solar radiation will always be positive. This can be used as a tool for quality assurance of your measured data.

7.1.6 Calculation of Net Long-wave Radiation

The net long-wave far infrared radiation is the part that contributes to heating or cooling of the earth's surface. In practice, usually the net long-wave far infrared radiation will be negative.

$$\text{Net Long-wave Radiation} = (\text{E upper Pyrgeometer}) - (\text{E lower Pyrgeometer}) \tag{7-5}$$

In the equation above, E is calculated according to Equation 7-2. According to Equation 7-5 above, the terms that contain the sensor body temperature, T, cancel each other. Therefore, if one is only interested in the net long-wave radiation, instead of separate upper and lower components of the long-wave radiation, the CNR4 temperature measurement is not required.

The E measured with the pyrgeometer actually represents the irradiance of the sky (for upward-facing pyrgeometer) or the ground (for downward-facing pyrgeometer). Assuming that these two, ground and sky, behave like perfect blackbodies, theoretically, one can calculate an effective "sky temperature" and an effective "ground temperature".

$$\text{Sky Temperature} = \left[\frac{\text{E upper Pyrgeometer}}{5.67 \cdot 10^{-8}}\right]^{1/4} \tag{7-6}$$

$$\text{Ground Temperature} = \left[\frac{\text{E lower Pyrgeometer}}{5.67 \cdot 10^{-8}}\right]^{1/4} \tag{7-7}$$

As a rule of thumb, for ambient temperatures of about 20 degrees Celsius, one can say that one degree of temperature difference between two objects results in a 5 W/m^2 exchange of radiative energy (infinite objects):

$$1 \text{ degree of temperature difference} = 5 \text{ W/m}^2 \text{ (rule of thumb)}$$

7.1.7 Calculation of Net (Total) Radiation

In the four separate components mode, net radiation, R_n, can be calculated using the individual sensor measurement results:

$$R_n = \{(E\ \text{upper Pyranometer}) - (E\ \text{lower Pyranometer})\} + \{(E\ \text{upper Pyrgeometer}) - (E\ \text{lower Pyrgeometer})\} \quad (7\text{-}8)$$

Where E upper/lower pyranometers are calculated according to Equation 7-1, and E upper/lower pyrgeometers are calculated according to Equation 7-2. The terms with T cancel each other out.

7.2 Wiring

The CNR4 has two outputs for short-wave radiation, two outputs for long-wave radiation, thermistor output, and Pt-100 temperature sensor output. In addition, if a user chooses to attach the optional CNF4 heater/ventilator unit, it will have power wires for heater and ventilator. All wiring diagrams shown in this manual and the sample programs will use the thermistor for the temperature measurement of the CNR4. The wiring diagrams for the thermistor in this manual is applicable only if the CNR4 and the cables were purchased from Campbell Scientific, Inc.

The CNR4 comes with two sets of cables labelled SOLAR and TEMP, as shown in FIGURE 7-1. FIGURE 7-2 shows the marks by the connecting ports at the sensor's end for the cable connection: S and T for SOLAR and TEMP cables, respectively. The two cables, SOLAR and TEMP, have identical connectors, and care should be used to ensure that the correct cables are connected to the correct ports of the sensor.

FIGURE 7-1. The CNR4 sensor with SOLAR and TEMP cables

FIGURE 7-2. The marks on the end of the CNR4: S for SOLAR cable, and T for TEMP cable

The measurement details for Pt-100 sensor, including the wiring diagram and sample program, are explained in Appendix C, *CR3000 Program for Measuring Pt-100 Temperature Sensor*.

The four radiation outputs can be measured using differential or single-ended inputs on the datalogger. A differential voltage measurement is recommended because it has better noise rejection than a single-ended measurement.

NOTE When differential inputs are used, jumper the low side of the input to AG or ⏚ to keep the signal in common mode range.

TABLE 7-3 and TABLE 7-4 show the wiring instructions for the differential measurement and single-ended measurement connections to the datalogger, respectively. The cables have the white band at the pigtail end of the cable with the color keys. See FIGURE 7-3 and FIGURE 7-4 below for the labels on the cable for both the SOLAR and TEMP cables.

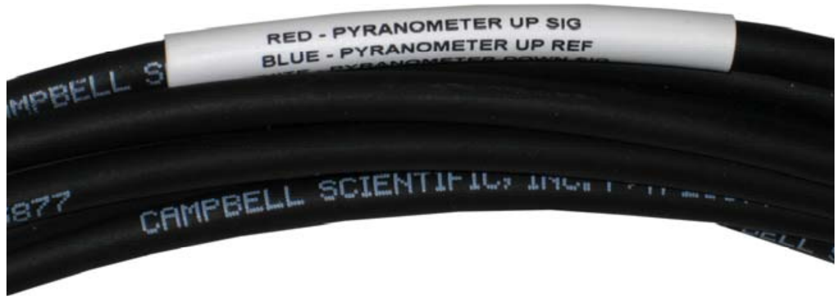


FIGURE 7-3. Labels on the pigtail end of the SOLAR cable

FIGURE 7-4. Labels on the pigtail end of the TEMP cable.

TABLE 7-3. Datalogger Connections for Differential Measurement

Function	Wire Color	CR1000	CR3000/CR5000
Pyranometer Up Signal	Red	Differential Input (H)	Differential Input (H)
Pyranometer Up Reference	*Blue	Differential Input (L)	Differential Input (L)
Pyranometer Down Signal	White	Differential Input (H)	Differential Input (H)
Pyranometer Down Reference	*Black	Differential Input (L)	Differential Input (L)
Pyrgeometer Up Signal	Grey	Differential Input (H)	Differential Input (H)
Pyrgeometer Up Reference	*Yellow	Differential Input (L)	Differential Input (L)
Pyrgeometer Down Signal	Brown	Differential Input (H)	Differential Input (H)
Pyrgeometer Down Reference	*Green	Differential Input (L)	Differential Input (L)
Shield	Clear	⏚	⏚
Thermistor Signal	White	Single-Ended Input	Single-Ended Input
Thermistor Voltage Excitation	Red	Voltage Excitation (VX)	Voltage Excitation (VX)
Thermistor Signal Reference	Black	⏚	⏚
Shield	Clear	⏚	⏚

*Jumper to ⏚ with user supplied wire.

TABLE 7-4. Datalogger Connections for Single-Ended Measurement

Function	Wire Color	CR1000	CR3000/CR5000
Pyranometer Up Signal	Red	Single-Ended Input	Single-Ended Input
Pyranometer Up Reference	Blue	⏚	⏚
Pyranometer Down Signal	White	Single-Ended Input	Single-Ended Input
Pyranometer Down Reference	Black	⏚	⏚
Pyrgeometer Up Signal	Grey	Single-Ended Input	Single-Ended Input
Pyrgeometer Up Reference	Yellow	⏚	⏚
Pyrgeometer Down Signal	Brown	Single-Ended Input	Single-Ended Input
Pyrgeometer Down Reference	Green	⏚	⏚
Shield	Clear	⏚	⏚
Thermistor Signal	White	Single-Ended Input	Single-Ended Input
Thermistor Voltage Excitation	Red	Voltage Excitation (VX)	Voltage Excitation (VX)
Thermistor Signal Reference	Black	⏚	⏚
Shield	Clear	⏚	⏚

*Pull back wires for Pt-100 (grey, brown, green, and yellow), which are not in use, and tie them around the TEMP cable using a cable tie or electrical tape to avoid possible damage to the Pt-100, due to electrical short circuit.

7.3 Datalogger Programming

The CNR4 outputs four voltages that typically range from 0 to 15 mV for the pyranometers, and ± 5 mV for the pyrgeometers. A differential voltage measurement is recommended because it has better noise rejection than a single-ended measurement. If differential channels are not available, single-ended measurements can be used. The acceptability of a single-ended measurement can be determined by simply comparing the results of single-ended and differential measurements made under the same conditions.

Additionally, one voltage excitation channel and one single-ended analog channel are required to make the temperature measurement of the sensor body, using the thermistor.

7.3.1 Sensor Sensitivity

The CNR4 comes with four different sensor sensitivity values for four separate probes. The CNR4 sensor comes with two copies of its 'Certificate of Calibration' by the manufacturer. They show the sensor serial number and sensitivity values for four individual probes: one copy for pyranometers, and another copy for pyrgeometers. The serial number and sensitivity values are also shown on a label affixed to the bottom of the sensor. If you choose to attach the CNF4 heater/ventilator unit to the CNR4, the label showing the serial number and sensitivity values will be covered. After attaching the CNF4 heater/ventilator, affix the extra label to the bottom of the CNF4 in a visible location. The extra label containing the serial number and sensitivity values is supplied with the purchase of the CNR4. Please refer to Appendix B, *CNF4 Heater/Ventilator*, for more details.

The sensor sensitivity is in $\mu V/(W/m^2)$. This needs to be converted into $(W/m^2)/mV$ to be used as a multiplier parameter inside the datalogger program. To convert the units, divide the sensor sensitivity value into 1000. For example, if the sensitivity is 7.30 $\mu V/(W/m^2)$, the multiplier is 1000/7.3 = 136.99 $(W/m^2)/mV$.

7.3.2 Example Programs

7.3.2.1 Example 1, CR1000 Program Using Differential Measurements

Example 1 requires four differential channels to measure the four radiation outputs, one excitation channel, and one single-ended channel to measure the thermistor. The program measures the sensors every 1 second, performs the online processing of the data, and stores the following processed data to a data table called cnr4_data once every 60 minutes. It also stores the raw time-series data from CNR4 to data table called cnr4_ts.

Minimum battery voltage
Sample datalogger panel temperature
Average short-wave radiation (pyranometer up)
Average short-wave radiation (pyranometer down)
Average long-wave radiation (pyrgeometer up)
Average long-wave radiation (pyrgeometer down)
Average CNR4 thermistor temperature (degrees C)
Average CNR4 thermistor temperature (Kelvin)
Average corrected long-wave radiation (pyrgeometer up)
Average corrected long-wave radiation (pyrgeometer down)

Average short-wave net radiation
Average long-wave net radiation
Average albedo
Average net radiation

```
'CR1000 Series Datalogger
'
'CNR4 program
'This program measures CNR4 four-component net radiometer
'This program also measures the thermistor inside the CNR4
'
'User must enter the sensitivity values for all four probes in the program and save/compile
'prior to downloading it to the datalogger.
'Search for the text string "unique" to find places to enter the sensitivity values.
'

'Wiring Instructions
'
'ANALOG CHANNELS
'1H     CNR4 Pyranometer Upper signal (red)
'1L     CNR4 Pyranometer Upper signal reference (blue)
'gnd    jumper to 1L
'
'2H     CNR4 Pyranometer Lower signal (white)
'2L     CNR4 Pyranometer Lower signal reference (black)
'gnd    jumper to 2L
'
'3H     CNR4 Pyrgeometer Upper signal (grey)
'3L     CNR4 Pyrgeometer Upper signal reference (yellow)
'gnd    jumper to 3L
'
'4H     CNR4 Pyrgeometer Lower signal (brown)
'4L     CNR4 Pyrgeometer Lower signal reference (green)
'gnd    jumper to 4L
'       CNR4 shield (clear)
'
'
'
'8H
'8L     CNR4 thermistor signal (white)
'gnd    CNR4 thermistor signal reference (black)
'       CNR4 thermistor shield (clear)
'

'VOLTAGE EXCITATION
'
'EX2    CNR4 thermistor voltage excitation (red)
'

'CNR4 sensor
Public logger_temp, batt_volt
Public cnr4(4)
Alias cnr4(1) = short_up
Alias cnr4(2) = short_dn
Alias cnr4(3) = long_up
Alias cnr4(4) = long_dn

Public cnr4_T_C       'CNR4 thermistor temperature in Celcius
Public cnr4_T_K       'CNR4 thermistor temperature in Kelvin
Public long_up_corr   'Downwelling long-wave radiation with temperature correction
Public long_dn_corr   'Upwelling long-wave radiation with temperature correction
Public Rs_net         'short-wave net radiation
Public Rl_net         'long-wave net radiation
Public albedo         'Albedo
Public Rn             'total net radiation
```

```
Units logger_temp = degC
Units batt_volt = volts
Units short_up = W/m^2
Units short_dn = W/m^2
Units long_up = W/m^2
Units long_dn = W/m^2
Units cnr4_T_C = deg_C
Units cnr4_T_K = K
Units long_up_corr = W/m^2
Units long_dn_corr = W/m^2
Units Rs_net = W/m^2
Units Rl_net = W/m^2
Units albedo = W/m^2
Units Rn = W/m^2

Dim Rs, Vs_Vx

'CNR4 sensitivities: refer to the Certificate of Calibration from Kipp & Zonen for sensitivity values
'for each probes, and enter them below.
Const pyranometer_up_sensitivity = 15.35   'unique sensitivity for upper pyranometer
                                           '(microV/W/m^2)
Const pyranometer_dn_sensitivity = 15.41   'unique sensitivity for lower pyranometer
                                           '(microV/W/m^2)
Const pyrgeometer_up_sensitivity = 8.50    'unique sensitivity for upper pyrgeometer
                                           '(microV/W/m^2)
Const pyrgeometer_dn_sensitivity = 7.09    'unique sensitivity for lower pyrgeometer
                                           '(microV/W/m^2)

'CNR4 multipliers
Public cnr4_mult(4)
Const pyranometer_up_mult = 1000/pyranometer_up_sensitivity     '(W/m^2/mV)
Const pyranometer_dn_mult = 1000/pyranometer_dn_sensitivity     '(W/m^2/mV)
Const pyrgeometer_up_mult = 1000/pyrgeometer_up_sensitivity     '(W/m^2/mV)
Const pyrgeometer_dn_mult = 1000/pyrgeometer_dn_sensitivity     '(W/m^2/mV)

DataTable (cnr4_data,True,-1)
  DataInterval (0,60,Min,10)
    CardOut (1,-1)
  Minimum (1,batt_volt,FP2,0,False)
  Sample (1,logger_temp,FP2)
  Average (4,cnr4(1),IEEE4,False)
  Average (1,cnr4_T_C,IEEE4,False)
  Average (1,cnr4_T_K,IEEE4,False)
  Average (1,long_up_corr,IEEE4,False)
  Average (1,long_dn_corr,IEEE4,False)
  Average (1,Rs_net,IEEE4,False)
  Average (1,Rl_net,IEEE4,False)
  Average (1,albedo,IEEE4,False)
  Average (1,Rn,IEEE4,False)
EndTable

DataTable (cnr4_ts,True,-1)
  DataInterval (0,1,Sec,10)
    CardOut (1,-1)
  Sample (4,cnr4(1),IEEE4)
  Sample (1,cnr4_T_K,IEEE4)
EndTable

BeginProg
'Load the multiplier values for the CNR4
            cnr4_mult(1) = pyranometer_up_mult
            cnr4_mult(2) = pyranometer_dn_mult
            cnr4_mult(3) = pyrgeometer_up_mult
            cnr4_mult(4) = pyrgeometer_dn_mult
```

```
  Scan (1,Sec,3,0)
    PanelTemp (logger_temp,250)
    Battery (batt_volt)

'CNR4 radiation measurements
        VoltDiff (cnr4(),4,mV20C,1,True ,0,_60Hz,cnr4_mult(),0)

'CNR4 thermistor measurement
        BrHalf (Vs_Vx,1,mV2500,16,Vx2,1,2500,True ,0,250,1.0,0)
            Rs = 1000*(Vs_Vx/(1-Vs_Vx))
              cnr4_T_C = 1/(1.0295e-3+2.391e-4*LN(Rs)+1.568e-7*(LN(Rs))^3)-273.15

'Convert CNR4 temperature to Kelvin
              cnr4_T_K = cnr4_T_C+273.15

'Correct the long-wave radiation values from pyrgeometers
              long_up_corr = long_up+5.67e-8*cnr4_T_K^4
              long_dn_corr = long_dn+5.67e-8*cnr4_T_K^4

'Compute short-wave net radiation
              Rs_net = short_up - short_dn

'Compute long-wave net radiation
              Rl_net = long_up - long_dn

'Compute albedo
              albedo = short_dn/short_up

'Compute net radiation
              Rn = Rs_net + Rl_net

    CallTable cnr4_data
    CallTable cnr4_ts

  NextScan
EndProg
```

7.3.2.2 Example 2, CR3000 Program Using Differential Measurements

Example 2 requires four differential channels to measure the four radiation outputs and one excitation channel and one single-ended channel to measure the thermistor. The program measures the sensors every 1 second, performs the online processing of the data and stores the following processed data to a data table called cnr4_data once every 60 minutes. It also stores the raw time-series data from CNR4 to data table called cnr4_ts.

Minimum battery voltage
Sample datalogger panel temperature
Average short-wave radiation (pyranometer up)
Average short-wave radiation (pyranometer down)
Average long-wave radiation (pyrgeometer up)
Average long-wave radiation (pyrgeometer down)
Average CNR4 thermistor temperature (degrees C)
Average CNR4 thermistor temperature (Kelvin)
Average corrected long-wave radiation (pyrgeometer up)
Average corrected long-wave radiation (pyrgeometer down)
Average short-wave net radiation
Average long-wave net radiation
Average albedo
Average net radiation

```
'CR3000 Series Datalogger
'
'CNR4 program
'This program measures CNR4 four-component net radiometer
'This program also measures the thermistor inside the CNR4
'
'User must enter the sensitivity values for all four probes in the program and save/compile
'prior to downloading it to the datalogger.
'Search for the text string "unique" to find places to enter the sensitivity values.
'

'Wiring Instructions
'
'ANALOG CHANNELS
'1H     CNR4 Pyranometer Upper signal (red)
'1L     CNR4 Pyranometer Upper signal reference (blue)
'gnd    jumper to 1L
'
'2H     CNR4 Pyranometer Lower signal (white)
'2L     CNR4 Pyranometer Lower signal reference (black)
'gnd    jumnper to 2L
'
'3H     CNR4 Pyrgeometer Upper signal (grey)
'3L     CNR4 Pyrgeometer Upper signal reference (yellow)
'gnd    jumper to 3L
'
'4H     CNR4 Pyrgeometer Lower signal (brown)
'4L     CNR4 Pyrgeometer Lower signal reference (green)
'gnd    jumper to 4L
'       CNR4 shield (clear)
'
'
'8H
'8L     CNR4 thermistor signal (white)
'gnd    CNR4 thermistor signal reference (black)
'       CNR4 thermistor shield (clear)
'

'VOLTAGE EXCITATION
'
'VX1    CNR4 thermistor voltage excitation (red)
'

'CNR4 sensor
Public logger_temp, batt_volt
Public cnr4(4)
Alias cnr4(1) = short_up
Alias cnr4(2) = short_dn
Alias cnr4(3) = long_up
Alias cnr4(4) = long_dn

Public cnr4_T_C       'CNR4 thermistor temperature in Celcius
Public cnr4_T_K       'CNR4 thermistor temperature in Kelvin
Public long_up_corr   'Downwelling long-wave radiation with temperature correction
Public long_dn_corr   'Upwelling long-wave radiation with temperature correction
Public Rs_net         'short-wave net radiation
Public Rl_net         'long-wave net radiation
Public albedo         'Albedo
Public Rn             'total net radiation

Units logger_temp = degC
Units batt_volt = volts
Units short_up = W/m^2
Units short_dn = W/m^2
Units long_up = W/m^2
Units long_dn = W/m^2
Units cnr4_T_C = deg_C
Units cnr4_T_K = K
```

```
Units long_up_corr = W/m^2
Units long_dn_corr = W/m^2
Units Rs_net = W/m^2
Units Rl_net = W/m^2
Units albedo = W/m^2
Units Rn = W/m^2

Dim Rs, Vs_Vx

'CNR4 sensitivities: refer to the Certificate of Calibration from Kipp & Zonen for sensitivity values
'for each probes, and enter them below.
Const pyranometer_up_sensitivity = 15.35   'unique sensitivity for upper pyranometer
                                           '(microV/W/m^2)
Const pyranometer_dn_sensitivity = 15.41   'unique sensitivity for lower pyranometer
                                           '(microV/W/m^2)
Const pyrgeometer_up_sensitivity = 8.50    'unique sensitivity for upper pyrgeometer
                                           '(microV/W/m^2)
Const pyrgeometer_dn_sensitivity = 7.09    'unique sensitivity for lower pyrgeometer
                                           '(microV/W/m^2)

'CNR4 multipliers
Public cnr4_mult(4)
Const pyranometer_up_mult = 1000/pyranometer_up_sensitivity     '(W/m^2/mV)
Const pyranometer_dn_mult = 1000/pyranometer_dn_sensitivity     '(W/m^2/mV)
Const pyrgeometer_up_mult = 1000/pyrgeometer_up_sensitivity     '(W/m^2/mV)
Const pyrgeometer_dn_mult = 1000/pyrgeometer_dn_sensitivity     '(W/m^2/mV)

DataTable (cnr4_data,True,-1)
  DataInterval (0,60,Min,10)
    CardOut (1,-1)
  Minimum (1,batt_volt,FP2,0,False)
  Sample (1,logger_temp,FP2)
  Average (4,cnr4(1),IEEE4,False)
  Average (1,cnr4_T_C,IEEE4,False)
  Average (1,cnr4_T_K,IEEE4,False)
  Average (1,long_up_corr,IEEE4,False)
  Average (1,long_dn_corr,IEEE4,False)
  Average (1,Rs_net,IEEE4,False)
  Average (1,Rl_net,IEEE4,False)
  Average (1,albedo,IEEE4,False)
  Average (1,Rn,IEEE4,False)
EndTable

DataTable (cnr4_ts,True,-1)
  DataInterval (0,1,Sec,10)
    CardOut (1,-1)
  Sample (4,cnr4(1),IEEE4)
  Sample (1,cnr4_T_K,IEEE4)
EndTable

BeginProg
'Load the multiplier values for the CNR4
            cnr4_mult(1) = pyranometer_up_mult
            cnr4_mult(2) = pyranometer_dn_mult
            cnr4_mult(3) = pyrgeometer_up_mult
            cnr4_mult(4) = pyrgeometer_dn_mult

  Scan (1,Sec,3,0)
    PanelTemp (logger_temp,250)
    Battery (batt_volt)

'CNR4 radiation measurements
        VoltDiff (cnr4(),4,mV20C,1,True ,0,_60Hz,cnr4_mult(),0)
```

```
'CNR4 thermistor measurement
        BrHalf (Vs_Vx,1,mv5000,16,Vx1,1,2500,True ,0,250,1.0,0)
            Rs = 1000*(Vs_Vx/(1-Vs_Vx))
              cnr4_T_C = 1/(1.0295e-3+2.391e-4*LN(Rs)+1.568e-7*(LN(Rs))^3)-273.15

'Convert CNR4 temperature to Kelvin
              cnr4_T_K = cnr4_T_C+273.15

'Correct the long-wave radiation values from pyrgeometers
              long_up_corr = long_up+5.67e-8*cnr4_T_K^4
              long_dn_corr = long_dn+5.67e-8*cnr4_T_K^4

'Compute short-wave net radiation
              Rs_net = short_up - short_dn

'Compute long-wave net radiation
              Rl_net = long_up - long_dn

'Compute albedo
              albedo = short_dn/short_up

'Compute net radiation
              Rn = Rs_net + Rl_net

    CallTable cnr4_data
    CallTable cnr4_ts

  NextScan
EndProg
```

7.3.2.3 Example 3, CR5000 Program Using Differential Measurements

Example 3 requires four differential channels to measure the four radiation outputs, one excitation channel, and one single-ended channel to measure the thermistor. The program measures the sensors every 1 second, performs the online processing of the data, and stores the following processed data to a data table called cnr4_data once every 60 minutes. It also stores the raw time-series data from CNR4 to data table called cnr4_ts.

NOTE The variables for the CR5000 datalogger can be up to 16 characters in length. However, if the variable is processed in the output table by an output type other than Sample, the name will be truncated in the datalogger to 12 characters, plus an underscore and a 3 digit suffix indicating the output type (for example, _avg, _max).

Minimum battery voltage
Sample datalogger panel temperature
Average short-wave radiation (pyranometer up)
Average short-wave radiation (pyranometer down)
Average long-wave radiation (pyrgeometer up)
Average long-wave radiation (pyrgeometer down)
Average CNR4 thermistor temperature (degrees C)
Average CNR4 thermistor temperature (Kelvin)
Average corrected long-wave radiation (pyrgeometer up)
Average corrected long-wave radiation (pyrgeometer down)
Average short-wave net radiation
Average long-wave net radiation
Average albedo
Average net radiation

```
'CR5000 Series Datalogger
'
'CNR4 program
'This program measures CNR4 four-component net radiometer
'This program also measures the thermistor inside the CNR4
'
'User must enter the sensitivity values for all four probes in the program and save/compile
'prior to downloading it to the datalogger.
'Search for the text string "unique" to find places to enter the sensitivity values.
'

'Wiring Instructions
'
'ANALOG CHANNELS
'1H     CNR4 Pyranometer Upper signal (red)
'1L     CNR4 Pyranometer Upper signal reference (blue)
'gnd    jumper to 1L
'
'2H     CNR4 Pyranometer Lower signal (white)
'2L     CNR4 Pyranometer Lower signal reference (black)
'gnd    jumnper to 2L
'
'3H     CNR4 Pyrgeometer Upper signal (grey)
'3L     CNR4 Pyrgeometer Upper signal reference (yellow)
'gnd    jumper to 3L
'
'4H     CNR4 Pyrgeometer Lower signal (brown)
'4L     CNR4 Pyrgeometer Lower signal reference (green)
'gnd    jumper to 4L
'       CNR4 shield (clear)
'
'
'8H
'8L     CNR4 thermistor signal (white)
'gnd    CNR4 thermistor signal reference (black)
'       CNR4 thermistor shield (clear)
'

'VOLTAGE EXCITATION
'
'VX1    CNR4 thermistor voltage excitation (red)
'

'CNR4 sensor
Public logger_temp, batt_volt
Public cnr4(4)
Alias cnr4(1) = short_up
Alias cnr4(2) = short_dn
Alias cnr4(3) = long_up
Alias cnr4(4) = long_dn

Public cnr4_T_C       'CNR4 thermistor temperature in Celcius
Public cnr4_T_K       'CNR4 thermistor temperature in Kelvin
Public long_up_corr   'Downwelling long-wave radiation with temperature correction
Public long_dn_corr   'Upwelling long-wave radiation with temperature correction
Public Rs_net         'short-wave net radiation
Public Rl_net         'long-wave net radiation
Public albedo         'Albedo
Public Rn             'total net radiation

Units logger_temp = degC
Units batt_volt = volts
Units short_up = W/m^2
Units short_dn = W/m^2
Units long_up = W/m^2
Units long_dn = W/m^2
Units cnr4_T_C = deg_C
```

```
Units cnr4_T_K = K
Units long_up_corr = W/m^2
Units long_dn_corr = W/m^2
Units Rs_net = W/m^2
Units Rl_net = W/m^2
Units albedo = W/m^2
Units Rn = W/m^2

Dim Rs, Vs_Vx

'CNR4 sensitivities: refer to the Certificate of Calibration from Kipp & Zonen for sensitivity values
'for each probes, and enter them below.
Const pyra_up_sensitiv = 15.35  'unique sensitivity for upper pyranometer (microV/W/m^2)
Const pyra_dn_sensitiv = 15.41  'unique sensitivity for lower pyranometer (microV/W/m^2)
Const pyrg_up_sensitiv = 8.50   'unique sensitivity for upper pyrgeometer (microV/W/m^2)
Const pyrg_dn_sensitiv = 7.09   'unique sensitivity for lower pyrgeometer (microV/W/m^2)

'CNR4 multipliers
Public cnr4_mult(4)
Const pyra_up_mult = 1000/pyra_up_sensitiv       '(W/m^2/mV)
Const pyra_dn_mult = 1000/pyra_dn_sensitiv       '(W/m^2/mV)
Const pyrg_up_mult = 1000/pyrg_up_sensitiv       '(W/m^2/mV)
Const pyrg_dn_mult = 1000/pyrg_dn_sensitiv       '(W/m^2/mV)

DataTable (cnr4_dat,True,-1)
  DataInterval (0,60,Min,10)
    CardOut (1,-1)
  Minimum (1,batt_volt,FP2,0,False)
  Sample (1,logger_temp,FP2)
  Average (4,cnr4(1),IEEE4,False)
  Average (1,cnr4_T_C,IEEE4,False)
  Average (1,cnr4_T_K,IEEE4,False)
  Average (1,long_up_corr,IEEE4,False)
  Average (1,long_dn_corr,IEEE4,False)
  Average (1,Rs_net,IEEE4,False)
  Average (1,Rl_net,IEEE4,False)
  Average (1,albedo,IEEE4,False)
  Average (1,Rn,IEEE4,False)
EndTable

DataTable (cnr4_ts,True,-1)
  DataInterval (0,1,Sec,10)
    CardOut (1,-1)
  Sample (4,cnr4(1),IEEE4)
  Sample (1,cnr4_T_K,IEEE4)
EndTable

BeginProg
'Load the multiplier values for the CNR4
            cnr4_mult(1) = pyra_up_mult
            cnr4_mult(2) = pyra_dn_mult
            cnr4_mult(3) = pyrg_up_mult
            cnr4_mult(4) = pyrg_dn_mult

  Scan (1,Sec,3,0)
    PanelTemp (logger_temp,250)
    Battery (batt_volt)

'CNR4 radiation measurements
        VoltDiff (cnr4(),4,mV20C,1,True ,0,_60Hz,cnr4_mult(),0)

'CNR4 thermistor measurement
        BrHalf (Vs_Vx,1,mv5000,21,Vx1,1,2500,True ,0,250,1.0,0)
            Rs = 1000*(Vs_Vx/(1-Vs_Vx))
              cnr4_T_C = 1/(1.0295e-3+2.391e-4*LN(Rs)+1.568e-7*(LN(Rs))^3)-273.15
```

```
'Convert CNR4 temperature to Kelvin
              cnr4_T_K = cnr4_T_C+273.15

'Correct the long-wave radiation values from pyrgeometers
              long_up_corr = long_up+5.67e-8*cnr4_T_K^4
              long_dn_corr = long_dn+5.67e-8*cnr4_T_K^4

'Compute short-wave net radiation
              Rs_net = short_up - short_dn

'Compute long-wave net radiation
              Rl_net = long_up - long_dn

'Compute albedo
              albedo = short_dn/short_up

'Compute net radiation
              Rn = Rs_net + Rl_net

    CallTable cnr4_dat
    CallTable cnr4_ts

  NextScan
EndProg
```

8. Troubleshooting

If there is no indication as to what may be the problem, start performing the following “upside-down test”, which is a rough test for a first diagnosis. It can be performed both outdoors and indoors. Indoors, a lamp can be used as a source for both short-wave and long-wave radiation. Outdoors, one should preferably work with a solar elevation of more than 45 degrees (45 degrees above horizon) and under stable conditions (no large changes in solar irradiance, and preferably no clouds).

1. Measure the radiation outputs in the normal position. Record the measured values when the signals have stabilized, i.e. after about three minutes.

2. Rotate the instrument 180 degrees, so that the upper and the lower sensors are now in the reverse orientation as to the previous position.

3. Measure the radiation outputs once more. Record the measured values when the radiometers have stabilized.

4. The computed net radiation values in rotated position should be equal in magnitude but only differing in sign. In a rough test like this, deviations of ± 10 % can be tolerated. If deviations greater than this are encountered, additional testing is warranted.

8.1 Testing the Pyranometer

As a first test, check the sensor impedance. It should have a nominal value as indicated in the specifications. Zero, or infinite resistance, indicates a failure in hardware connection.

Before starting the second test measurement, let the pyranometer rest for at least five minutes to let it regain its thermal equilibrium. For testing, set a voltmeter to its most sensitive range setting. Darken the sensor. The signal should read zero; this response can take up to one minute. Small deviations from zero are possible; this is caused by the thermal effects, such as touching the pyranometer with your hand. This thermal effect can be demonstrated by deliberately heating the pyranometer with your hand. If the zero offset is within specifications, proceed with the third test.

In the third test, the sensor should be exposed to light. The signal should be a positive reading. Set the voltmeter range in such a way that the expected full-scale output of the pyranometer is within the full-scale input range of the voltmeter. The range can be estimated on theoretical considerations. When the maximum expected radiation is 1500 W/m^2, which is roughly equal to normal outdoor daylight conditions, and the sensitivity of the pyranometer is 15 µV per W/m^2, the expected output range of the pyranometer is equal to 22500 µV, or 22.5 mV. One can calculate the radiation intensity by dividing the pyranometer output as measured by the voltmeter (for example, 22.5 mV) by the sensor sensitivity (15 $\mu V/W/m^2$). If no faults are found up to this point, your pyranometer is probably operating correctly.

8.2 Testing the Pyrgeometer

It is assumed that the zero offset is no more than a few watts per square meter (see second test in Section 8.1, *Testing the Pyranometer*).

The CNR4 body and the ambient air should be at the same temperature. Let the pyrgeometer rest for at least five minutes to regain its thermal equilibrium. Set the voltmeter to its most sensitive range. To test if the pyrgeometer is working properly, put your hand in front of the pyrgeometer. The thermal radiation from your hand will cause the pyrgeometer to generate a positive voltage when the surface temperature of your hand is higher than the pyrgeometer temperature. The pyrgeometer will generate a negative voltage if the hand is colder. The signal is proportional to the temperature difference (see the rule of thumb in Section 7.1.6, *Calculation of Net Long-wave Radiation*). The radiation emitted by the hand can be calculated by dividing the pyrgeometer output by the sensor's sensitivity value, and subsequently correcting for the temperature, according to Equation 5-2. If there are still no faults found, your pyrgeometer is probably operating correctly.

8.3 Testing the Thermistor

Using a multimeter, measure the resistance between the black and white wires of the thermistor, and compare the value with the resistance values listed in TABLE 7-1. The resistance should be around 10 k Ω at 25 °C, and the cable resistance should add about 0.026 Ω per each foot of cable. When in doubt, the Pt-100 resistance (temperature) can be checked as well for reference.

8.4 Testing the Pt-100

Using a multimeter, measure the resistance between the two opposite wires of the Pt-100 (gray-yellow, gray-brown, green-yellow, green-brown), and compare the measured value with the resistance values listed in TABLE 7–2. The resistance should be above 100 Ω at 0°C, and the cable resistance should add about 0.026 Ω per each foot of cable. When in doub,t the thermistor resistance (temperature) can be checked as well for reference.

9. Maintenance and Recalibration

The CNR4 is weatherproof, and is intended for a continuous outdoor use. The materials used in the pyranometer and the pyrgeometer are robust and require little maintenance. For optimal results, however, proper care must be taken.

9.1 Cleaning Windows and Domes

The radiometer readings can be reduced if domes and windows are not clean. The site operator should check the windows and domes of the CNR4 regularly, and clean them as needed. Use distilled water or alcohol as cleaning solution, being careful not to scratch the windows and domes during cleaning.

9.2 Recalibration

For quality assurance of the measured data, the manufacturer recommends the CNR4 be recalibrated on a regular schedule by an authorized Kipp & Zonen calibration facility.

The CNR4 should be recalibrated every two years. Alternatively, one can check the sensor calibration by letting a higher standard run parallel to it over a two-day period and, then, comparing the results. For comparison of pyranometers, one should use a clear day. For comparison of pyrgeometers, one should compare the nighttime results. If the deviations are greater than 6%, the sensor should be recalibrated.

Please contact Campbell Scientific to obtain an RMA number for recalibration.

9.3 Replacing the Drying Cartridge

The CNR4 has a drying cartridge inside the sensor to help keep the electronics dry. The manufacturer recommends replacing the drying cartridge every 6 to 12 months. The three screws holding the white solar shield and the six screws holding the aluminium base plate need to be removed to access the drying cartridge, as shown in FIGURE 9-1. Make sure that the black rubber gasket is put in place properly before the base plate is put back to keep the compartment sealed. The CNR4 comes with two spare drying cartridges. Additional drying cartridges, pn 26006, can be purchased from Campbell Scientific.

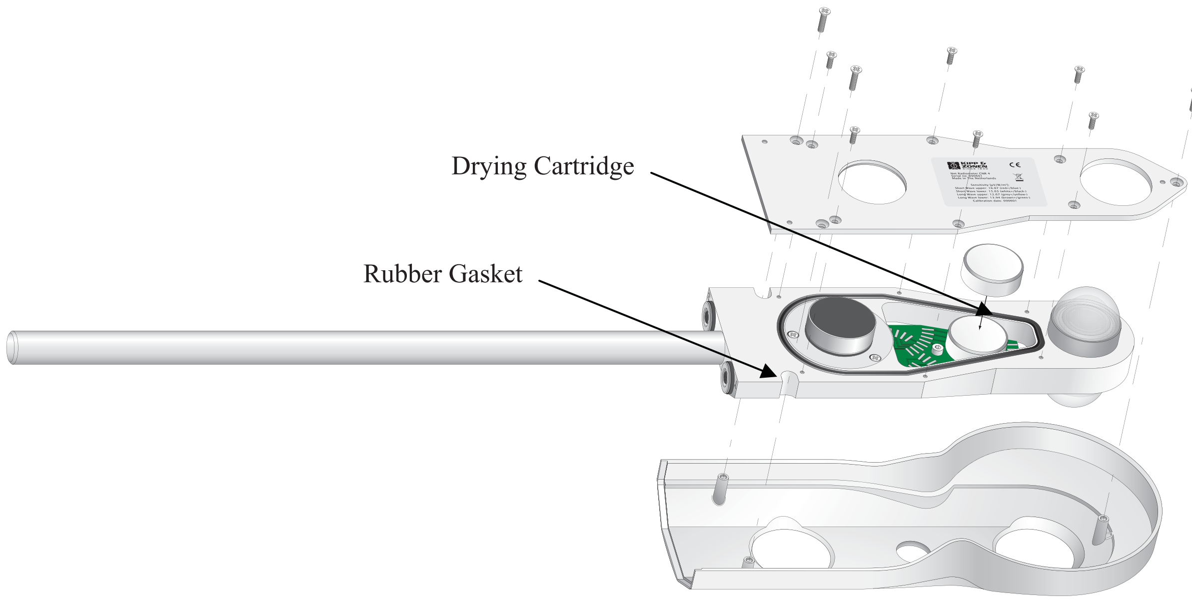


FIGURE 9-1. Replacing the drying cartridge

9.4 Replacement Parts

The following is the list of replacement parts for the CNR4 and CNF4 (heater/ventilator) available from Campbell Scientific.

CSI Part Number	Description
CNR4CBL1-L	Replacement CNR4 Solar Cable
CNR4CBL2-L	Replacement CNR4 Temperature Cable
CNF4CBL-L	Replacement CNF4 Cable
26006	Replacement Drying Cartridges
26010	Replacement Fan Filter (Set of 5). See Appendix B, *CNF4 Heater/Ventilator*, for fan filter replacement instruction.

Appendix A. CNR4 Performance and Measurements under Different Conditions

TABLE A-1 shows what one might typically expect to measure under different meteorological conditions.

The first parameter is day and night. At night, the solar radiation is zero. The second column shows if it is cloudy or clear. A cloud acts like a blanket, absorbing part of the solar radiation, and keeping net far infrared radiation close to zero. The third parameter is ambient temperature; this is included to show that the sky temperature, column nine, "sky T", tracks the ambient temperature. Under cloudy conditions this is logical; cloud bases will be colder than the ambient temperature. At instrument level, the temperature difference depends roughly on cloud altitude.

Under clear sky conditions, it is less obvious that sky temperature "adjusts" to the ambient temperature. This can roughly be attributed to the water vapor in the air, which is a major contributor to the far infrared radiation.

TABLE A-1. Typical output signals of CNR4 under different meteorological conditions. Explanation can be found in the text.

1	2	3	4	5	6	7	8	9	10
Day night	Cloudy clear	+20ºC –20ºC	Pyrgeo–meter Up	Pyrgeo–meter low	Pyrano–meter up	Pyrano–meter low	Pt 100	sky T	ground T
d	cloud	+20	0	0	0–500	0–150	20	20	20
d	cloud	–20	0	0	0–500	0–150	–20	–20	–20
d	clear	+20	–100*	0	0–1300	0–400	20	1*	20
d	clear	–20	–100*	0	0–1300	0–400	–20	–53*	–20
n	cloud	+20	0	0	0	0	20	20	20
n	cloud	–20	0	0	0	0	–20	–20	–20
n	clear	+20	–100***	0	0**	0	20	1***	20
n	clear	–20	–100***	0	0**	0	–20	–53***	–20

* Values may suffer from the so-called window heating offset; the sun heats the pyrgeometer window causing a measurement error of +10 Watts per square meter (maximum).

** Values may suffer from negative infrared offsets, caused by cooling off of the pyranometer dome by far infrared radiation. The maximum expected offset value is 15 Watts per square meter.

*** Values may suffer from dew deposition. This causes the pyrgeometer-up values to rise from –100 to 0 Watts per square meter.

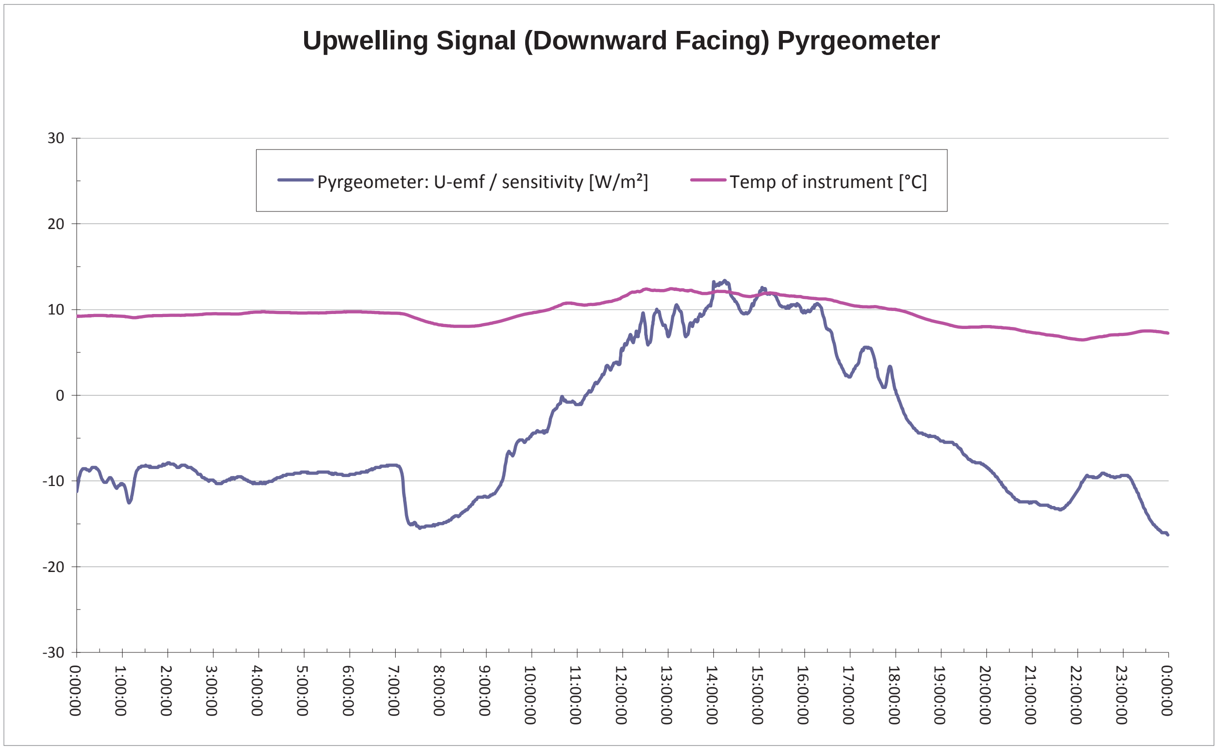


FIGURE A-3. Clear day for the downward facing pyrgeometer

It is assumed that when ambient temperature varies, the net far infrared radiation remains roughly the same, independent of ambient temperature. The resulting measured values of the pyrgeometers and pyranometers are shown in columns 4 to 7 in TABLE A-1. These are indicative figures only, they depend strongly on other circumstances; the pyrgeometer results, of course, change with the sensor temperature. This is indicated in column 8. During the day, the Pt-100 reading may rise due to solar heating, up to 10 degrees above ambient temperature. During the night, the sensor temperature may be lower than the ambient temperature due to far infrared radiative cooling. The latter two effects do not influence the end result of the calculations of sky T and ground T. Therefore, they are not taken into account in the table. In column 4, one might expect to see “0 to –50” for all positions that are showing “0”; in column 5, the “0” values may in reality be “-20 to +20”. The resulting sky temperature is indicated in column 9. Under cloudy conditions, this sky temperature is equal to ambient temperature. Under clear conditions, the sky temperature is lower than the ambient temperature.

The ground temperature, in column 10, is assumed to be equal to the ambient temperature. In practice, it may be higher during the day, due to solar heating. Ground temperature may be lower than ambient during the night, due to far infrared radiative cooling. The sky and the ground temperature can be calculated from the measured values of the sensors using formulas A-1 and A-2 below.

$$\text{Sky Temperature} = \left[\frac{\text{E upper CG3}}{5.67 \cdot 10^{-8}}\right]^{1/4} \tag{A-1}$$

$$\text{Ground Temperature} = \left[\frac{\text{E lower CG3}}{5.67 \cdot 10^{-8}}\right]^{1/4} \tag{A-2}$$

Appendix B. CNF4 Heater/Ventilator

NOTE Whenever the heater is used, the heating may cause errors in the measurement of the sensor temperature. Under most conditions, the accuracy gained by heating will be larger than the errors introduced by heating.

In both the pyranometer and the pyrgeometer, thermal sensors are used, and these sensors, in principle, measure a heat flow. For optimal performance, these sensors should be at thermal equilibrium with the ambient air. Heating the sensor disturbs this equilibrium. The heating causes the zero offset error on the pyranometer (10 W/m^2 typical), and the temperature measurement error on the sensor (2 degree typical). Therefore, the heater should be used only if absolutely necessary. The pyrgeometer is less sensitive to this. Offset values for the pyrgeometer cannot be determined, and, therefore, are not specified.

B.1 General Information

The primary reason for heating the sensor is to avoid the water deposition on the pyrgeometer sensor window and on the pyranometer domes. The water deposition on the pyrgeometer window will ultimately obstruct the far infrared radiation completely. During a rain event, this will probably not lead to significant errors, because with an overcast sky, the signal is close to zero anyway. However, the dew deposition is far more significant. Dew deposition will probably take place under conditions with large far infrared irradiation from the pyrgeometer to the clear sky, typically –100 W/m^2. The dew on the windows of pyrgeometer can cause the –100 W/m^2 signal to go to zero. In such a case, the heater should be used because the error described above is significantly smaller than the gain obtained by heating the sensor to avoid the dew deposition.

Please refer to the following diagram to determine whether or not the heater should be used.

10 watt power available?	Not available →	**DO NOT HEAT**
	Available →	Consider options below ↓
Clock and relay available?	Not Available →	**DO NOT HEAT (recommendation)**
	Available →	Heat from 1 hour before sunset until 1 hour after sunrise.

The heater power can be controlled using one of the SW12V channels of the Campbell Scientific dataloggers. The heater's current drain is approximately 850 mA at 12 Vdc (10 watts). The ventilator draws additional 5 watts of power at 12 Vdc. Connect the power ground from the heater to a G terminal close to the SW12V channel of the datalogger (not to an analog ground near the measurement inputs).

The heater power can be controlled by the datalogger program. For example, the datalogger program can turn on the heater only when the light level falls below 20 W/m^2 or, if a measurement of air humidity is available, when the dew point of the air falls to within 1ºC of the sensor body temperature.

CAUTION Do not use the SW12 channel of a CR1000 or CR3000 to simultaneously power the heater and ventilator. Simultaneously powering the heater and ventilator will exceed the current limit of the SW12 channel. If the heater and ventilator need to be used at the same time, connect the CNF4 to the 12V channel instead of the SW12 channel and use an external relay to switch the power on and off. Refer to Section 4.2 of the CR1000 and CR3000 manual for details on the 12V current source limits.

B.2 Attaching the Optional CNF4 Heater/Ventilator Unit to CNR4

1. The CNF4 heater/ventilator unit comes with the following: the heater/ventilator, the white solar shield, three pan-head screws with washers, and four flat-head screws as shown in FIGURE B-1.

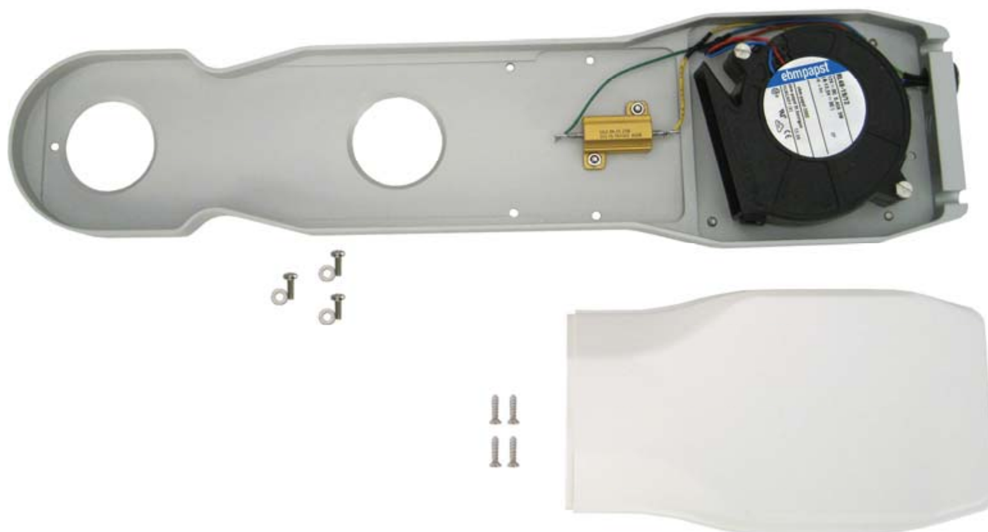


FIGURE B-1. CNF4 package contents

2. Attach the heater/ventilator unit unto the bottom of the CNR4 sensor, using the three pan-head screws and washers, as shown in FIGURE B-2. Make sure that the pyranometer and the pyrgeometer windows are not scratched during the installation.

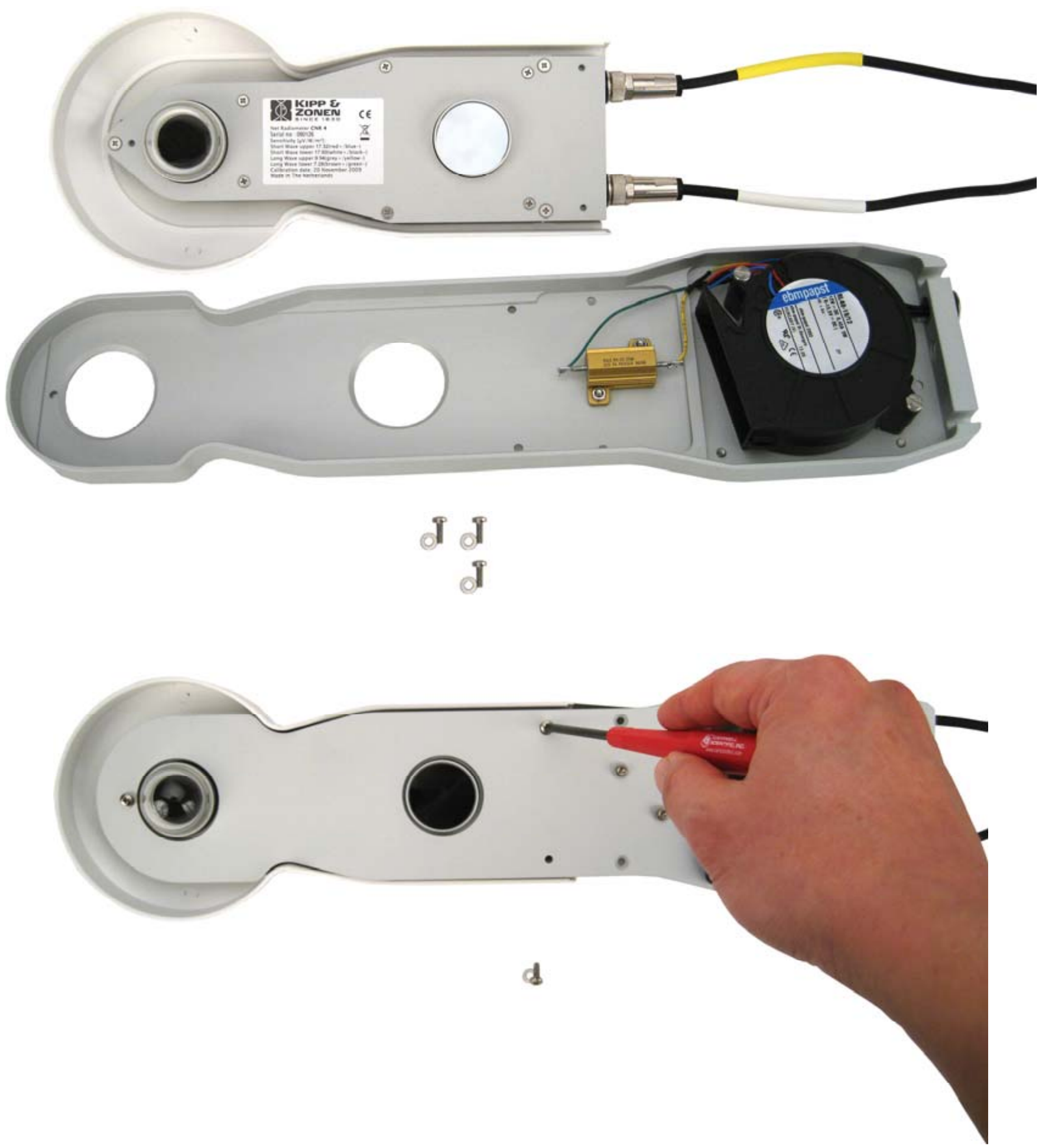


FIGURE B-2. Attaching the CNF4 to CNR4 using pan-head screws and washers

3. Make sure the cables are cleared from the edges of the CNF4, as shown in FIGURE B-3, and place the white solar shield over it. Use the four flat-head screws provided to complete the solar shield installation to the CNF4, as shown in FIGURE B-4 and FIGURE B-5.

FIGURE B-3. Making sure the cables are clear from the edges

FIGURE B-4. CNF4 solar shield and four flat-head screws

FIGURE B-5. Attaching the solar shield to CNF4 using four flat-head screws

4. Once the CNF4 heater/ventilator unit is attached to the bottom side of the CNR4, the CNF4 will cover the label that contains the serial number and the sensitivity values for the four sensors. Affix the extra label that came with the sensor to the bottom side of the CNF4's anodized aluminium base so that the label is in a visible location. See FIGURE B-6 below.

FIGURE B-6. Affixing the sensor label to CNF4

5. Connect the heater/ventilator power control cable and the mounting rod to the CNF4, as shown in FIGURE B-7.

FIGURE B-7. Connecting the CNF4 power control cable and the mounting rod

B.3 Wiring

The following table shows the recommended datalogger wiring for using the CNR4 sensor with the CNF4 heater/ventilator while making the differential measurement.

TABLE B-1. CR1000 and CR3000 Datalogger Connections for Differential Measurement with Heater/Ventilator Control

Function	Wire Color	CR1000	CR3000
Pyranometer Up Signal	Red	Differential Input (H)	Differential Input (H)
Pyranometer Up Reference	*Blue	Differential Input (L)	Differential Input (L)
Pyranometer Down Signal	White	Differential Input (H)	Differential Input (H)
Pyranometer Down Reference	*Black	Differential Input (L)	Differential Input (L)
Pyrgeometer Up Signal	Grey	Differential Input (H)	Differential Input (H)
Pyrgeometer Up Reference	*Yellow	Differential Input (L)	Differential Input (L)
Pyrgeometer Down Signal	Brown	Differential Input (H)	Differential Input (H)
Pyrgeometer Down Reference	*Green	Differential Input (L)	Differential Input (L)
Shield	Clear	⏚	⏚
Thermistor			
Thermistor Signal	White	Single-Ended Input	Single-Ended Input
Thermistor Voltage Excitation	Red	Voltage Excitation (VX)	Voltage Excitation (VX)
Thermistor Signal Reference	Black	⏚	⏚
Shield	Clear	⏚	⏚
CNF4 Heater/Ventilator			
Ventilator Power	Red	SW12V	SW12V-1
Ventilator Ground	Blue	G	G
Heater Power	Green	SW12V	SW12V-2
Heater Ground	Yellow	G	G
Shield	Clear	⏚	⏚

*Jumper to ⏚ with user supplied wire

Pull back wires for Pt-100 (grey, brown, green, and yellow), which are not in use, and tie them around the TEMP cable using a cable tie or electrical tape to avoid possible damage to the Pt-100, due to electrical short circuit.

CAUTION Do not use the SW12 channel of a CR1000 or CR3000 to simultaneously power the heater and ventilator. Simultaneously powering the heater and ventilator will exceed the current limit of the SW12 channel. If the heater and ventilator need to be used at the same time, connect the CNF4 to the 12V channel instead of the SW12 channel and use an external relay to switch the power on and off. Refer to Section 4.1 of the CR1000 and CR3000 manual for details on the 12V current source limits.

B.4 Example B, CR3000 Datalogger Program with Heater/Ventilator Control

Example B measures the four radiation outputs, thermistor temperature, and controls the ventilator and heater using SW12V-1 and SW12V-2 channels on the CR3000, respectively. In this example program, the ventilator and heater can be turned on or off by manually setting the flag(1) and flag(2) high or low, respectively. The program can be modified to include the conditional statements to control the heater and ventilator based upon the environmental parameters, such as light level and dew point temperature.

CAUTION Do not use the SW12 channel of a CR1000 or CR3000 to simultaneously power the heater and ventilator. Simultaneously powering the heater and ventilator will exceed the current limit of the SW12 channel. If the heater and ventilator need to be used at the same time, connect the CNF4 to the 12V channel instead of the SW12 channel and use an external relay to switch the power on and off. Refer to Section 4.1 of the CR1000 and CR3000 manual for details on the 12V current source limits.

```
'CR3000 Series Datalogger
'
'CNR4 program
'This program measures CNR4 four-component net radiometer
'This program also measures the thermistor inside the CNR4
'In addition this program controls heater and ventilator
'  using separate SW12V-1 and SW12V-2 channels
'The heater and ventilator are turned on/off by setting flag(1), and flag(2) high and low, respectively.
'
'
'User must enter the sensitivity values for all four probes in the program and save/compile
'prior to downloading it to the datalogger.
'Search for the text string "unique" to find places to enter the sensitivity values.
'

'Wiring Instructions
'
'ANALOG CHANNELS
'1H      CNR4 Pyranometer Upper signal (red)
'1L      CNR4 Pyranometer Upper signal reference (blue)
'gnd     jumper to 1L
'
'2H      CNR4 Pyranometer Lower signal (white)
'2L      CNR4 Pyranometer Lower signal reference (thin black)
'gnd     jumper to 2L
'
'3H      CNR4 Pyrgeometer Upper signal (grey)
'3L      CNR4 Pyrgeometer Upper signal reference (yellow)
'gnd     jumper to 3L
'
'4H      CNR4 Pyrgeometer Lower signal (brown)
'4L      CNR4 Pyrgeometer Lower signal reference (green)
'gnd     jumper to 4L
'        CNR4 shield (clear)
'
'
```

```
'8H
'8L      CNR4 thermistor signal (white)
'gnd     CNR4 thermistor signal reference (black)
'        CNR4 thermistor shield (clear)
'

'VOLTAGE EXCITATION
'
'VX1      CNR4 thermistor voltage excitation (red)
'

'POWER OUT
'SW12V-1    CNF4 ventilator + (red)
'
'SW12V-2    CNF4 heater + (green)
'
'G                  CNF4 ventilator - (blue)
'                     CNF4 heater - (yellow)
'
'gnd     ventilator & heater shield (clear)

PipeLineMode

'CNR4 sensor
Public logger_temp, batt_volt
Public flag(2) As Boolean
Public cnr4(4)
Alias cnr4(1) = short_up
Alias cnr4(2) = short_dn
Alias cnr4(3) = long_up
Alias cnr4(4) = long_dn

Public cnr4_T_C       'CNR4 thermistor temperature in Celcius
Public cnr4_T_K       'CNR4 thermistor temperature in Kelvin
Public long_up_corr   'Downwelling long-wave radiation with temperature correction
Public long_dn_corr   'Upwelling long-wave radiation with temperature correction
Public Rs_net         'short-wave net radiation
Public Rl_net         'long-wave net radiation
Public albedo         'Albedo
Public Rn             'total net radiation

Units logger_temp = degC
Units batt_volt = volts
Units short_up = W/m^2
Units short_dn = W/m^2
Units long_up = W/m^2
Units long_dn = W/m^2
Units cnr4_T_C = deg_C
Units cnr4_T_K = K
Units long_up_corr = W/m^2
Units long_dn_corr = W/m^2
Units Rs_net = W/m^2
Units Rl_net = W/m^2
Units albedo = W/m^2
Units Rn = W/m^2

Dim Rs, Vs_Vx

'CNR4 sensitivities: refer to the Certificate of Calibration from Kipp & Zonen for sensitivity values
'for each probes, and enter them below.
Const pyranometer_up_sensitivity = 15.35   'unique sensitivity for upper pyranometer
                                           '(microV/W/m^2)
Const pyranometer_dn_sensitivity = 15.41   'unique sensitivity for lower pyranometer
                                           '(microV/W/m^2)
Const pyrgeometer_up_sensitivity = 8.50    'unique sensitivity for upper pyrgeometer
                                           '(microV/W/m^2)
Const pyrgeometer_dn_sensitivity = 7.09    'unique sensitivity for lower pyrgeometer
                                           '(microV/W/m^2)
```

```
'CNR4 multipliers
Public cnr4_mult(4)
Const pyranometer_up_mult = 1000/pyranometer_up_sensitivity     '(W/m^2/mV)
Const pyranometer_dn_mult = 1000/pyranometer_dn_sensitivity     '(W/m^2/mV)
Const pyrgeometer_up_mult = 1000/pyrgeometer_up_sensitivity     '(W/m^2/mV)
Const pyrgeometer_dn_mult = 1000/pyrgeometer_dn_sensitivity     '(W/m^2/mV)

DataTable (cnr4_data,True,-1)
  DataInterval (0,60,Min,10)
    CardOut (1,-1)
  Minimum (1,batt_volt,FP2,0,False)
  Sample (1,logger_temp,FP2)
  Average (4,cnr4(1),IEEE4,False)
  Average (1,cnr4_T_C,IEEE4,False)
  Average (1,cnr4_T_K,IEEE4,False)
  Average (1,long_up_corr,IEEE4,False)
  Average (1,long_dn_corr,IEEE4,False)
  Average (1,Rs_net,IEEE4,False)
  Average (1,Rl_net,IEEE4,False)
  Average (1,albedo,IEEE4,False)
  Average (1,Rn,IEEE4,False)
EndTable

DataTable (cnr4_ts,True,-1)
  DataInterval (0,1,Sec,10)
    CardOut (1,-1)
  Sample (4,cnr4(1),IEEE4)
  Sample (1,cnr4_T_K,IEEE4)
EndTable

BeginProg
'Load the multiplier values for the CNR4
            cnr4_mult(1) = pyranometer_up_mult
            cnr4_mult(2) = pyranometer_dn_mult
            cnr4_mult(3) = pyrgeometer_up_mult
            cnr4_mult(4) = pyrgeometer_dn_mult

  Scan (1,Sec,3,0)
    PanelTemp (logger_temp,250)
    Battery (batt_volt)

'CNR4 radiation measurements
        VoltDiff (cnr4(),4,mV20C,1,True ,0,_60Hz,cnr4_mult(),0)

'CNR4 thermistor measurement
        BrHalf (Vs_Vx,1,mv5000,16,Vx1,1,2500,True ,0,250,1.0,0)
            Rs = 1000*(Vs_Vx/(1-Vs_Vx))
              cnr4_T_C = 1/(1.0295e-3+2.391e-4*LN(Rs)+1.568e-7*(LN(Rs))^3)-273.15

'Convert CNR4 temperature to Kelvin
              cnr4_T_K = cnr4_T_C+273.15

'Correct the long-wave radiation values from pyrgeometers
              long_up_corr = long_up+5.67e-8*cnr4_T_K^4
              long_dn_corr = long_dn+5.67e-8*cnr4_T_K^4

'Compute short-wave net radiation
              Rs_net = short_up - short_dn

'Compute long-wave net radiation
              Rl_net = long_up - long_dn

'Compute albedo
              albedo = short_dn/short_up
```

```
'Compute net radiation
              Rn = Rs_net + Rl_net

'CNF4 ventilator control - the ventilator will be turned on when flag(1) is set high
          SW12 (1,flag(1))

'CNF4 heater control - the heater will be turned on when flag(2) is set high
          SW12 (2,flag(2))

    CallTable cnr4_data
    CallTable cnr4_ts

  NextScan
EndProg
```

B.5 CNF4 Heater/Ventilator Maintenance

B.5.1 Testing the Heater

The optional CNF4 consists of a heater and a ventilator. To check the heater unit, measure the resistance between the two heater wires (green and yellow). The resistance value of the heating resistor inside should be around 15 Ω (cable resistance should add about 0.026 Ω per each foot of cable). An infinite resistance reading indicates the likelihood of a broken wire, or cable.

B.5.2 Testing the Ventilator

To check the ventilator, first measure the impedance of the ventilator motor. The value should be around 30 Ω (cable resistance should add about 0.026 Ω per each foot of cable). If the correct resistance value is measured, but the ventilator still mal-functions, it is possible that the ventilator is stalled by an object blocking the fan. Remove the black cover at the bottom side of the ventilator unit, by prying it open with a small flat-head screw driver or by pulling it straight out. Inspect the fan inside for any object that might impede the fan's rotation. Upon completing the inspection, put the filter and the cover back in place.

B.5.3 Replacing the Filter for the Ventilator

The filter needs to be checked for every 6 to 12 months. Remove the black cover at the bottom side of the ventilator by prying it open with a small flat-head screw driver or by pulling it straight out. Inspect the filter for dust and particles that might impede the air flow into the ventilator. The filter can be cleaned with warm clean water, or can be replaced with the new one. You can purchase the replacement filters, pn 26010, from Campbell Scientific.

Appendix C. CR3000 Program for Measuring Pt-100 Temperature Sensor

Example C measures the Pt-100 sensor for the body temperature of the CNR4. This program requires four differential channels to measure the four radiation outputs, one current excitation channel, and one differential channel for Pt-100 measurement. The program measures the sensors every 1 second, performs the online processing of the data, and stores the following processed data to a data table called cnr4_data once every 60 minutes. It also stores the raw time-series data from CNR4 to data table called cnr4_ts.

Minimum battery voltage
Sample datalogger panel temperature
Average short-wave radiation (pyranometer up)
Average short-wave radiation (pyranometer down)
Average long-wave radiation (pyrgeometer up)
Average long-wave radiation (pyrgeometer down)
Average CNR4 thermistor temperature (degrees C)
Average CNR4 thermistor temperature (Kelvin)
Average corrected long-wave radiation (pyrgeometer up)
Average corrected long-wave radiation (pyrgeometer down)
Average short-wave net radiation
Average long-wave net radiation
Average albedo
Average net radiation

TABLE C-1. Datalogger Connections for Differential Measurement with Pt-100

Function	Wire Color	CR3000/CR5000
Pyranometer Up Signal	Red	Differential Input (H)
Pyranometer Up Reference	*Blue	Differential Input (L)
Pyranometer Down Signal	White	Differential Input (H)
Pyranometer Down Reference	*Black	Differential Input (L)
Pyrgeometer Up Signal	Grey	Differential Input (H)
Pyrgeometer Up Reference	*Yellow	Differential Input (L)
Pyrgeometer Down Signal	Brown	Differential Input (H)
Pyrgeometer Down Reference	*Green	Differential Input (L)
Shield	Clear	⏚
PRT (Pt-100) Current Excitation	Grey	Current Excitation (IX)
PRT (Pt-100) Current Return	Brown	Current Excitation Return (IXR)
PRT (Pt-100) Signal	Green	Differential Input (H)
PRT (Pt-100) Signal Reference	Yellow	Differential Input (L)
Shield	Clear	⏚

*Pull back wires for thermistor (white, red, and black), which are not in use, and tie them around the TEMP cable using a cable tie or electrical tape to avoid possible damage to the thermistor, due to electrical short circuit.

```
'CR3000 Series Datalogger
'
'CNR4 program
'This program measures CNR4 four-component net radiometer
'This program also measures the Pt-100 sensor inside the CNR4
'
'User must enter the sensitivity values for all four probes in the program and
save/compile
'prior to downloading it to the datalogger.
'Search for the text string "unique" to find places to enter the sensitivity values.
'

'Wiring Instructions
'
'ANALOG CHANNELS
'1H      CNR4 Pyranometer Upper signal (red)
'1L      CNR4 Pyranometer Upper signal reference (blue)
'gnd     jumper to 1L
'
'2H      CNR4 Pyranometer Lower signal (white)
'2L      CNR4 Pyranometer Lower signal reference (thin black)
'gnd     jumnper to 2L
'
'3H      CNR4 Pyrgeometer Upper signal (grey)
'3L      CNR4 Pyrgeometer Upper signal reference (yellow)
'gnd     jumper to 3L
'
'4H      CNR4 Pyrgeometer Lower signal (brown)
'4L      CNR4 Pyrgeometer Lower signal reference (green)
'gnd     jumper to 4L
'        CNR4 shield (clear)
'
'
'8H      CNR4 PRT (Pt-100) signal (green)
'8L      CNR4 PRT (Pt-100) signal reference (yellow)
'gnd     CNR4 PRT (Pt-100) shield (clear)
'

'CURRENT EXCITATION
'IX1     CNR4 PRT (Pt-100) current excitation (grey)
'
'IXR     CNR4 PRT (Pt-100) current excitation return (brown)
'

'CNR4 sensor
Public logger_temp, batt_volt
Public cnr4(4)
Alias cnr4(1) = short_up
Alias cnr4(2) = short_dn
Alias cnr4(3) = long_up
Alias cnr4(4) = long_dn

Public cnr4_T_C       'CNR4 thermistor temperature in Celcius
Public cnr4_T_K       'CNR4 thermistor temperature in Kelvin
Public long_up_corr   'Downwelling long-wave radiation with temperature correction
Public long_dn_corr   'Upwelling long-wave radiation with temperature correction
Public Rs_net         'short-wave net radiation
Public Rl_net         'long-wave net radiation
Public albedo         'Albedo
Public Rn             'total net radiation

Units logger_temp = degC
Units batt_volt = volts
Units short_up = W/m^2
Units short_dn = W/m^2
Units long_up = W/m^2
Units long_dn = W/m^2
Units cnr4_T_C = deg_C
```

```
Units cnr4_T_K = K
Units long_up_corr = W/m^2
Units long_dn_corr = W/m^2
Units Rs_net = W/m^2
Units Rl_net = W/m^2
Units albedo = W/m^2
Units Rn = W/m^2

Dim cnr4_prt_R, Rs_R0

'CNR4 sensitivities: refer to the Certificate of Calibration from Kipp & Zonen for sensitivity values
'for each probes, and enter them below.
Const pyranometer_up_sensitivity = 15.35   'unique sensitivity for upper pyranometer
                                           '(microV/W/m^2)
Const pyranometer_dn_sensitivity = 15.41   'unique sensitivity for lower pyranometer
                                           '(microV/W/m^2)
Const pyrgeometer_up_sensitivity = 8.50    'unique sensitivity for upper pyrgeometer
                                           '(microV/W/m^2)
Const pyrgeometer_dn_sensitivity = 7.09    'unique sensitivity for lower pyrgeometer
                                           '(microV/W/m^2)

'CNR4 multipliers
Public cnr4_mult(4)
Const pyranometer_up_mult = 1000/pyranometer_up_sensitivity     '(W/m^2/mV)
Const pyranometer_dn_mult = 1000/pyranometer_dn_sensitivity     '(W/m^2/mV)
Const pyrgeometer_up_mult = 1000/pyrgeometer_up_sensitivity     '(W/m^2/mV)
Const pyrgeometer_dn_mult = 1000/pyrgeometer_dn_sensitivity     '(W/m^2/mV)

DataTable (cnr4_data,True,-1)
  DataInterval (0,60,Min,10)
    CardOut (1,-1)
  Minimum (1,batt_volt,FP2,0,False)
  Sample (1,logger_temp,FP2)
  Average (4,cnr4(1),IEEE4,False)
  Average (1,cnr4_T_C,IEEE4,False)
  Average (1,cnr4_T_K,IEEE4,False)
  Average (1,long_up_corr,IEEE4,False)
  Average (1,long_dn_corr,IEEE4,False)
  Average (1,Rs_net,IEEE4,False)
  Average (1,Rl_net,IEEE4,False)
  Average (1,albedo,IEEE4,False)
  Average (1,Rn,IEEE4,False)
EndTable

DataTable (cnr4_ts,True,-1)
  DataInterval (0,1,Sec,10)
    CardOut (1,-1)
  Sample (4,cnr4(1),IEEE4)
  Sample (1,cnr4_T_K,IEEE4)
EndTable

BeginProg
'Load the multiplier values for the CNR4
            cnr4_mult(1) = pyranometer_up_mult
            cnr4_mult(2) = pyranometer_dn_mult
            cnr4_mult(3) = pyrgeometer_up_mult
            cnr4_mult(4) = pyrgeometer_dn_mult

  Scan (1,Sec,3,0)
    PanelTemp (logger_temp,250)
    Battery (batt_volt)

'CNR4 radiation measurements
        VoltDiff (cnr4(),4,mV20C,1,True ,0,_60Hz,cnr4_mult(),0)
```

```
'PRT (Pt-100) temperature measurement
          Resistance (cnr4_prt_R,1,mV200,8,Ix1,1,1500,True,True,0,_60Hz,1,0)
            Rs_R0 = cnr4_prt_R/100
        PRT (cnr4_T_C,1,Rs_R0,1,0)

'Convert CNR4 temperature to Kelvin
              cnr4_T_K = cnr4_T_C+273.15

'Correct the long-wave radiation values from pyrgeometers
              long_up_corr = long_up+5.67e-8*cnr4_T_K^4
              long_dn_corr = long_dn+5.67e-8*cnr4_T_K^4

'Compute short-wave net radiation
              Rs_net = short_up - short_dn

'Compute long-wave net radiation
              Rl_net = long_up - long_dn

'Compute albedo
              albedo = short_dn/short_up

'Compute net radiation
              Rn = Rs_net + Rl_net

    CallTable cnr4_data
    CallTable cnr4_ts

  NextScan
EndProg
```

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