METEOROLOGICAL INSTRUMENTS

YOUNG

INSTRUCTIONS

WIND MONITOR
MODEL 05103

CE

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PN: 05103-90
REV: L060915

MODEL 05103
WIND MONITOR

WIND SPEED SPECIFICATION SUMMARY

Range	0 to 100 m/s (224 mph)
Sensor	18 cm diameter 4-blade helicoid propeller molded of polypropylene
Pitch	29.4 cm air passage per revolution
Distance Constant	2.7 m (8.9 ft.) for 63% recovery
Threshold Sensitivity	1.0 m/s (2.2 mph)
Transducer	Centrally mounted stationary coil, 2K Ohm nominal DC resistance
Transducer Output	AC sine wave signal induced by rotating magnet on propeller shaft. 80 mV p-p at 100 rpm. 8.0 V p-p at 10,000 rpm.
Output Frequency	3 cycles per propeller revolution (0.098 m/s per Hz)

WIND DIRECTION (AZIMUTH) SPECIFICATION SUMMARY

Range	360° mechanical, 355° electrical (5° open)
Sensor	Balanced vane, 38 cm (15 in) turning radius.
Damping Ratio	0.3
Delay Distance	1.3 m (4.3 ft) for 50% recovery
Threshold Sensitivity	1.1 m/s (2.5 mph) at 10° displacement
Damped Natural Wavelength	7.4 m (24.3 ft)
Undamped Natural Wavelength	7.2 m (23.6 ft)
Transducer	Precision conductive plastic potentiometer, 10K ohm resistance (±20%), 0.25% linearity, life expectancy 50 million revolutions, rated 1 watt at 40° C, 0 watts at 125° C
Transducer Excitation Requirement	Regulated DC voltage, 15 VDC max
Transducer Output	Analog DC voltage proportional to azimuth angle with regulated excitation voltage applied across potentiometer.

GENERAL

Operating Temperature: -50 to 50°C (-58 to 122°F)

INTRODUCTION

The Wind Monitor measures horizontal wind speed and direction. Originally developed for ocean data buoy use, it is rugged and corrosion resistant yet accurate and light weight. The main housing, nose cone, propeller, and other internal parts are injection molded U.V. stabilized plastic. Both the propeller and vertical shafts use stainless steel precision grade ball bearings. Bearings have light contacting teflon seals and are filled with a wide temperature range grease to help exclude contamination and moisture.

Propeller rotation produces an AC sine wave signal with frequency proportional to wind speed. This AC signal is induced in a stationary coil by a six pole magnet mounted on the propeller shaft. Three complete sine wave cycles are produced for each propeller revolution.

Vane position is transmitted by a 10K ohm precision conductive plastic potentiometer which requires a regulated excitation voltage. With a constant voltage applied to the potentiometer, the output signal is an analog voltage directly proportional to wind direction angle.

The instrument mounts on standard one inch pipe, outside diameter 34 mm (1.34"). An orientation ring is provided so the instrument can be removed for maintenance and reinstalled without loss of wind direction reference. Both the mounting post assembly and the orientation ring are secured to the mounting pipe by stainless steel band clamps. Electrical connections are made in a junction box at the base. A variety of devices are available for signal conditioning, display, and recording of wind speed and direction.

INITIAL CHECKOUT

When the Wind Monitor is unpacked it should be checked carefully for any signs of shipping damage.

Remove the plastic nut on the propeller shaft. Install the propeller on the shaft so the serial number on the propeller faces forward (into the wind). Engage the propeller into the molded ribs on the propeller shaft hub. The instrument is aligned, balanced and fully calibrated before shipment, however, it should be checked both mechanically and electrically before installation. The vane and propeller should easily rotate 360° without friction. Check vane balance by holding the instrument base so the vane surface is horizontal. It should have near neutral torque without any particular tendency to rotate. A slight imbalance will not degrade performance.

The potentiometer requires a stable DC excitation voltage. Do not exceed 15 volts. When the potentiometer wiper is in the 5° deadband region, the output signal is "floating" and may show varying or unpredictable values. To prevent false readings, signal conditioning electronics should clamp the signal to excitation or reference level when this occurs. **NOTE: Young signal conditioning devices clamp the signal to excitation level.** Avoid a short circuit between the wind direction signal line and either the excitation or reference lines. Although there is a 1K ohm current limiting resistor in series with the wiper for protection, damage to the potentiometer may occur if a short circuit condition exists.

Before installation, connect the instrument to an indicator as shown in the wiring diagram and check for proper wind speed and wind direction values. To check wind speed, temporarily remove the propeller and connect the shaft to an Anemometer Drive. Details appear in the CALIBRATION section of this manual.

INSTALLATION

Proper placement of the instrument is very important. Eddies from trees, buildings, or other structures can greatly influence wind speed and wind direction observations. To get meaningful data for most applications locate the instrument well above or upwind from obstructions. As a general rule, the air flow around a structure is disturbed to twice the height of the structure upwind, six times the height downwind, and up to twice the height of the structure above ground. For some applications it may not be practical or necessary to meet these requirements.

FAILURE TO PROPERLY GROUND THE WIND MONITOR MAY RESULT IN ERRONEOUS SIGNALS OR TRANSDUCER DAMAGE.

Grounding the Wind Monitor is vitally important. Without proper grounding, static electrical charge can build up during certain atmospheric conditions and discharge through the transducers. This discharge can cause erroneous signals or transducer failure. To direct the discharge away from the transducers, the mounting post assembly is made with a special antistatic plastic. It is very important that the mounting post be connected to a good earth ground. There are two ways this may be accomplished. First, the Wind Monitor may be mounted on a metal pipe which is connected to earth ground. The mounting pipe should not be painted where the Wind Monitor is mounted. Towers or masts set in concrete should be connected to one or more grounding rods. If it is difficult to ground the mounting post in this manner, the following method should be used. Inside the junction box the terminal labeled EARTH GND is internally connected to the antistatic mounting post. This terminal should be connected to an earth ground (Refer to wiring diagram).

Initial installation is most easily done with two people; one to adjust the instrument position and the other to observe the indicating device. After initial installation, the instrument can be removed and returned to its mounting without realigning the vane since the orientation ring preserves the wind direction reference. Install the Wind Monitor following these steps:

1. MOUNT WIND MONITOR
   a) Place orientation ring on mounting post. Do Not tighten band clamp yet.
   b) Place Wind Monitor on mounting post. Do Not tighten band clamp yet.

2. CONNECT SENSOR CABLE
   a) Refer to wiring diagram located at back of manual.

3. ALIGN VANE
   a) Connect instrument to an indicator.
   b) Choose a known wind direction reference point on the horizon.
   c) Sighting down instrument centerline, point nose cone at reference point on horizon.
   d) While holding vane in position, slowly turn base until indicator shows proper value.
   e) Tighten mounting post band clamp.
   f) Engage orientation ring indexing pin in notch at instrument base.
   g) Tighten orientation ring band clamp.

CALIBRATION

The Wind Monitor is fully calibrated before shipment and should require no adjustments. Recalibration may be necessary after some maintenance operations. Periodic calibration checks are desirable and may be necessary where the instrument is used in programs which require auditing of sensor performance.

Accurate wind direction calibration requires a Model 18112 Vane Angle Bench Stand. Begin by connecting the instrument to a signal conditioning circuit which has some method of indicating wind direction value. This may be a display which shows wind direction values in angular degrees or simply a voltmeter monitoring the output. Orient the base so the junction box faces due south. Visually align the vane with the crossmarkings and observe the indicator output. If the vane position and indicator do not agree within 5°, adjust the potentiometer coupling inside the main housing. Details for making this adjustment appear in the MAINTENANCE, POTENTIOMETER REPLACEMENT, outline, step 7.

It is important to note that, while the sensor mechanically rotates through 360°, the full scale wind direction signal from the signal conditioning occurs at 355°. The signal conditioning electronics must be adjusted accordingly. For example, in a circuit where 0 to 1.000 VDC represents 0° to 360°, the output must be adjusted for 0.986 VDC when the instrument is at 355°. (355°/360° X 1.000 volts = 0.986 volts)

Wind speed calibration is determined by propeller pitch and the output characteristics of the transducer. Calibration formulas showing wind speed vs. propeller rpm and output frequency are included below. Standard accuracy is ± 0.3 m/s (0.6mph). For greater accuracy, the sensor must be individually calibrated in comparison with a wind speed standard. Contact the factory or your supplier to schedule a NIST (National Institute of Standards & Technology) traceable wind tunnel calibration in our facility.

To calibrate wind system electronics using a signal from the instrument, temporarily remove the propeller and connect an Anemometer Drive (18802 or equivalent) to the propeller shaft. Apply the appropriate calibration formula to the calibrating motor rpm and adjust the electronics for the proper value. For example, with the propeller shaft turning at 3600 rpm, adjust an indicator to display 17.6 meters per second [3600 rpm X 0.00490 (m/s)/rpm =17.6 m/s]

Details on checking bearing torque, which affects wind speed and direction threshold, appear in the following section.

CALIBRATION FORMULAS

Model 05103 Wind Monitor w / 08234 Propeller

WIND SPEED vs PROPELLER RPM

m/s	=	0.00490 x rpm
knots	=	0.00952 x rpm
mph	=	0.01096 x rpm
km/h	=	0.01764 x rpm

WIND SPEED vs OUTPUT FREQUENCY

m/s	=	0.0980 x Hz
knots	=	0.1904 x Hz
mph	=	0.2192 x Hz
km/h	=	0.3528 x Hz

MAINTENANCE

Given proper care, the Wind Monitor should provide years of service. The only components likely to need replacement due to normal wear are the precision ball bearings and the wind direction potentiometer. Only a qualified instrument technician should perform the replacement. If service facilities are not available, return the instrument to the company. Refer to the drawings to become familiar with part names and locations. The asterisk * which appears in the following outlines is a reminder that maximum torque on all set screws is 80 oz-in.

POTENTIOMETER REPLACEMENT

The potentiometer has a life expectancy of fifty million revolutions. As it becomes worn, the element may begin to produce noisy signals or become nonlinear. When signal noise or non-linearity becomes unacceptable, replace the potentiometer. Refer to exploded view drawing and proceed as follows:

1. REMOVE MAIN HOUSING
   a) Unscrew nose cone from main housing. Set o-ring aside for later use.
   b) Gently push main housing latch.
   c) While pushing latch, lift main housing up and remove it from vertical shaft bearing rotor.

2. UNSOLDER TRANSDUCER WIRE
   a) Remove junction box cover, exposing circuit board.
   b) Remove screws holding circuit board.
   c) Unsolder three potentiometer wires (white, green, black), two wind speed coil wires (red, black) and earth ground wire (red) from board.

3. REMOVE POTENTIOMETER
   a) Loosen set screw on potentiometer coupling and remove it from potentiometer adjust thumbwheel.
   b) Loosen set screw on potentiometer adjust thumbwheel and remove it from potentiometer shaft.
   c) Loosen two set screws at base of transducer assembly and remove assembly from vertical shaft.
   d) Unscrew potentiometer housing from potentiometer mounting & coil assembly.
   e) Push potentiometer out of potentiometer mounting & coil assembly by applying firm but gentle pressure on potentiometer shaft. Make sure that the shaft o-ring comes out with the potentiometer. If not, then gently push it out from the top of the coil assembly.

4. INSTALL NEW POTENTIOMETER
   a) Push new potentiometer into potentiometer mounting & coil assembly making sure o-ring is on shaft.
   b) Feed potentiometer and coil wires through hole in bottom of potentiometer housing.
   c) Screw potentiometer housing onto potentiometer mounting & coil assembly.
   d) Gently pull transducer wires through bottom of potentiometer housing to take up any slack. Apply a small amount of silicone sealant around hole.
   e) Install transducer assembly on vertical shaft allowing 0.5 mm (0.020") clearance from vertical bearing. Tighten set screws* at bottom of transducer assembly.
   f) Place potentiometer adjust thumbwheel on potentiometer shaft and tighten set screw*.
   g) Place potentiometer coupling on potentiometer adjust thumbwheel. Do Not tighten set screw yet.

5. RECONNECT TRANSDUCER WIRES
   a) Using needle-nose pliers or a paper clip bent to form a small hook, gently pull transducer wires through hole in junction box.
   b) Solder wires to circuit board according to wiring diagram. Observe color code.
   c) Secure circuit board in junction box using two screws removed in step 2b. Do not overtighten.

6. REPLACE MAIN HOUSING
   a) Place main housing over vertical shaft bearing rotor. Be careful to align indexing key and channel in these two assemblies.
   b) Place main housing over vertical shaft bearing rotor until potentiometer coupling is near top of main housing.
   c) Turn potentiometer adjust thumbwheel until potentiometer coupling is oriented to engage ridge in top of main housing. Set screw on potentiometer coupling should be facing the front opening.
   d) With potentiometer coupling properly oriented, continue pushing main housing onto vertical shaft bearing rotor until main housing latch locks into position with a “click”.

7. ALIGN VANE
   a) Connect excitation voltage and signal conditioning electronics to terminal strip according to wiring diagram.
   b) With mounting post held in position so junction box is facing due south, orient vane to a known angular reference. Details appear in CALIBRATION section.
   c) Reach in through front of main housing and turn potentiometer adjust thumbwheel until signal conditioning system indicates proper value.
   d) Tighten set screw* on potentiometer coupling.

8. REPLACE NOSE CONE
   a) Screw nose cone into main housing until o-ring seal is seated. Be certain threads are properly engaged to avoid cross-threading.

FLANGE BEARING REPLACEMENT

If anemometer bearings become noisy or wind speed threshold increases above an acceptable level, bearings may need replacement. Check anemometer bearing condition using a Model 18310 Propeller Torque Disc. If needed, bearings are replaced as follows.

1. REMOVE OLD BEARINGS
   a) Unscrew nose cone. Set o-ring aside for later use.
   b) Loosen set screw on magnet shaft collar and remove magnet.
   c) Slide propeller shaft out of nose cone assembly.
   d) Remove front bearing cap which covers front bearing.
   e) Remove both front and rear bearings from nose cone assembly. Insert edge of a pocket knife under bearing flange and lift it out.

2. INSTALL NEW BEARINGS
   a) Insert new front and rear bearings into nose cone.
   b) Replace front bearing cap.
   c) Carefully slide propeller shaft thru bearings.
   d) Place magnet on propeller shaft allowing 0.5 mm (0.020") clearance from rear bearing.
   e) Tighten set screw* on magnet shaft collar.
   f) Screw nose cone into main housing until o-ring seal is seated. Be certain threads are properly engaged to avoid cross-threading.

*Max set screw torque 80 oz-in

VERTICAL SHAFT BEARING REPLACEMENT

Vertical shaft bearings are much larger than the anemometer bearings. Ordinarily, these bearings require replacement less frequently than anemometer bearings. Check bearing condition using a Model 18331 Vane Torque Gauge.

Since this procedure is similar to POTENTIOMETER REPLACEMENT, only the major steps are listed here.

1. REMOVE MAIN HOUSING
2. UNSOLDER TRANSDUCER WIRES AND REMOVE TRANSDUCER ASSEMBLY
   Loosen set screws at base of transducer assembly and remove entire assembly from vertical shaft.
3. REMOVE VERTICAL SHAFT BEARING ROTOR by sliding it upward off vertical shaft.
4. REMOVE OLD VERTICAL BEARINGS AND INSTALL NEW BEARINGS. When inserting new bearings, be careful not to apply pressure to bearing shields.
5. REPLACE VERTICAL SHAFT BEARING ROTOR.
6. REPLACE TRANSDUCER & RECONNECT WIRES
7. REPLACE MAIN HOUSING
8. ALIGN VANE
9. REPLACE NOSE CONE

WARRANTY

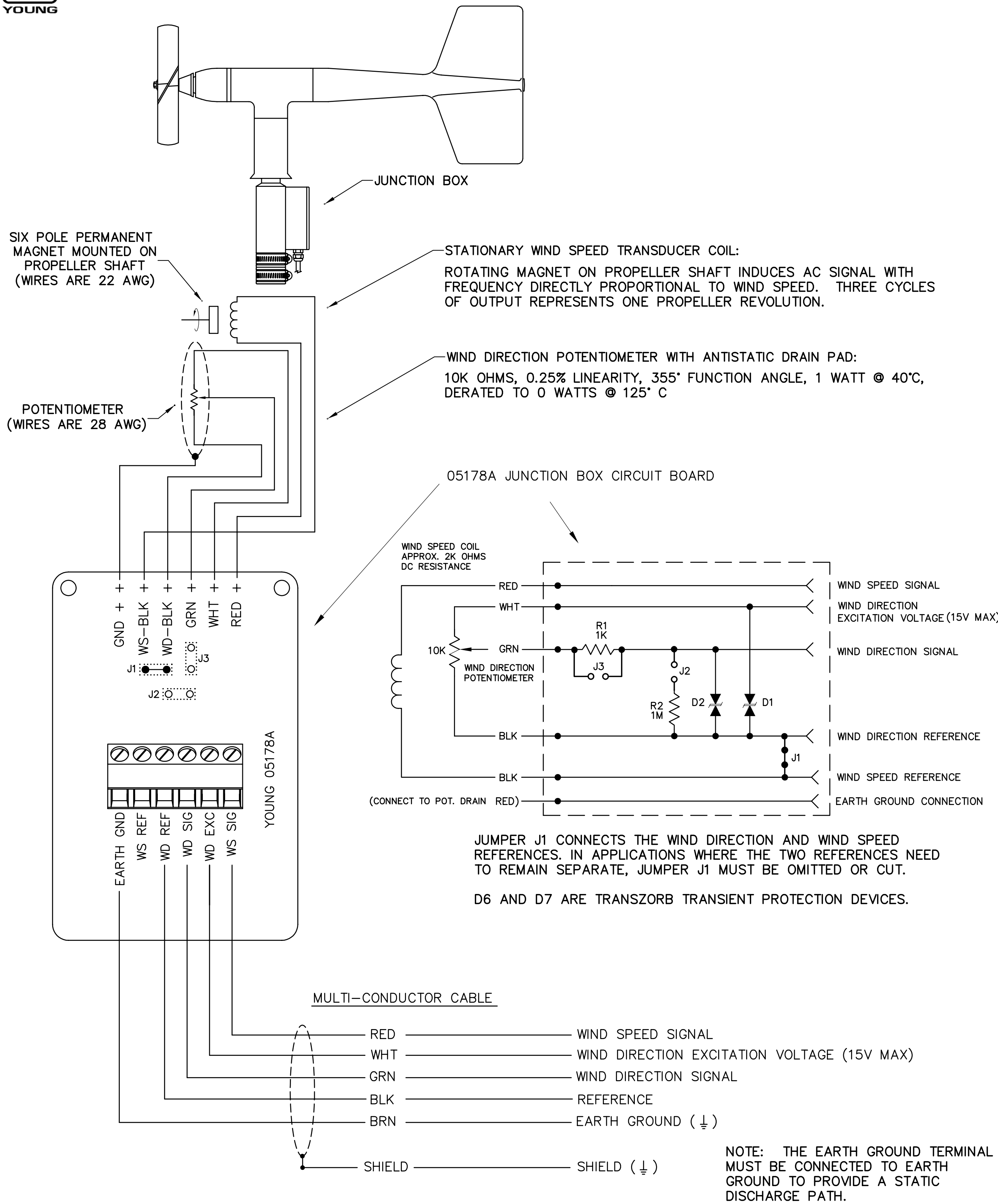
This product is warranted to be free of defects in materials and construction for a period of 12 months from date of initial purchase. Liability is limited to repair or replacement of defective item. A copy of the warranty policy may be obtained from R. M. Young Company.

CE COMPLIANCE

This product has been tested and complies with European CE requirements for the EMC Directive. Please note that shielded cable must be used.

CABLE & WIRING DIAGRAM

MODEL 05103 WIND MONITOR



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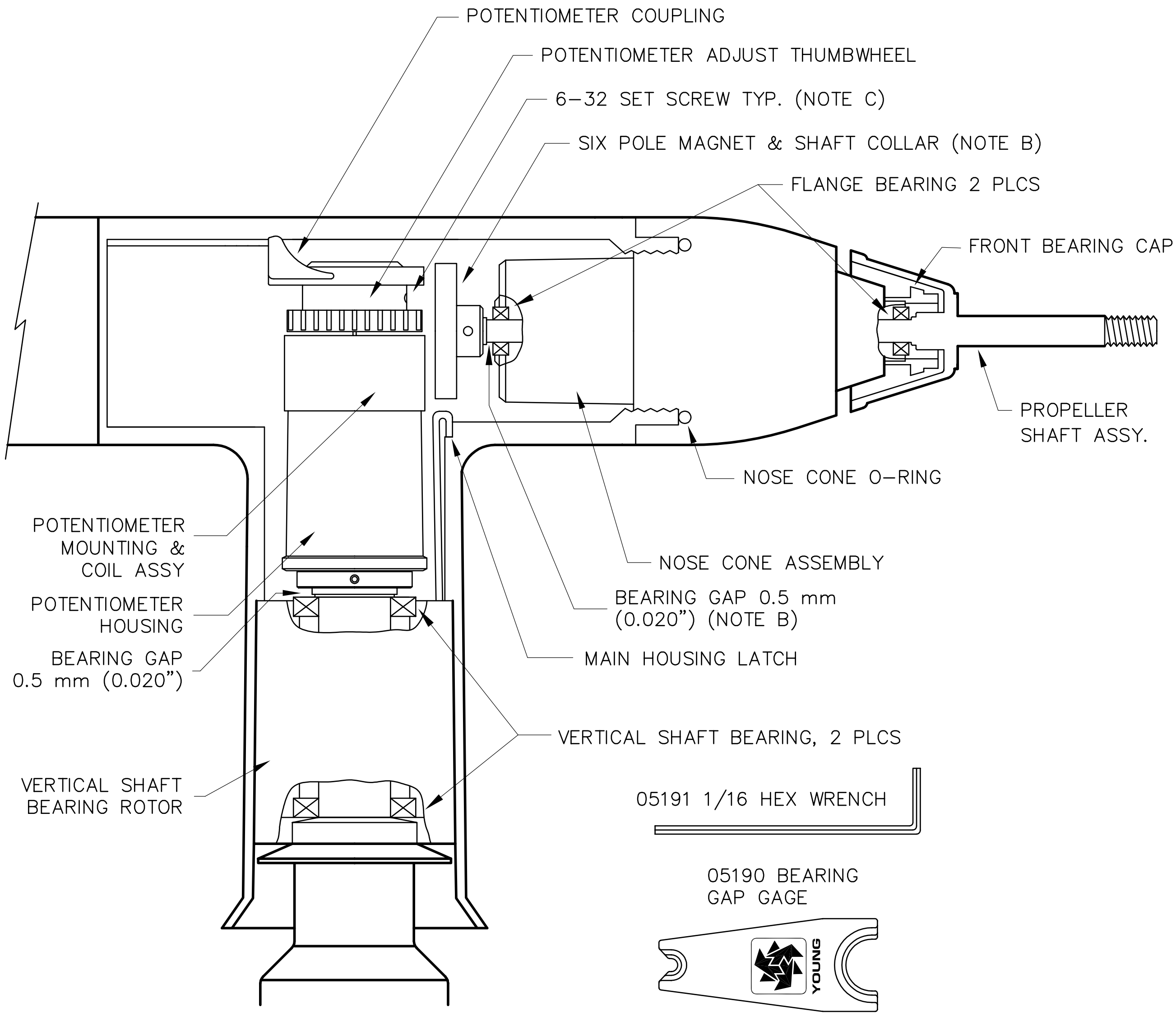
BEARING REPLACEMENT & POTENTIOMETER ADJUSTMENT



NOTES:

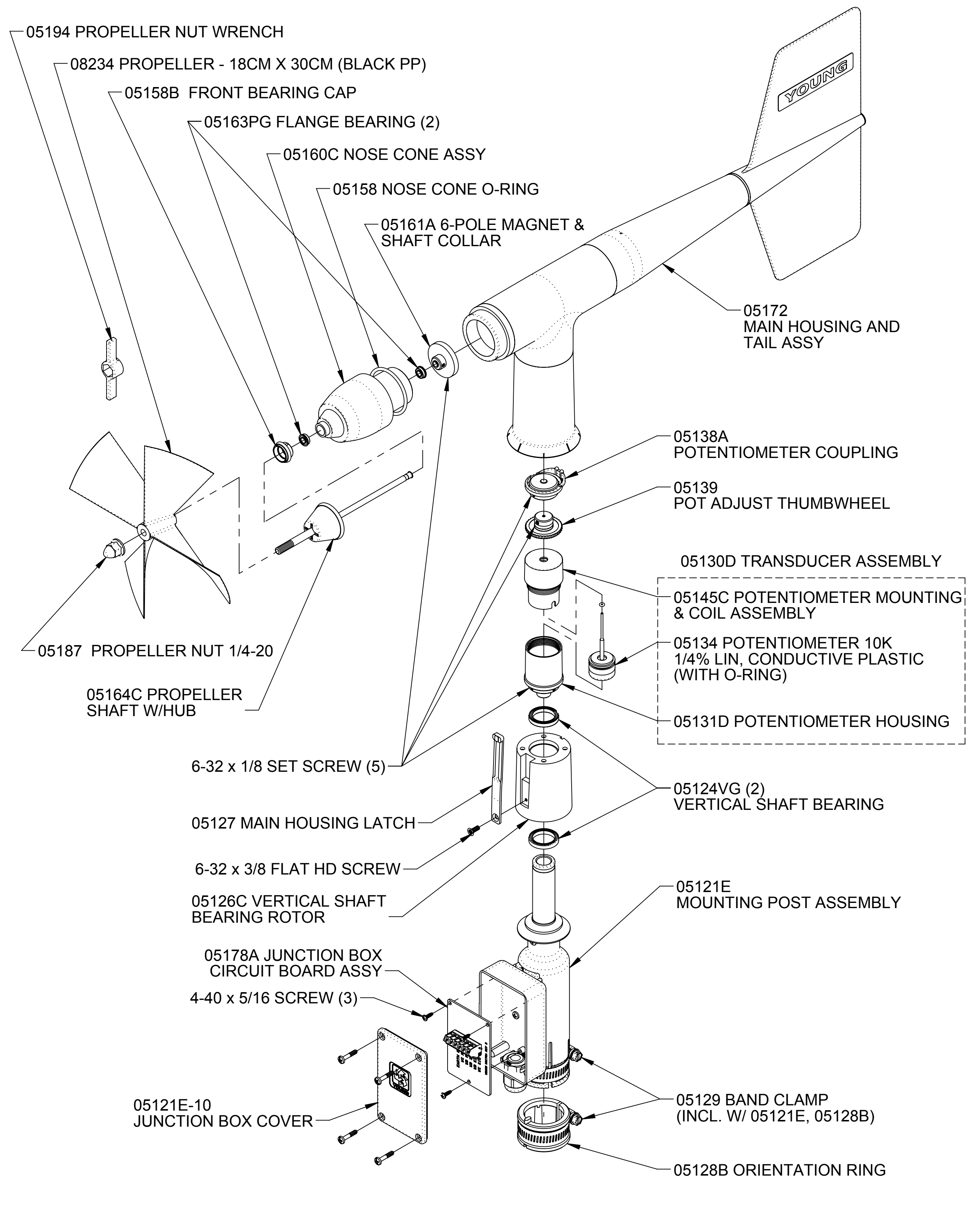
A. TO REMOVE HOUSING – UNTHREAD NOSE CONE ASSEMBLY, PUSH MAIN HOUSING LATCH, LIFT UPWARD.

B. TO REPLACE ANEMOMETER FLANGE BEARINGS – UNTHREAD NOSE CONE, REMOVE SIX POLE MAGNET, SLIDE PROPELLER SHAFT AND HUB ASSEMBLY FOREWARD, REMOVE FRONT BEARING CAP AND FLANGE BEARINGS. AFTER BEARING REPLACEMENT, SET BEARING GAP TO 0.5mm (0.020")

C. TO ADJUST POTENTIOMETER OUTPUT SIGNAL – REMOVE NOSE CONE, LOOSEN SET SCREW IN POTENTIOMETER COUPLING, ADJUST OUTPUT SIGNAL BY MEANS OF POTENTIOMETER ADJUSTMENT THUMBWHEEL, RE-TIGHTEN SET SCREW.

GENERAL ASSEMBLY & REPLACEMENT PARTS

MODEL 05103 WIND MONITOR



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Calibration Accessories

Model 18802
Anemometer Drive

Model 18112
Vane Angle Bench Stand

Model 18331 Vane Torque Gauge

Model 18212
Vane Angle Fixture-Tower Mount

Model 18310
Propeller Torque Disc

Model 18301
Vane Alignment Rod

YOUNG Calibration Accessories

Model 18802 Anemometer Drive provides a convenient and accurate way to rotate an anemometer shaft at a known rate. The motor may be set to rotate clockwise or counter-clockwise at any rate between 200 and 15,000 RPM in 100 RPM increments. The LCD display is referenced to an accurate and stable quartz timebase. For completely portable operation, the unit can be operated on internal batteries. For extended operation, an AC wall adapter is included.

Model 18811 Anemometer Drive is identical to Model 18802 except the drive motor incorporates a gear reducer for operation in the range of 20 to 990 RPM in 10 RPM increments. The lower range is recommended for cup anemometer calibration.

Model 18112 Vane Angle Bench Stand is used for benchtop wind direction calibration of the Wind Monitor family of sensors. The mounting post engages the direction orientation notch on the Wind Monitor. An easy to read pointer indicates 0 to 360 degrees with 1/2 degree resolution.

Model 18212 Vane Angle Fixture - Tower Mount similar to the Model 18112, the tower mount feature allows use on the tower as well as the bench top. The fixture is temporarily placed on the tower between the Wind Monitor and its tower mounting. Index keys and notches are engaged to preserve direction reference.

Model 18310 Propeller Torque Disc checks anemometer bearing torque with 0.1 gm/cm resolution. The disc temporarily replaces the propeller for torque measurement or simple yet accurate pass/fail checks. Charts included with the unit relate torque to propeller threshold with limits for acceptable bearing performance.

Model 18312 Cup-Wheel Torque Disc checks cup anemometer bearing torque.

Model 18331 Vane Torque Gauge checks vane bearing torque of the Wind Monitor family sensors. Slip the fixture over the main housing and make simple yet accurate vane torque measurements. Charts relating vane torque to vane threshold provide limits for acceptable bearing performance.

Model 18301 Vane Alignment Rod helps align the vane of a wind sensor to a known direction reference during installation. The base of the device has an index key that engages the direction orientation notch in the sensor allowing the sensor to be removed without losing wind direction reference.

Ordering Information

	MODEL
ANEMOMETER DRIVE *200 to 15,000 RPM*	**18802**
ANEMOMETER DRIVE *20 TO 990 RPM*	**18811**
230V / 50-60 HZ INPUT POWER	***ADD SUFFIX "H"***
VANE ANGLE BENCH STAND	**18112**
VANE ANGLE FIXTURE - TOWER MOUNT	**18212**
PROPELLER TORQUE DISC	**18310**
CUP-WHEEL TORQUE DISC	**18312**
VANE TORQUE GAUGE	**18331**
VANE ALIGNMENT ROD	**18301**

Specifications

MODEL 18802 **ANEMOMETER DRIVE**
(Replaces 18801)

Range:
200 to 15,000 RPM in 100 RPM increments

Rotation:
Clockwise or Counter-Clockwise

Display Resolution:
1 RPM

Quartz Timebase Reference:
0.1 RPM

Power Requirement:
2x9 V (alkaline or lithium) batteries
115 VAC wall adapter included
(230 VAC – add suffix H)

MODEL 18811 **ANEMOMETER DRIVE**
(Replaces 18810)

Range:
20 to 990 RPM in 10 RPM increments

Display Resolution:
0.1 RPM

MODEL 18112, 18212 **VANE ANGLE CALIBRATION DEVICES**

Range:
0 to 360 degrees

Resolution:
0.5 degree

MODEL 18310, 18312 **TORQUE DISC DEVICES**

Range:
0 to 5.4 gm-cm

Resolution:
0.1 gm-cm

MODEL 18331 **VANE TORQUE GAUGE**

Range:
0 to 50 gm-cm

Resolution:
5 gm-cm

Specifications subject to change without notice.

YOUNG
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Web Site: www.youngusa.com

CNR 4

Net Radiometer

Instruction Manual

IMPORTANT USER INFORMATION

Reading this entire manual is recommended for full understanding of the use of this product.

The exclamation mark within an equilateral triangle is intended to alert the user to the presence of important operating and maintenance instructions in the literature accompanying the instrument.

Should you have any comments on this manual we will be pleased to receive them at:

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P.O. Box 507
2600 AM Delft

The Netherlands
+31 15 2755 210
info@kippzonen.com
www.kippzonen.com

Kipp & Zonen reserve the right to make changes to the specifications without prior notice.

WARRANTY AND LIABILITY

Kipp & Zonen guarantees that the product delivered has been thoroughly tested to ensure that it meets its published specifications. The warranty included in the conditions of delivery is valid only if the product has been installed and used according to the instructions supplied by Kipp & Zonen.

Kipp & Zonen shall in no event be liable for incidental or consequential damages, including without limitation, lost profits, loss of income, loss of business opportunities, loss of use and other related exposures, however caused, arising from the faulty and incorrect use of the product.
User made modifications can affect the validity of the CE declaration.

Manual version: 1409

KIPP & ZONEN
SINCE 1830

CE

DECLARATION OF CONFORMITY

According to EC guideline 89/336/EEC 73/23/EEC

We:	Kipp & Zonen B.V. Delftechpark 36 2628 XH Delft The Netherlands

Declare under our sole responsibility that the product

Type: CNR 4
Name: Net Radiometer

And

Type: CNF 4
Name: Ventilation Unit

To which this declaration relates is in conformity with the following standards

Imissions	EN 50082-1	Group standard
Emissions	EN 50081-1 EN 55022	Group standard
Safety standard	IEC 1010-1	

Following the provisions of the directive

Dr. Foeke Kuik
CEO
Kipp & Zonen B.V.

CONTENTS

1 GENERAL INFORMATION

The CNR 4 is a 4 component net radiometer that measures the energy balance between incoming short-wave and long-wave Far Infrared (FIR) radiation versus surface-reflected short-wave and outgoing long-wave radiation.
The CNR 4 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 the short-wave radiation. And the pyrgeometer pair measures long-wave radiation. The upper long-wave detector of CNR 4 has a meniscus dome. This ensures that water droplets role off easily and improves the field of view to nearly 180°, compared with a 150° for a flat window. All 4 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 Pt-100 and Thermistor, are integrated for compatibility with every data logger. 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 assures that the temperatures of the measurement surfaces are the same and accurately known. This improves the quality of the long-wave measurements.
The design is very light in weight and has an integrated sun shield that reduces thermal effects on both long-wave and short-wave measurements. The cables are yellow with waterproof connectors as used with all our new radiometers. The mounting rod can be unscrewed for transport, like the CNR 2.
An optional ventilation unit with heater is designed as an extension of the sunshield and can be fitted new to the CNR 4 or retro-fitted later. The ventilation unit CNF 4 is compact and provides efficient air-flow over the domes and windows to minimize the formation of dew and reduce the frequency of cleaning. The integrated heater can be used to melt frost.
The CNR 4 specifications when used with CNF 4 comply with the WMO classification of Good Quality

The Net Radiometer, CNR 4, is intended for the analysis of the radiation balance of Solar and Far Infrared radiation. The most common application is the measurement of Net (total) Radiation at the earth's surface.

The CNR 4 design is such that both the upward facing and the downward-facing instruments measure the energy that is received from the whole hemisphere (180 degrees field of view). The output is expressed in Watts per square meter. The total spectral range that is measured is roughly from 0.3 to 42 micrometers. This spectral range covers both the Solar Radiation, 0.3 to 3 micrometers, and the Far Infrared radiation, 4.5 to 42 micrometers.

Chapter 1 describes how to operate the CNR 4, giving separate attention to the use of the individual pyranometers and pyrgeometers. More about the physics of the pyranometer and pyrgeometer can be found in chapter 2.

The CNR 4 radiometers all have individual calibration factors. As opposed to the CNR 1 they are not made equal. The advantage is that the individual sensitivities are more accurate then when made equal with shunt and series resistors.

For quality assurance of the measurement data, we recommend the recalibration of the CNR 4 as part of a regular maintenance schedule every two years. More about calibration can be found in chapter 3.

The CNR 4 is intended for continuous outdoor use. It is weatherproof. The materials used in Pyranometer and pyrgeometer are robust. Contrary to most competitive instruments, plastic domes are not used. Therefore the CNR 4 requires very low maintenance. For optimal results however, proper care must be taken. More about maintenance can be found in chapter 4. Chapter 5 can be consulted if a problem with the CNR 4 is suspected; this chapter addresses trouble shooting.
The general user should read chapter 1 and chapter 4.

1.1 Connecting the CNR 4

1.1.1 The difference between temperature and sensor connection

CNR 4 has several output signals: two voltages for the pyranometers, two voltages for the pyrgeometers, and two temperature sensors as standard: a 4 wire Pt-100 connection and a 2 wire connection for the 10k thermistor. Depending on the used data logger one of the temperature sensors can be used.
The connector with the 4 sensor outputs is indicated with an S on the back of the CNR 4, the temperature connector is indicated with a T. The sensor connector has 8 pins and 8 wires are coming out of the cable on the other end. The Temperature connector has also 8 pins but only 6 wires are coming out of the cable.
Exchanging the connectors will not damage the CNR 4. To prevent mix up of the cables after installation it is advised to mark the cables with a permanent marker or tape showing also S and T.

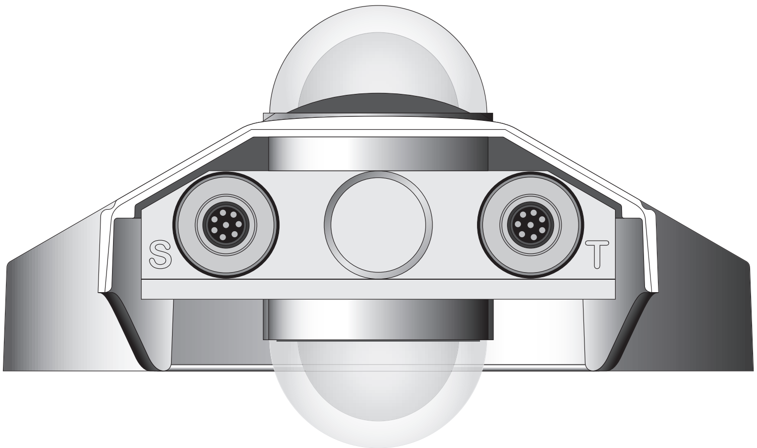


Figure 1.1 Back of the CNR 4 with the connector for sensor outputs on the left, the temperature connector on the right and mounting rod in the middle.

1.1.2 The radiometer Sensor connector (S)

CNR 4 sensor connector carries the signals for the two pyranometers and two pyrgeometers. The pin numbers and wire colours are indicated in the diagram below. The shield of the cable is twisted together and covered with a black sleeve. If the CNR 4 (rod) is grounded to the mast it is advised not to connect the shielding on the data logger side. This might cause ground loops and offsets in the signal.

CNR 4 NET RADIOMETER • SENSOR

8 WIRE CABLE • 8-ADRIGES KABEL • CÂBLE 8 FILS • CABLE DE 8 CONDUCTORES

	Wire Kabel Fil Cable		Function Funktion Fonction Función	Connect with Anschluss an Relier à Conectar con
1	Red Rot • Rouge • Rojo	+	Pyranometer Upper Oben • Supérieur • Superior	+ Hi
2	Blue Blau • Bleu • Azul	−		− Lo
7	White Weiss • Blanc • Blanco	+	Pyranometer Lower Unten • Inférieur • Más bajo	+ Hi
8	Black Schwarz • Noir • Negro	−		− Lo
5	Grey Grau • Gris • Gris	+	Pyrgeometer Upper Oben • Supérieur • Superior	+ Hi
4	Yellow Gelb • Jaune • Amarillo	−		− Lo
6	Brown Braun • Brun • Marrón	+	Pyrgeometer Lower Unten • Inférieur • Más bajo	+ Hi
3	Green Grün • Vert • Verde	−		− Lo
	Shield Abschirmung Protection Malla		Housing Gehäuse Boîte Cubierta	⏚ Ground * Erde Terre Tierra

* Connect to ground if radiometer not grounded
Mit Erde verbinden, wenn das Radiometer nicht geerdet ist
Reliez à la terre si le radiomètre n'est pas connecté
Conectar a tierra si el radiómetro no lo está

Figure 1.2 The sensor connections of the CNR 4. The sensor has four mV outputs, 2 for the pyranometers and 2 for the pyrgeometers

1.1.3 The radiometer Temperature connector (T)

The temperature connector of the CNR 4 carries the signals for the PT-100 and Thermistor. The PT-100 and Thermistor have identical accuracy, the reason for selecting one or the other is mainly the data logger involved. The Pt-100 temperature sensor has 4 wires, two for the measuring current and two for measuring the voltage over the resistor (100 Ohm @ 0 °C) . In this way the measurement accuracy is minimally affected by the cable length. The thermistor has a higher impedance of 10 kOhm and is therefore less influenced by cable length but has no compensation for it. The shield of the cable is twisted together and covered with a black sleeve. If the CNR 4 (rod) is grounded to the mast it is advised not to connect the shielding on the data logger side. This might cause ground loops and offsets in the signal.

CNR 4 NET RADIOMETER • TEMPERATURE
6 WIRE CABLE • 6-ADRIGES KABEL • CÂBLE 6 FILS • CABLE DE 6 CONDUCTORES

7	White Weiss • Blanc • Blanco	Thermistor	Standard Standard Etalon Estándar
8	Black Schwarz • Noir • Negro		
5	Grey Grau • Gris • Gris	Combined Kombiniert Combiné Combinado	Pt-100 Standard Standard Etalon Estándar
3	Green Grün • Vert • Verde		
4	Yellow Gelb • Jaune • Amarillo	Combined Kombiniert Combiné Combinado	
6	Brown Braun • Brun • Marrón		
Shield Abschirmung Protection Malla	Housing Gehäuse Boîte Cubierta	Ground * Erde Terre Tierra	

Figure 1.3 The temperature connections of the CNR 4. The instrument has one (4-wire) Pt-100 output and a Thermistor with a 2-wire connection.

1.1.4 The (optional) CNF 4 connector

The optional ventilator CNF 4 for the CNR 1 has separate wires for heating and ventilation. In case the heater is used also the ventilator should be active. The other way around the ventilator can be used without heating. When the ventilation unit is mounted later on the CNR 4, the extra bottom plate mounts to the bottom of the CNR 4. The (S) and (T) cables run on both sides of the ventilator to the back of the CNF 4 housing. The extra cover that comes with the CNF 4 slides under the CNR 4 cover. The 4 pins connector on the back of the CNF 4 is shown below. The CNR 4 without CNF 4 is supplied with an extra serial number label. This can be used to put on the bottom of the CNF 4 when mounted (later) on the CNR 4.

CNF 4 VENTILATION UNIT
(OPTIONAL • OPTION • OPTION • OPCIONAL)

4 WIRE CABLE • 4-ADRIGES KABEL • CÂBLE 4 FILS • CABLE DE 4 CONDUCTORES

	Wire Kabel Fil Cable		Function Funktion Fonction Función	Connect with Anschluss an Relier à Conectar con
1	Red Rot • Rouge • Rojo	+	5 Watt ventilator Ventilator • Ventilateur • Ventilador	12 VDC
2	Blue Blau • Bleu • Azul	–		
3	Green Grün • Vert • Verde	+	10 Watt heater Heizung • Chauffage • Calentador	12 VDC
4	Yellow Gelb • Jaune • Amarillo	–		
	Shield Abschirmung Protection Malla		Housing Gehäuse Boîte Cubierta	Ground * Erde Terre Tierra

Figure 1.3 The heater and ventilator connections of the CNF 4.

1.1.5 Using the CNR 4 calibration factors

The pyranometer generates a mV signal that is simply proportional to the incoming solar Radiation. The conversion factor between voltage, V, and Watts per square metre of solar irradiance E, is the so-called calibration constant C (or sensitivity).

For each pyranometer $E = V/C$ (1.1)

When using the pyrgeometer, you should realise that the signal that is generated by the pyrgeometer represents the exchange of 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. This means that for estimating the Far Infrared radiation that is generated by the object that is faced by the pyrgeometer, usually the sky or the soil, you will have to take the pyrgeometer temperature, T, into account. This is why a the temperature sensors are incorporated in the CNR 4's body near the pyrgeometer sensing element, and has therefore the same temperature as the pyrgeometer sensor surface. The calculation of the Far Infrared irradiance, E, is done according to the following equation:

For the pyrgeometer only $E = V/C + 5.67 \cdot 10^{-8} * T^4$ (1.2)

In this equation C is the sensitivity of the sensor. Please bear in mind that T is in Kelvin, and not in Celsius or Fahrenheit.

1.1.6 Using the CNR 4 measuring Net Radiation

In the CNR 4 all components are measured separately. This implies that you should connect all individual radiometers and one of the temperature sensors. The two pyranometers will measure the solar radiation, both incoming and reflected, the two pyrgeometers will measure the Far Infrared radiation. For proper analysis of the pyrgeometer measurement results, they must be temperature corrected using the temperature measurement. The following paragraphs describe how you should treat the instrument, and how different parameters like net Solar radiation, net Far Infrared radiation, soil temperature, sky temperature, and Net (total) radiation can be calculated.
Because all radiometers have different sensitivities it is not possible to interconnect the outputs to get the total Net Radiation.

1.1.6.1 Measuring Solar radiation with the pyranometer

Measuring with a pyranometer can be done by connecting two pyranometer wires, + and -, to a voltmeter. Incidental light results in a positive signal. The pyranometer mounting plate and ambient air should be at the same temperature, as much as possible. Conversion of the voltage to irradiance can be done according to equation 1.1. This is sometimes done in the data logging system itself, sometimes during evaluation in the user's software. Measuring with the upward-facing pyranometer, the so-called global (solar) radiation is measured. The downward-facing pyranometer measures the reflected solar radiation. When calculating the Net radiation, the Reflected radiation must be subtracted from the global radiation. See 1.1.6.5.

1.1.6.2 Measuring Far Infrared radiation with the pyrgeometer

A measurement with the pyrgeometer can be performed by connecting two pyrgeometer wires, + and -, to a voltmeter. A signal radiating from a source which is warmer than the pyrgeometer results in a positive signal.

To measure the Far Infrared irradiances with the two pyrgeometers, separately the Pt-100 output is required. The formula 1.2 is used to calculate the Far Infrared irradiance of the sky and of the ground.
With the downward-facing pyrgeometer, you would generally measure the Far Infrared radiation that is emitted by the ground. In contrast, the upward-facing pyrgeometer is generally used to measure the Far Infrared radiation from the sky. As the sky is typically colder than the instrument, you can expect negative voltage signals from the upward-facing pyrgeometer.

1.1.6.3 Measuring the CNR 4's body temperature

The CNR 4 has two temperature sensors built in as standard. The main reason to choose between the Pt-100 or the Thermistor is the connected data logger.

Some data loggers have inputs for thermistors some only for thermistors some have both.
Check carefully the correct sensor regarding to the data logger. There is no difference in accuracy.
The Pt-100 however can be used in 4 wire mode as is therefore compensated for longer wires.
The Thermistor has itself higher impedance (10k) and is less susceptible for longer wires, but can not be compensated for it.

To obtain a signal from the Pt-100, a current of about 1 mA is fed through two wires on either side of the PT-100. The voltage that is generated must be measured using the other pair of wires which are connected in parallel with the PT-100.This is known as a 4-wire measurement. Measuring in this manner eliminates errors during measurement, which would be produced by additional wire length. Some systems have a 3-wire connection. In this case omit one current lead and follow the instructions of your measurement system manual. Table 1.1 states the Pt-100 resistance values as a function of temperature. Please note that for use in formula 1.2, you must use Kelvin, not degrees Celsius or Fahrenheit. Most data acquisition systems have standard readout and conversion for Pt-100's. .
The thermistor resistance values as a function of temperature are indicated in table 1.2.

Temperature [EC]	Resistance [Ω]	Temperature [EC]	Resistance [Ω]	Temperature [EC]	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

Table 1.1 Resistance values versus temperature in °C of the CNR 4's Pt-100.
The Pt-100 complies with the class A specifications of DIN.

Temperature [EC]	Resistance [Ω]	Temperature [EC]	Resistance [Ω]	Temperature [EC]	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
-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

Table 1.2 Resistance values versus temperature in ˚C of the CNR 4's thermistor.

Relatively small errors occur when the CNR 4 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 real sensor temperature and Pt-100 or thermistor reading is less than 0.5 degree.
The internal temperature sensors will not give a good indication of ambient air temperature; at 1000 Watts per square meter Solar Radiation, and no wind, the instrument temperature can rise a few degrees above ambient temperature. This will not affect the readings of the CNR 4
The offsets of both pyranometers and pyrgeometers might be larger than 5 Watts per square meter if large temperature gradients are forced on the instrument (larger than 5 K/hr). This happens for example when rain hits the instrument. The occurrence of this can be detected using the temperature sensor readout. It can be used as a tool for quality assurance of your data.

1.1.6.4 Calculation of the albedo for solar radiation

The albedo is the ratio of incoming and reflected Solar radiation. It is a figure somewhere between 0 and 1. Typical values are 0.9 for snow, and 0.3 for grassland. To determine albedo, the measured values of the two pyranometers can be used. The pyrgeometers are not involved, as they do not measure Solar radiation. Do not use measured values when solar elevation is lower than 10 degrees above the horizon. Errors in measurement at these elevations are likely and thus yielding unreliable results. This is due to deviations in the directional response of the pyranometers.

Albedo = (E lower pyranometer) / (E upper pyranometer) (1.3)

In the above formula, E is calculated according to formula 1.1.
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 this specific site.

1.1.6.5 Calculation of the Net Solar radiation

Net Solar radiation is the incoming Solar Radiation minus the reflected solar radiation. It equals the solar radiation that is absorbed by the earth's surface.

Net Solar radiation = (E upper pyranometer) - (E lower pyranometer) (1.4)

In this formula E is calculated according to formula 1.1.
Net Solar radiation will always be positive. Checking this can be used as a tool for quality assurance of your measured data.

Calculation of the Net Far Infrared radiation, soils temperature and sky temperature

Net Far Infrared radiation is, like Net Solar radiation, the part that contributes to heating or cooling of the earth's surface. In practice most of the time, Net Far Infrared radiation will be negative.

Net Far Infrared radiation = (E upper pyrgeometer) - (E lower pyrgeometer) (1.5)

In this formula E is calculated according to formula 1.2. From this equation the term with T cancels.

The E measured with the pyrgeometer, actually represents the irradiance of the sky (for the upward- facing pyrgeometer) or the ground (for the downward-facing pyrgeometer). Assuming that these two, ground and sky, behave like perfect blackbodies (actually this is only in theory), you can calculate an effective "Sky temperature" and an effective "Ground temperature".

Sky temperature = ((E upper pyrgeometer)/ $5.67 \cdot 10^{-8})^{1/4}$ (1.6)

Ground temperature = ((E lower pyrgeometer)/ $5.67 \cdot 10^{-8})^{1/4}$ (1.7)

As a rule of thumb, for ambient temperatures of about 20 degrees Celsius, you can say that one degree of temperature difference between two objects results in a 5 Watts per square metre exchange of radiative energy (infinite objects):

1 degree of temperature difference = 5 Watts per square metre (rule of thumb)

1.1.6.6 Calculation of the Net (total) radiation

The Net radiation, NR, can be calculated using all 4 sensor measurement results:

NR = (E upper pyranometer) + (E upper pyrgeometer) - (E lower pyranometer) - (E lower pyrgeometer) (1.8)

Where E is the irradiance that is calculated for the pyranometer according to equation 1.1, for the pyrgeometer according to equation 1.2. the terms with T cancel from this equation.

1.2 CNR 4 Performance under different conditions

Below, table 1.3, shows an indication of what you 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 indicates 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) 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 vapour in the air, which is a major contributor to the Far Infrared radiation.

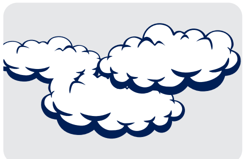
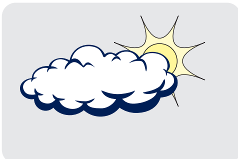
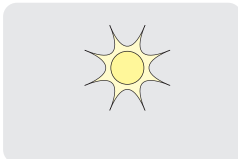
Values calculated using: Werte, errechnet aus Formel: Calcul des valeurs à l'aide: Utilizar valores calculados: $E = \frac{U_{emf}}{S}$	 Fully clouded Bewölkt Très nuageux Totalmente Nublado	 Sunny, partly clouded Sonnig, teils bewölkt Ensoleillé, un peu nuageux Parcialmente nublado	 Clear and Sunny Klarer Himmel und sonnig Clair et ensoleillé Cielo despejado
Pyranometer			
Upper Oben • Supérieur • Superior	50 ... 120 W/m²	120 ... 500 W/m²	500 ... 1000 W/m²
Lower Unten • Inférieur • Más bajo	0 ... 50 W/m²	50 ... 200 W/m²	200 ... 400 W/m²
Pyrgeometer			
Upper Oben • Supérieur • Superior	0 ... -10 W/m²	-10 ... -50 W/m²	-50 ... -150 W/m²
Lower Unten • Inférieur • Más bajo	-25 ... 25 W/m²	-25 ... 25 W/m²	-25 ... 25 W/m²

Fig. 1.2.1 Different measurement conditions and signals

Typical graphs for the pyrgeometers

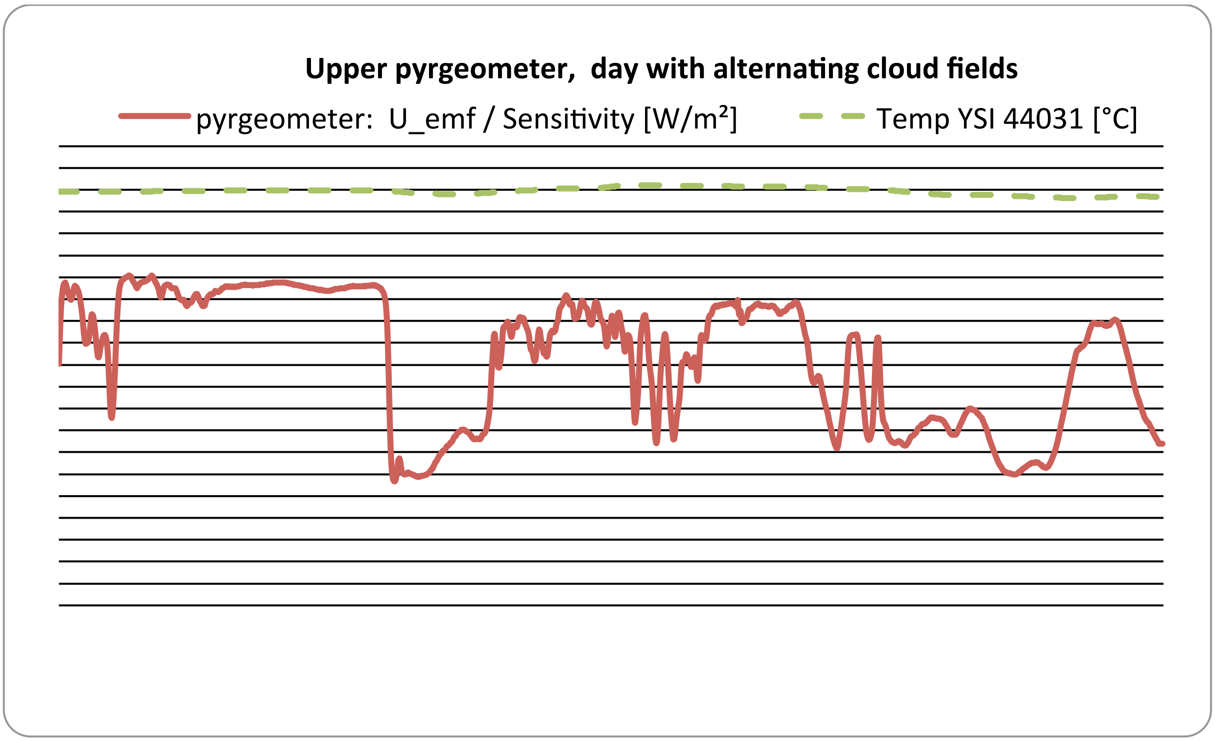


Figure 1.2.2 partly clouded day for the upper pyrgeometer

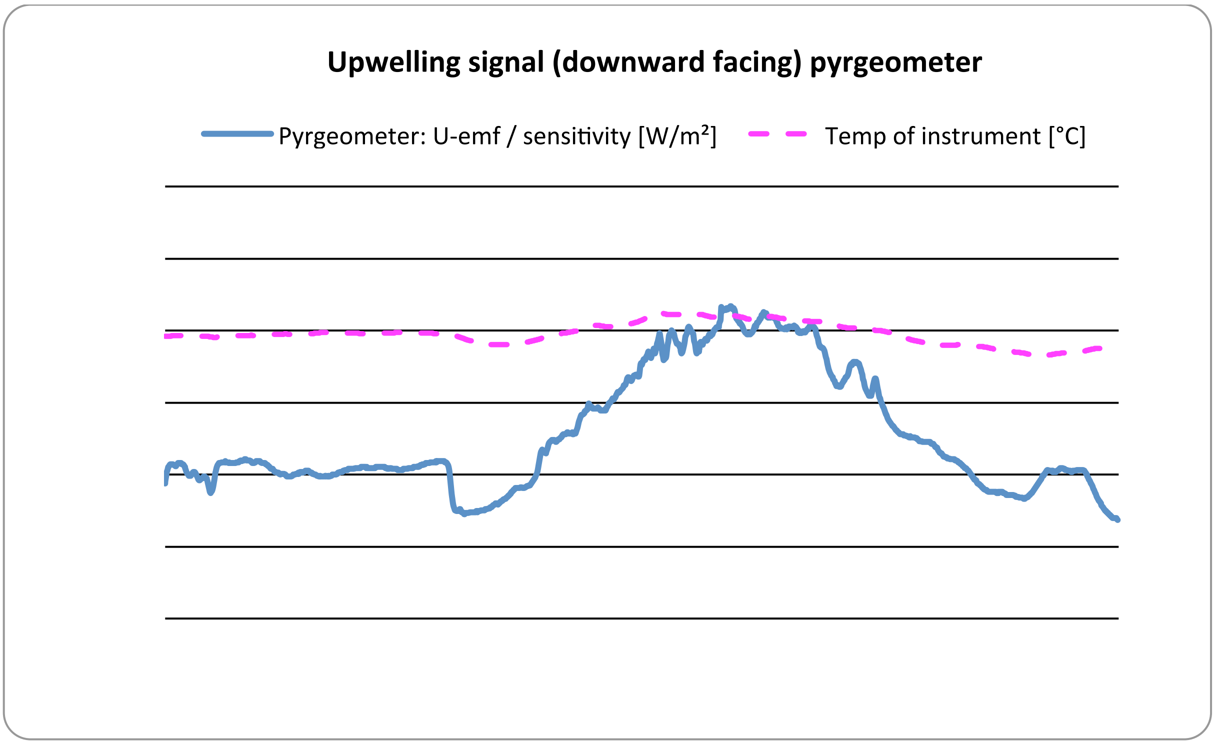


Figure 1.2.3 clear day for the downward facing pyrgeometer

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 pyrgeometer's and pyranometer's are stated in columns 4 to 7. 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. Actually in column 4 you 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 1.6 and 1.7.

day night	Cloudy clear	+20 °C - 20 °C	pyrgeo Up	pyrgeo low	pyrano up	pyrano low	Pt 100 thermistor	sky T	ground T
d	cloud	20	0	-20 - 20	0-500	0-150	20	20	20
d	cloud	-20	0	-20 - 20	0-500	0-150	-20	-20	-20
d	clear	20	-100*	-20 - 20	0-1300	0-400	20	1*	20
d	clear	-20	-100*	-20 - 20	0-1300	0-400	-20	-53*	-20
n	cloud	20	0	-20 - 20	0	0	20	20	20
n	cloud	-20	0	-20 - 20	0	0	-20	-20	-20
n	clear	20	-100***	-20 - 20	0**	0	20	1***	20
n	clear	-20	-100***	-20 - 20	0**	0	-20	-53***	-20

Table 1.2.2 Typical output signals of CNR 4 under different meteorological conditions. Explanation can be found in the text.

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

1.3 Quality assurance of data

Because of the fact that separate sensors are used in the CNR 4, there are possibilities to check the quality of the data by analysing the signals. For this, you can use the measurement results of the temperature, the albedo and the net-solar radiation. If the values that are obtained for these quantities exceed certain values, this can be an indication that something is wrong. For more details we refer to the paragraphs 1.2, table 1.2.1 and 1.2.2.

2 CNR 4 PROPERTIES

The CNR 4 consists of two pyranometers, for measuring solar radiation, and of two pyrgeometers for measuring Far Infrared radiation. Two temperature sensors are available as standard, a Pt-100 and thermistor. The optional ventilation unit CNF 4 is described in chapter 2.5

2.1 Properties of the CNR 4 Net-Radiometer

The properties of CNR 4 are mainly determined by the properties of the individual sensors. Generally the accuracy of CNR 4 will be higher than that of competitive Net-Radiometers. The main reasons are that the solar radiation measurement performed by the pyranometer is accurate, and offers a traceable calibration. Also the optionally integrated ventilation and heating improve the accuracy significantly. Due to the fact that the Net Solar radiation can be very intense, 1000 Watts per square metre compared to a typical -100 for the Net Far Infrared radiation, the accuracy of the solar measurement is very critical. Wind corrections, as applied by less accurate competitive instruments are not necessary. The robustness of the materials used implies that CNR 4 will not suffer from damage inflicted by birds. Figure 2.1 depicts a drawing of CNR 4. From a spectral point of view, the pyranometer and pyrgeometer are complementary. Together they cover the full spectral range: The pyranometer from 0.3 to 3 microns, and the pyrgeometer from 4.5 to 42 microns. The gap between these two produces negligible errors.

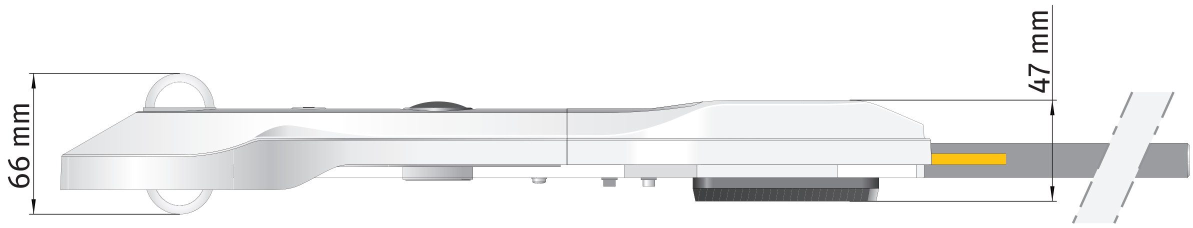


Figure 2.1 The dimensions of the CNR 4 with CNF 4 ventilation unit, side view

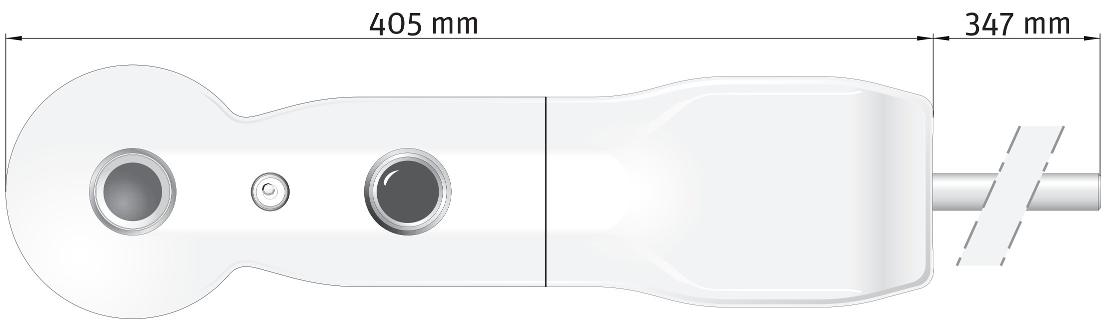


Figure 2.2 The dimensions of the CNR 4 with CNF 4 ventilation unit, top view

2.1.1 Specifications of the CNR 4

General specifications		
Environmental		**0 - 100% RH (Relative Humidity)**
Definition		*Intended for continuous outdoor use*
Bubble level sensitivity		< 0.5° (bubble half inside ring)
General Construction		
Sensor		**Thermopile**
Receiver paint		**Carbon Black**
Desiccant		**Silica gel** (replaceable)
Housing materials		**Anodized Aluminum body**
Cable Connectors		Binder series 712
Cable (2 cables)		Color Yellow, Poly Urethane, Halogen free, UV blocking
Cable length (2 cables)	m	10 (standard), 25, 50 (optional)
Weight	kg	0.85 (without cables)
Shock / vibration		IEC 721-3-2-2m2
Operating temperature	°C	-40 to +80
CE		according to EC guideline 89/336/EEC 73/23/EEC
Environmental protection		IP 67

2.2 Properties of the pyranometer

The pyranometer consists of a thermopile sensor and a glass dome both integrated in the CNR 4 body. The thermopile is coated with a black absorbent coating. The paint absorbs the radiation, and converts it to heat. The resulting heat flow causes a temperature difference across the thermopile. The thermopile generates a voltage output. The thermopile and the resistor determine most electrical specifications. The absorber paint and the dome determine spectral specifications. The thermopile is encapsulated in the housing in such a way that its field of view is 180 degrees, and that its angular characteristics fulfil the so-called cosine response.

2.2.1 Specifications of the pyranometer

Pyranometers Specification	Unit	Value (All indicated values are absolute values)
Spectral range	nm	300 - 2800 (50% points)
Definition		Instrument sensitivity within a specific spectral range
Sensitivity	µV/ W/m²	10 to 20
Definition		Calibration factor
Impedance	Ω	20 to 200, typically 50
Definition		*Typical resistance measured at the output*
Response time	s	< 18 (95% response)
Definition		*Sensor response time*
Non-linearity	%	< 1 (from 0 to 1000 W/m² irradiance)
Definition		*Maximum deviation from the responsivity at 500 W/m² due to any change of irradiance within the indicated range.*
Temperature dependence of sensitivity	%	N/S (- 40 °C to -10°C) < 4 (- 10 °C to +40 °C) N/S (+40 ºC to +80 ºC)
Definition		*Maximum error due to any change of instrument temperature within the indicated temperature interval.*
Tilt error	%	< 1
Definition		*Maximum deviation from the responsivity when tilted at any angle and at 1000 W/m² irradiance .*
Zero offset A	W/m²	< 15 (0 to -200 W/m² / IR net irradiance)
Definition		*Caused by cooling of the dome due to sky radiation*
Zero offset B	W/m²	< 3 (at 5 K/h temp. change) < 1 (with CVF 4 installed)
Definition		*Response to change in ambient temperature.*
Field of view: Upper detector Lower detector		180º 150º (due to lower sun shield. To prevent illumination at low zenith angles)
Definition		*Sensor opening angle*
Directional error	W/m²	< 20 (angles up to 80° with 1000 W/m² beam radiation)
Definition		*Combined zenith and azimuth error from 0°- 80° with 1000 W/m² beam radiation*

Irradiance:	W/m²	0 to 2000
Definition		*Measurement range*
Non-stability	%	< 1
Definition		*Maximum change of sensitivity per year, percentage of full scale*
Spectral selectivity	%	< 3% (350 – 1500 nm spectral interval)
Definition		*Deviation of the product of spectral absorption and spectral transmittance from the corresponding mean within the indicated spectral range*
Uncertainty in daily total	%	< 5 (95 % confidence level)
Definition		*Achievable uncertainty*
International standards		
WMO ISO		Good quality First Class
Instrument calibration		Indoors, side by side against reference CMP 3 pyranometer according to ISO 9847:1992 annex A.3.1

2.2.2 Spectral properties of the pyranometer

The spectral properties of the pyranometer are mainly determined by the properties of the absorber paint and the glass dome. These are depicted in figure 2.3

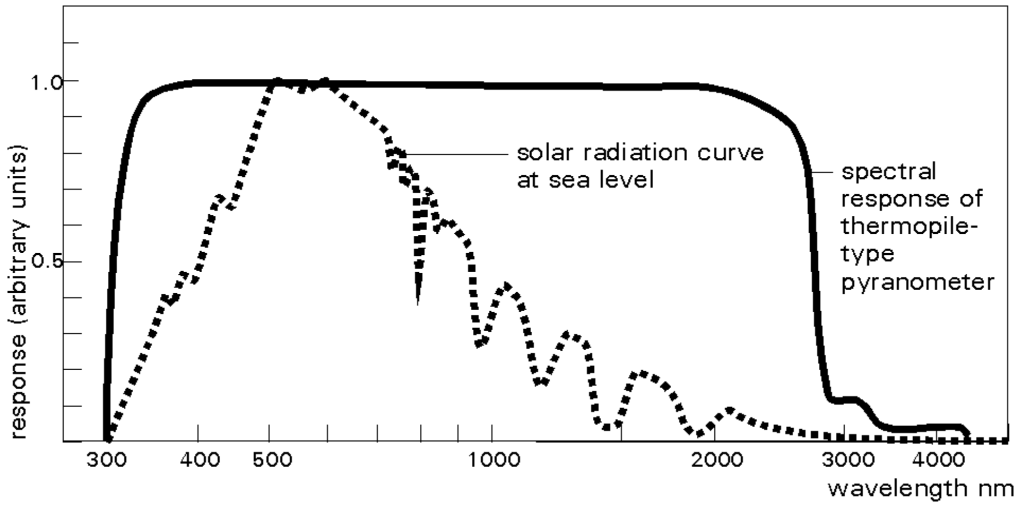


Figure 2.3 The spectral sensitivity of the pyranometer in combination with the spectrum of the sun, under a clear sky.

2.2.3 Directional / Cosine response of the pyranometer

The measurement of solar radiation falling on a surface (also called irradiance or radiative flux) requires three assumptions: The surface is spectrally black, i.e. that it absorbs all radiation from all wavelengths. Its field of view is 180 degrees. The directional properties are similar to that of a blackbody. Another way of expressing these directional properties is to say that the sensor has to comply with the cosine response.
A perfect cosine response will show maximum sensitivity (1) at an angle of incidence of 0E (perpendicular to the sensor surface) and zero sensitivity at an angle of incidence of 90E (radiation passing over the sensor surface). Between 90 and 0 degrees, the sensitivity should be proportional to the cosine of the angle of incidence. Figure 2.4 shows the behaviour of a typical pyranometer. The vertical axis shows the deviation from ideal behaviour, expressed in percentage of the ideal value.

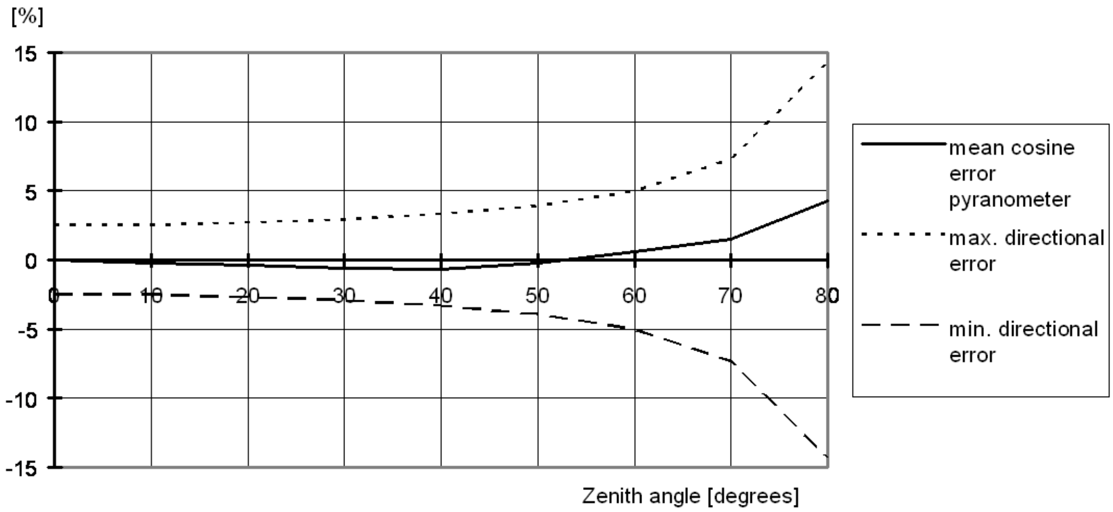


Figure 2.4 The directional response, or cosine response, of the pyranometer:
On the horizontal axis, the zenith angle is shown (0E zenith angle equals 90E angle of incidence).
The vertical axis shows the deviation from the ideal cosine behaviour expressed in percents.

2.3 Properties of the pyrgeometer

The pyrgeometer consists of a thermopile sensor and a silicon window integrated in the CNR 4 body. The thermopile is coated with a black absorbent coating. The paint absorbs the radiation and converts it to heat. The resulting heat flow is converted to a voltage by the thermopile. Most electrical specifications are determined by the thermopile and the resistor.
Spectral specifications are determined by the absorber paint and the window. The window serves both as environmental protection and as a filter. It only transmits the relevant Far Infrared radiation, while obstructing the Solar radiation. The upper thermopile has a dome shaped window so that its field of view is 180 degrees, and that its angular characteristics fulfil the so-called cosine response as much as possible, in this field of view. It causes water droplets to run of more easily.
The field of view of the lower pyrgeometer is 150 degrees. It is limited due to the use of a flat window. This does not produce a large error because the missing part of the field of view does not contribute significantly to the total, and is compensated for during calibration.

There is no international standard that classifies pyrgeometers. Pyrgeometers have two specific properties that deserve special attention. The first is the so-called window-heating offset; the second is the influence of water deposition on the window.

2.3.1 Window heating offset

The window heating offset is a measurement error that is introduced by the heating of the pyrgeometer window by the sun. It only occurs during the day. During a sunny day, the upper pyrgeometer will suffer from this. This error can be reduced by shading or ventilating. On a sunny windless day with a solar irradiance of 1000W/m², an error of 6 Watts per square meter can be expected. The window will absorb part of the solar radiation and will heat up. As a result of this heating, heat will irradiate towards the thermopile. This results in an error source, in the Infrared range. This error is neglected, however, in the net radiation calculation this is justified because the solar radiation is always dominant when this error occurs. Due to its construction the window heating offset in the CNR 4 is extremely small compared with other instruments.

2.3.2 Water deposition on the pyrgeometer window

The second specific error source of a pyrgeometer is the substantial measurement error introduced as the result of water deposition on the window. Water will completely obstruct the transmission of Far Infrared radiation. Water deposition will occur when it rains, snows, or when dew is deposited.
In the case of rain or snow, the resulting error is not very significant, mainly due to the fact that under these cloudy conditions, the pyrgeometer signal will be close to zero anyway. The cloud base temperature is generally close to ambient temperature. The conditions under which dew can form are much more likely to produce significant errors. A typical situation occurs at night, with a cloudless sky, low wind speeds, and high humidity (so-called clear, windless nights). Under these conditions, the upward-facing pyrgeometer signal is large, typically -100 Watts per square metre. When dew occurs, this reading can drop to zero, resulting in a 100 Watts per metre square error. Generally speaking this kind of error is too large, and if possible it should be avoided. Ventilation and heating can prevent dew deposition with the CNR 4's optional CNF 4. Heating will keep the instrument window above the dew point and ventilation will keep the domes clean from rain and snow.

2.3.3 Specifications of the Pyrgeometer

The output of the pyrgeometer is a small voltage, in the mV range. It is proportional to the temperature difference between the pyrgeometer and the object that it faces. This implies that for calculation of the absolute quantity of Far Infrared radiation, that is emitted by the sky or the ground you also need to take the pyrgeometer temperature into account. This temperature is measured by a Pt-100 that is incorporated in the body of CNR 4. The calculation of the Far Infrared irradiance is described in chapter 1.

Pyrgeometer Specification	Unit	Value
Spectral range	µm	4.5 to 42 (50% points)

Definition		Instrument sensitivity within a specific spectral range
Sensitivity	μV/W/m²	5 to 15
Definition		Calibration factor
Impedance	Ω	20 to 200, typically 50
Definition		*Typical resistance measured at the output*
Response time	s	< 18 (95% response)
Definition		*Sensor response time*
Non-linearity	%	< 1 (from -250 to +250 W/m² irradiance)
Definition		*Maximum deviation from the responsivity at -100 W/m² due to any change of irradiance within the indicated range.*
Temperature dependence of sensitivity	%	N/S (- 40 °C to -10°C) < 4 (- 10 °C to +40 °C) N/S (+40 ºC to +80 ºC)
Definition		*Maximum error due to any change of ambient temperature with the indicated interval.*
Tilt error	%	< 1 deviation when tilted at any angle off horizontal.
Definition		*Maximum deviation from the responsivity at angular tilt with 1000 W/m² beam.*
Window heating offset	W/m²	< 6 (0 to 1000 W/m² / solar irradiance)
Definition		*Caused by heating of the dome due to solar radiation*
Field of view: Upper detector Lower detector		 180º 150º
Definition		*Sensor opening angle*
Net irradiance range:	W/m²	-250 to +250
Definition		*Measurement range*
Non-stability	%	< 1
Definition		*Maximum change per year, percentage of full scale*
Spectral selectivity	%	< 5 (8 – 14 μm spectral range)
Definition		*Deviation of the product of spectral absorption and spectral transmittance from the corresponding mean within the indicated spectral range*
Environmental		humidity 0 - 100% RH
Definition		*Intended for continuous outdoor use*
Uncertainty in daily total	%	< 10 (95 % confidence level) Indoor calibration
Definition		*Achievable uncertainty*
Temperature sensor		Thermistor and Pt-100
International standards		
WMO ISO		Standards are not available
Instrument calibration		Indoors, side by side against reference CG(R) 3 pyrgeometer On request outdoors, side by side against reference CG(R) 4 pyrgeometer

2.3.4 Spectral properties of the pyrgeometer

The spectral properties of the pyrgeometer are mainly determined by the properties of the absorber paint and the silicon window. The silicon window is coated on the inside with an interference filter, which blocks the solar radiation. The spectral characteristics of the pyrgeometer are depicted in figure 2.5

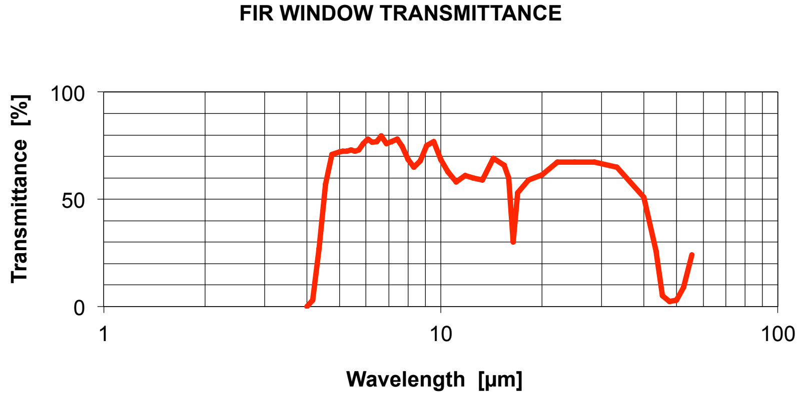


Figure 2.5 The spectral sensitivity of the pyrgeometer window: Theoretically it equals the spectral selectivity of the total instrument.

2.3.5 Directional / Cosine response of the pyrgeometer

The measurement of the Far Infrared radiation falling on a surface (also called irradiance or radiative flux) requires that the sensor has to comply with the cosine response.

A perfect cosine response will show a maximum sensitivity of (1) at an angle of incidence of 0E (perpendicular to the sensor surface) and zero sensitivity at an angle of incidence of 90E (radiation passing over the sensor surface). Between 90 and 0 degrees, the sensitivity should be proportional to the cosine of the angle of incidence.

2.4 Properties of the CNF 4 (optional) ventilation unit

The ventilator and heaters purpose is to prevent dew deposition on the pyrgeometer and pyrgeometer window, and thus increase measurement accuracy and reliability. Using the ventilator and heater will have negligible effect on the pyranometer reading.
Generally these errors are small relative to the errors that would have been caused by water deposition. More information for the pyrgeometer on this can be found in chapter 2.3.2

2.4.1 CNF 4 specifications

CNF 4 specifications	**Unit**	**Value**
Ventilation	W	5 W @ 12 VDC
Voltage	V	8 ... 13.5 VDC
Heater	W	10 W @ 12 VDC (15 Ohm)
Weight	kg	0.5 kg (CNR 4 + CNF 4 = 1.35 kg) *without cables*
Operating temperature:	°C	-40 to +80

There is one major reason for heating and ventilation: avoiding water deposition on the pyrgeometer window and on the pyranometer dome. In case of dew deposition on the pyrgeometer window, the dew will ultimately obstruct the Far Infrared radiation completely, causing a signal close to zero. In the case of rain, this will probably not lead to significant errors, because with an overcast sky the signal is close to zero anyway. The case of dew deposition is far more significant. Dew deposition will probably take place under conditions with large Far Infrared irradiation from the pyrgeometer detector to the clear sky, typically minus (-) 100 Watts per metre square. Under conditions where clouds or wind are present, dew is less likely to occur. A situation where dew depositing on the window of the pyrgeometer, causing a signal of -100 Watts per square metre to drop to zero, is certainly significant. If ventilation and heating can avoid this, it certainly should be done because all errors that are described above are much smaller than the gain in accuracy of 100 Watts per metre square.

For decisions about heating you can make the following diagram:

12 VDC, 6 VA available?	not available	Do not heat
	available	consider options below
Clock and relay available?	not available	heat all day, all night
	available	heat from 1 hour before sunset until one hour after sunrise.

The nominal power for the heater is 10 VA. In case of snow or frost you might also consider heating at a higher level than the usual. Heating at 20 VA will melt snow in most cases. 20 VA can be reached at 24 Volt. If lower voltage is available, you might consider heating at a lower power. The 10 VA is designed for extreme conditions. 5 VA (at 6V) is sufficient for moderate conditions.
Time needed for reaching a stable instrument temperature when heating is about 60 minutes.

2.5 Properties of the Pt-100 and thermistor

The Pt-100 is a common temperature sensor. Essentially it is a resistor that is temperature dependent. The Pt-100 complies with the specifications of DIN, class A. A table stating the resistance values can be found in chapter 1.1.6.3

Alternatively the thermistor, (nominal value is 10k Ohms at 25 degrees Celsius) can be used. A table stating the resistance values can be found in table 1.1 The thermistor has a much larger resistance value than the Pt-100, also the change in resistance with respect to temperature, in absolute terms, is greater. Therefore the cable resistance can be neglected, and only a 2-wire connection is used for the thermistor measurement, contrary to the 4-wire connection of the Pt-100.

The accuracy of both temperature sensors is equal and the selection to use one or the other mainly depends on the possibilities of the connected data logger or data acquisition system.

3 CALIBRATION

3.1 Calibration of the pyranometers

The primary standard for pyranometers is the World Radiometric Reference. Reference pyranometers that are used at Kipp & Zonen are calibrated using the primary standard.
The Kipp & Zonen pyranometer calibration is traceable to the World Radiometric Reference.
Further reference conditions are as follows: temperature 20 degrees Celsius, irradiance 500 Watts per metre square, in the horizontal position. Each pyranometer has an individual calibration factor.
These factors can be found on the calibration certificate, included with the instrument and on the label applied on the instrument itself.

3.2 Calibration of the pyrgeometers

There is no primary standard for pyrgeometer measurements.
The pyrgeometers in the CNR 4 are calibrated relative to the reference that is present at Kipp & Zonen.
In turn this reference has been calibrated against the World Reference at WMO in Davos

3.3 Recalibration of pyranometers and pyrgeometers

We suggest recalibration for all sensors, pyranometers, and pyrgeometers to be performed every two years by an authorised Kipp & Zonen calibration facility, or as an alternative, by letting a higher standard run parallel to it over a two-day period and then comparing the results. For comparison of pyranometers, you should use a clear day. For comparison of pyrgeometers, you should compare night time results.

3.4 Checking the Pt-100 and Thermistor

Please check the reliability of the Pt-100 / Thermistor measurement by doing a parallel measurement with the other temperature sensor. If this is not possible it can be done by temporarily attaching a stick-on type thermocouple to the CNR 4's body, and then subsequently comparing the readout of the thermocouple with the readout of the Pt-100 / Thermistor. The discrepancy, assuming that the thermocouple has a +/- 0.2 degrees accuracy, should be within +/- 0.7 degrees. If it is greater, the deviating temperature sensor should be replaced.

4 INSTALLATION AND MAINTENANCE

For measurement of the Net Radiation, it is most important that the instrument is located in a place that is representative of the entire region that you wish to study.

When installed permanently, the net radiometer should be attached to its mounting platform with the rod that is attached to its body.

When installed on a mast, the preferred orientation should be such that no shadow is cast on the Net Radiometer at any time during the day. In the Northern Hemisphere this implies that the Net Radiometer should be mounted south of the mast.
It is suggested that the CNR 4 is mounted at a height of at least 1.5 metres above the surface, to avoid shading effects of the instruments on the soil and to promote spatial averaging of the measurement. If the instrument is H metres 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 radius < 0.1 H will affect the measurement by less than 1%.
The Net Radiometer should be installed horizontally, using the level on the body of the CNR 4.

For installation in buildings or in solar energy applications, you will often have to mount the CNR 4 parallel to the surface that is being studied. This may be in a tilted, or a vertical position. The sensitivity of the radiometers will be affected, but only in a minor way. This is specified as the so-called tilt effect. From the specifications in chapter 2.2.1 and 2.3.3 you can see that the tilt effect (this is change in sensitivity) remains within 1 %.

4.1 Replacing the drying cartridge

The Net Radiometer is an all-weather instrument.
Once installed it needs little maintenance. It is suggested that you clean the windows and domes as part of a regular routine, using water or alcohol. The drying cartridge needs to be replaced every 2 years. The 3 screws for the plastic cover and the 6 screws for the base plate need to be removed using a screwdriver with a Philips tip size PH1. Under the base plate the drying cartridge is located. The (black) rubber ring as indicated in the picture below must be in place to keep the compartment sealed.

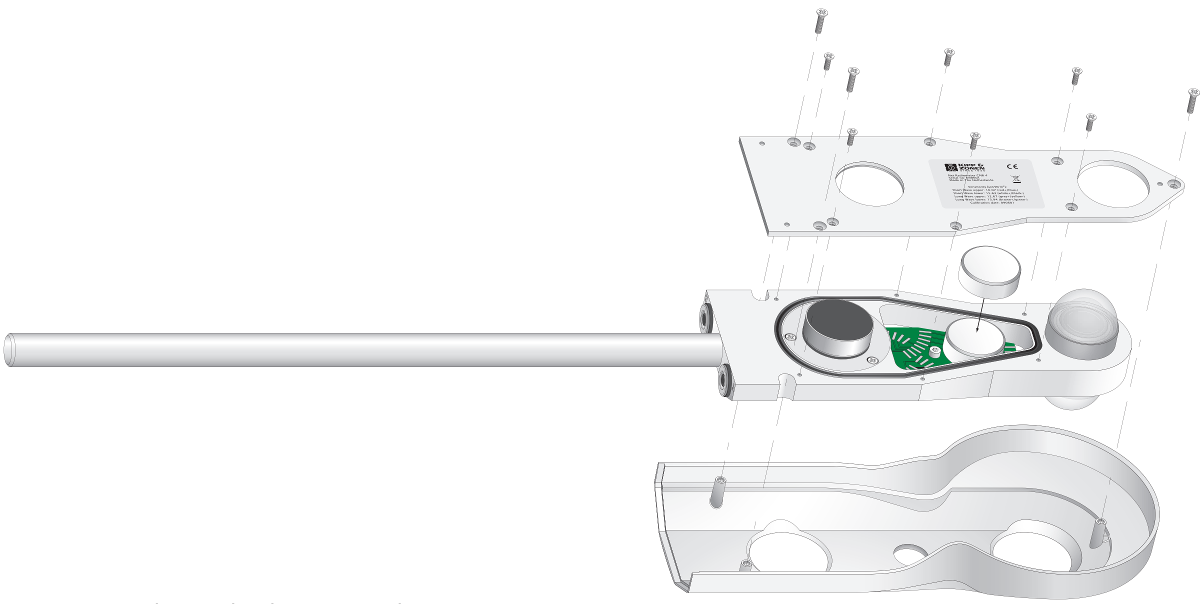


Figure 4.1 Replacing the drying cartridge

4.2 Replacing the Ventilator Filter

The CNF 4 ventilation unit has a filter that can be checked and if required cleaned or replaced. The cover of the ventilator cover (black part in picture below) can be removed by just pulling it down from the CNR 4. The filter needs to be checked for dust and particles every 6 - 12 months. It can be cleaned by simply washing it in clean water or it can be replaced by a new one. To remount the cover and filter just click it back on the ventilator.

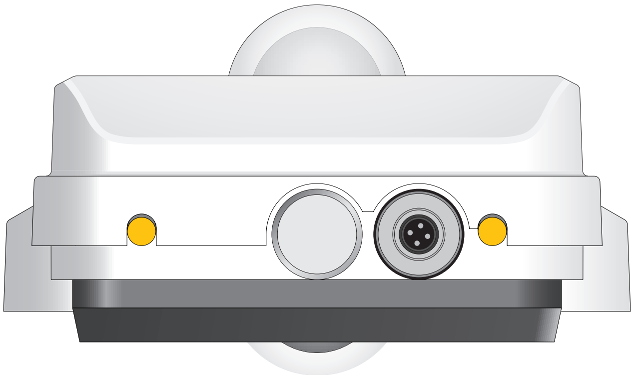


Fig 4.2 Back of CNF 4 with filter cover

5 TROUBLE SHOOTING

This chapter describes what to do if there appears to be a problem. The following chapters give individual information for checking the pyranometer, pyrgeometer, the temperature sensors and the ventilation unit with heater.

All connections to the CNR 4 are made with connectors and cables that can be separated from the main instrument. Check at all times that these connectors are properly attached and screwed to the body of the CNR 4.

If there is no clue 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 Solar and Far Infrared radiation. Outdoors you should preferably work with a solar elevation of more than 45 degrees (45 degrees above horizon) and of course under stable conditions (no large changes in solar irradiance, preferably cloudless) :

1. Measure the output in the normal position. Record the measured values when the signals have stabilised, i.e. after about 3 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 output once more. Record the measured values when the radiometers have stabilised.

4. The calculated radiation for the sensors in the rotated position should be equal in magnitude, only differing in sign. In a rough test like this, deviations of +/- 10 % should be tolerated. If deviations greater than this are encountered, the following tests might help.

5.1 Testing the pyranometer

As a first test we recommend that you check the sensor impedance. It should have a nominal value between 20 and 200 Ohm. 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. Bear in mind that the response takes about one minute. Small deviations from zero are possible; this is caused by thermal effects like touching the pyranometer with your hand. The latter effect can be demonstrated by deliberately heating the pyranometer with your hand. Another cause might be the zero offset of the data logger. When this is the case, the same offset will also be present when the data logger is short-circuited with a 200 Ohm resistor. This is an amplifier error from the data logger. This amplifier error should not be larger than 5 Watts per square meter. If the amplifier error 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 Watts per square metre, which is roughly equal to normal outdoor daylight conditions, and the sensitivity of the pyranometer is 15 µV per Watt per square metre, the expected output range of the pyranometer is 1500 times 15 which is equal to 22500 µV, or 0.0225 Volts). You can calculate the radiation intensity by dividing the pyranometer output (0.0225 volts) by the calibration factor (0.000015 volt per watt per square metre). Still no faults found? Your pyranometer is probably doing fine.

5.2 Testing of the pyrgeometer

It is assumed that the data logger (amplifier) circuit is the same as the one used for pyranometer, and that its zero offset is no more than a few watts per square metre, let us say 5 Watts per square metre just as an example, (see test in 5.1).

The CNR 4 body and ambient air should be at the same temperature as much as possible. 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, we suggest putting your hand in front of the pyrgeometer. The thermal radiation will cause pyrgeometer to generate a positive voltage when the hand's surface temperature 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 of 1.1.6.5). The radiation that is emitted by the hand can be calculated by dividing the pyrgeometer output by the calibration factor, and subsequently correcting for the temperature, according to equation 1.2. Still no faults found? Your pyrgeometer is probably doing fine.

5.3 Testing the Pt-100

Using a meter, which measures resistance, you can check the operation of the Pt-100. If connected properly, the resistance of two opposite wires of the Pt-100 should be measured. The value can be read in the table 1.1 and should be above 100 Ohms (cable resistance should measure about 0.1 ohms per metre cable). When in doubt the thermistor resistance (temperature) can be checked as well for reference

5.4 Testing the thermistor

Using a meter, which measures resistance, you can check the operation of the thermistor. If connected properly, the resistance of two wires of the thermistor should be measured. The value can be read in the table 1.2 and should be around 10.000 Ohms for 25 °C. (cable resistance should measure about 0.1 ohms per metre cable). When in doubt the Pt-100 resistance (temperature) can be checked as well for reference

5.5 Testing the Heater

The optional CNF 4 consists of a heater and ventilator. Using a meter, which measures resistance you can check the operation of the heating resistor. The value should be around 15 Ohm. (Cable resistance should measure about 0.1 ohms per metre cable).

Using a meter, which measures resistance, you can check the operation of the heater. If connected properly, the resistance of two opposite wires of the heater should measure about 8 ohms (this includes the cable resistance for the standard 10-meter cable). The cable resistance should measure about 0.1 ohms per metre cable. An infinite resistance reading indicates the likelihood of a broken wire, or cable.

5.6 Testing the Ventilator

The impedance of the ventilator motor can be checked to tested for reference The value should be around 30 Ohms (cable resistance should measure about 0.1 ohms per metre cable). In this case a correct value is measured this does not guarantee proper operation. It is possible the ventilator is stalled by an object blocking the fan. This can be checked by removing the cover and filter and inspecting the rotation of the fan by hand.

6 CMB 1 OPTIONAL MOUNTING BRACKET

The CMB 1 mounting bracket is ideal for mounting the CNR 4 to a pole or wall. The stainless steel construction ensures a durable fixation to almost any object. The top U bolts allow rotation of the CNR 4 rod, while the extra screw under the front U bolt allows the rod to tilt. All mounting material for fixation to a horizontal or vertical pole is included. The 2 different sized pairs of U bolts allow for pole sizes between 22 mm and 60 mm. Wall mounting bolts and or plugs are not included.

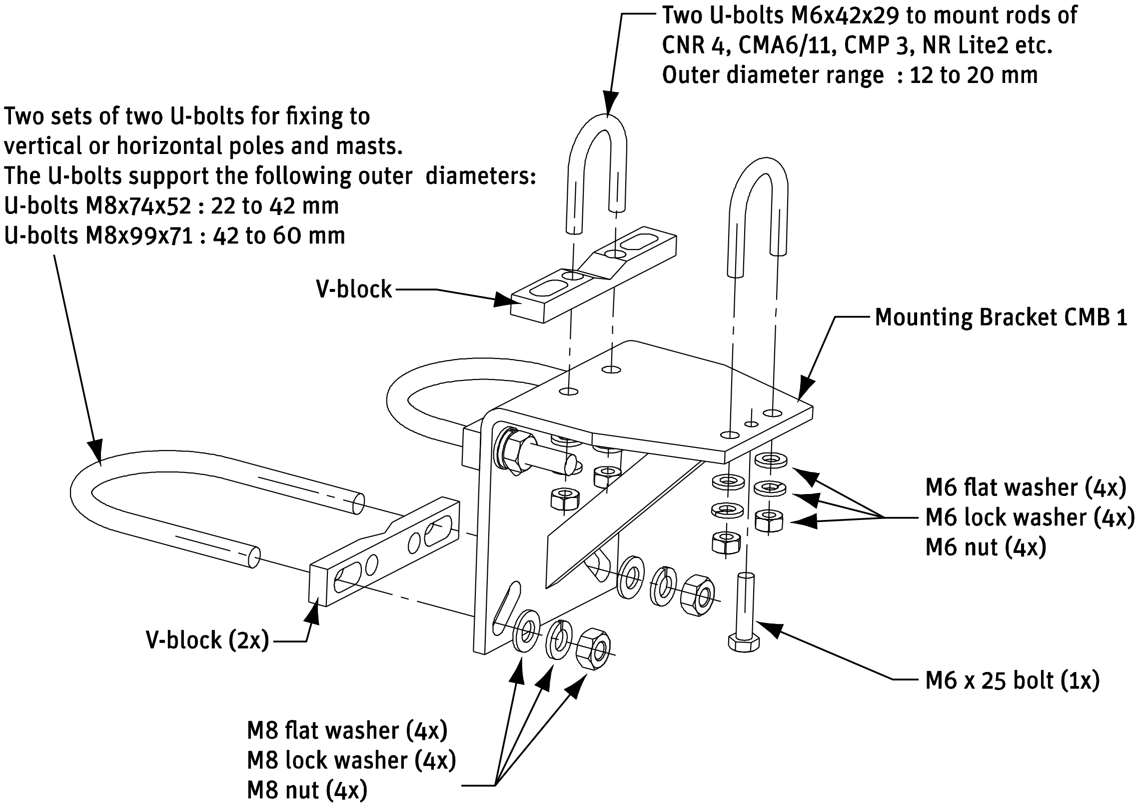


Fig 7.1 CMB 1 mounting bracket with mounting material

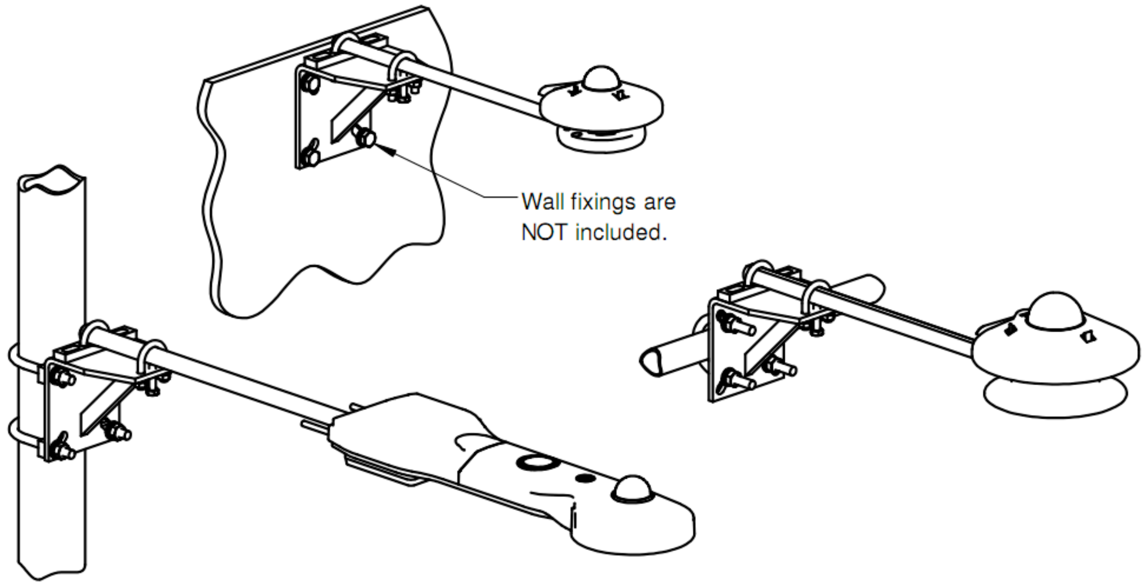


Fig 7.2 CMB 1 mounting examples with CNR 4, albedometer and pyranometer

7 DELIVERY

Check the contents of the shipment for completeness (see below) and note whether any damage has occurred during transport. If there is damage, a claim should be filed with the carrier immediately. In this case, or if the contents are not complete, your dealer should be notified in order to facilitate the repair or replacement of the instrument.

The CNR 4 Net-Radiometer delivery will include the following items:

A delivery includes:	One CNR 4 One mounting rod Two cables Two drying cartridges Four calibration values on 2 calibration sheets (long and short wave) One CD with instruction manual
Optional CNF 4	One CNF 4 mounted to the CNR 4 One (4 wire) cable

Unpacking

Keep the original packaging for later shipments (e.g. recalibration)!

Although all sensors are weatherproof and suitable for harsh ambient conditions, they do partially consist of delicate mechanical parts. It is recommended to use the original shipment packaging to safely transport the equipment to the measurement site.

8 RECALIBRATION SERVICE

Pyranometers, UV-meters, pyrgeometers, Net radiometers & Sunshine duration meters

Kipp & Zonen solar radiation measurement instruments comply with the most demanding international standards. In order to maintain the specified performance of these instruments, Kipp & Zonen recommends calibration of their instruments at least every two years.

This can be done at the Kipp & Zonen factory. Here, recalibration to the highest standards can be performed at low cost. Recalibration can usually be performed within four weeks. If required, urgent recalibration can be accomplished in three weeks or less (subject to scheduling restrictions). Kipp & Zonen will confirm the duration of recalibration at all times. Please note that special quantity recalibration discounts are available.

Please contact us at:

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For all returns, the customer must fill out a "Statement of Product Cleanliness and Decontamination" form and comply with the requirements specified in it. The form is available from our website at *www.campbellsci.com/repair*. A completed form must be either emailed to *repair@campbellsci.com* or faxed to (435) 227-9106. Campbell Scientific is unable to process any returns until we receive this form. If the form is not received within three days of product receipt or is incomplete, the product will be returned to the customer at the customer's expense. Campbell Scientific reserves the right to refuse service on products that were exposed to contaminants that may cause health or safety concerns for our employees.

Safety

DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND **TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC**. FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at www.campbellsci.com or by telephoning (435) 227-9000 (USA). You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified engineer. If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

General

- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations, such as those of the FAA in the USA.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a **hardhat** and **eye protection**, and take **other appropriate safety precautions** while working on or around tripods and towers.
- **Do not climb** tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

Utility and Electrical

- **You can be killed** or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in **contact with overhead or underground utility lines**.
- Maintain a distance of at least one-and-one-half times structure height, 20 feet, or the distance required by applicable law, **whichever is greater**, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.

Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

WHILE EVERY ATTEMPT IS MADE TO EMBODY THE HIGHEST DEGREE OF SAFETY IN ALL CAMPBELL SCIENTIFIC PRODUCTS, THE CUSTOMER ASSUMES ALL RISK FROM ANY INJURY RESULTING FROM IMPROPER INSTALLATION, USE, OR MAINTENANCE OF TRIPODS, TOWERS, OR ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.

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EC150 CO_2/H_2O Open-Path Gas Analyzer

1. Introduction

The EC150 is an in situ, open-path, mid-infrared absorption gas analyzer that measures the absolute densities of carbon dioxide and water vapor. The EC150 was designed for open-path eddy covariance flux measurements as part of an open-path eddy covariance measurement system. It is most often used in conjunction with the CSAT3A sonic anemometer and thermometer, which measures orthogonal wind components along with sonically determined air temperature.

Before attempting to assemble, install or use the EC150, please study:

- Section 2, *Precautions* *(p. 1)*
- Section 3, *Initial Inspection* *(p. 2)*
- Section 6, *Installation* *(p. 11)*

Greater detail is available in the remaining sections.

Other manuals that may be helpful include:

- *CR3000 Micrologger Operator's Manual*
- *CFM100 CompactFlash Module Instruction Manual*
- *NL115 Ethernet and CompactFlash Module Instruction Manual*
- *Application Note 3SM-F, PC/CF Card Information*
- *LoggerNet Instruction Manual, Version 4.1*
- *CSAT3 Three Dimensional Sonic Anemometer Manual*
- *ENC10/12, ENC12/14, ENC14/16, ENC16/18 Instruction Manual*
- *CM106 Tripod Instruction Manual*
- *Tripod Installation Manual Models CM110, CM115, CM120*

2. Precautions

- DANGER:
  - The scrubber bottles in the EC150 contain sodium hydroxide (NaOH) and anhydrous magnesium perchlorate ($Mg(ClO_4)_2$). Do not attempt to access or remove these chemical bottles before reviewing Section 8.5, *Replacing CO2 Scrubber Bottles* *(p. 33)*.
    - Avoid direct contact with the chemicals.
    - Ensure your work area is well ventilated and free of reactive compounds and combustible materials.
    - Store used chemical bottles in a sealed container until disposal.
    - Dispose of chemicals and bottles properly.
- WARNING:
  - Do not carry the EC150 by the arms or the strut between the arms. Always hold it by the mounting base where the upper and lower arms connect.

  - Handle the EC150 carefully. The optical source may be damaged by rough handling, especially while the analyzer is powered.
  - Overtightening bolts will damage or deform the mounting hardware.
- CAUTION:
  - Grounding the EC100 measurement electronics is critical. Proper grounding to Earth will ensure maximum electrostatic discharge (ESD) and lightning protection and improve measurement accuracy.
  - Do not connect or disconnect the gas analyzer or sonic anemometer connectors while the EC100 is powered.
  - Resting the analyzer on its side during the zero-and-span procedure may result in measurement inaccuracy.

3. Initial Inspection

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

Model numbers are found on each component. On cables, the model number is located both on the sensor head and on the connection end of the cable. Check this information against the enclosed shipping document to verify the expected products and that the correct accessories are included.

4. Overview

4.1 General

The EC150 measures absolute densities of carbon dioxide and water vapor. The EC150 analyzer was designed specifically for open-path, eddy covariance flux measurement systems. The EC150 gas analyzer head connects directly to Campbell Scientific's EC100 electronics. The EC150 is commonly used with a CSAT3A sonic anemometer head. When the CSAT3A is used in conjunction with the EC150, the EC100 can make gas and wind measurements simultaneously. Similarly, the EC100 can simultaneously record measurements from temperature sensors and a pressure transducer.

The EC150 analyzer has a rugged, aerodynamic design with low power requirements, making it suitable for field applications including those with remote access.

4.2 Features

The EC150 has been designed specifically to address issues of aerodynamics, power consumption, spatial displacement, temporal synchronicity, and to minimize sensitivity to environmental factors.

The analyzer windows are scratch resistant and treated with a durable hydrophobic coating that facilitates shedding of raindrops from critical surfaces. The coating also impedes the accumulation of dust and deposits, and keeps the surfaces cleaner over longer periods of time. To minimize data loss due to humid environments, the EC150 is provided with window wicks that draw moisture away from the measurement path and are easily replaceable during routine maintenance.

- Unique design contains little obstruction surrounding the sample volume
- 5W total power consumption
- Synchronously samples data from the EC150 and CSAT3A
- Automatically configured via a Campbell Scientific datalogger
- Minimal spatial displacement between sample volume and CSAT3A
- Slim housings located away from the measurement volume to minimize body heating effects due to solar radiation
- Symmetrical design for improved flux measurements without a bias for updrafts and downdrafts
- Slanted windows to prevent water from pooling and blocking the optical path
- Scratch-resistant windows for easy cleaning
- Hydrophobic coating on windows to repel water, dust and pollen and to prolong time between window cleaning
- Equipped with internal window heaters to keep the windows surfaces free from condensation and frost – especially beneficial in humid environments or conditions with frequent frost formation
- Optical layout that is not affected by solar interference
- Mercury cadmium telluride (MCT) detector for low-noise measurements and long-term stability of factory calibration
- Chopper housing without thermal control results in significantly reduced power consumption
- Any CSAT3A with serial numbers of 2000 or greater have an updated design with more rigid geometry for improved sonic-temperature accuracy and stability, and with a more stream-lined, aerodynamic mounting block

4.3 Gas Head Memory

The EC100 electronics (see Section 4.6, *EC100 Electronics Module (p. 4)*) are universal for the entire Campbell Scientific family of gas analyzer heads. In addition to the EC150 gas analyzer head, the IRGASON or EC155 gas analyzer head can be connected to the EC100 electronics (one gas analyzer head per EC100). All sensor heads have dedicated, non-volatile memory, which stores all calibration, configuration, and setting information. The EC100 electronics can be mated with any of these gas analyzers or an optional CSAT3A sonic anemometer head.

4.4 Self-diagnostics and Data Integrity

EC100 electronics provide an extensive set of diagnostic tools which include warning flags, status LEDs, and signal strength outputs to identify instrument malfunctions and warn the user of compromised data. These flags are further described in Section 8.7.4, *Diagnostic Flags (p. 36)*. The flags also prompt the user when the instrument needs servicing and can facilitate troubleshooting in the field. The EC150 outputs the optical strength of signals, which can be used to filter data when the path of the instrument is obstructed due to precipitation or dirty windows.

4.5 Field Zero/Span Capabilities

A zero/span for CO_2 and H_2O can be accomplished in the field with an optional shroud. The shroud allows the flow of a gas with known composition in the measurement path of the analyzer to account for instrument drift and changing environmental conditions.

4.6 EC100 Electronics Module

The EC100 electronics module (shown in FIGURE 4-1) controls the EC150 and optional CSAT3A sonic anemometer head. The EC100 synchronizes measurements and processes data from the EC150 and the CSAT3A.

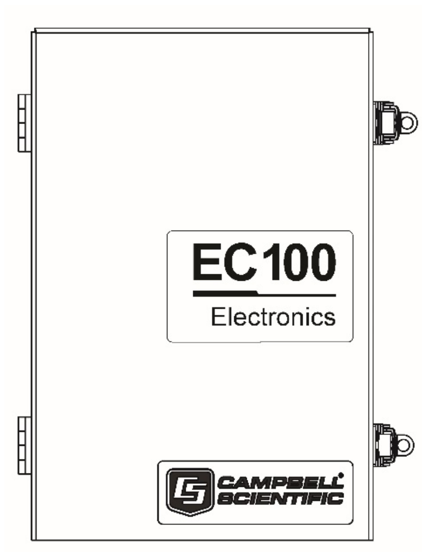

FIGURE 4-1. EC100 electronics module

4.6.1 EC100 Communications and Control

The EC100 supports several serial communication interfaces, including USB, RS-485, and Synchronous Device for Measurement (SDM). SDM is a Campbell Scientific communication protocol that allows synchronized measurement and rapid communication between a Campbell Scientific datalogger and multiple devices including the EC150. Although nearly all Campbell Scientific dataloggers support SDM, only the CR1000, CR3000, and CR5000 dataloggers support communications with the EC100 electronics with the **EC100()** instruction.

The SDM protocol allows the user to configure and control the analyzer through CRBasic instructions in the datalogger. For example, in solar-powered applications with limited daylight, battery power can be conserved by programming the datalogger to turn off the EC150 at night or when conditions are not suitable for eddy-covariance measurements. The datalogger can also be used to change settings such as bandwidth, and perform the zero/span procedure in the field.

4.6.2 EC100 Outputs

The EC100 outputs data in one of four types: SDM, USB, RS-485, or analog. In general, Campbell Scientific recommends that SDM be used if a Campbell Scientific datalogger is collecting data. However, RS-485 output is recommended over SDM if cable lengths exceed 100 meters. If a PC is being used as the data collection platform, USB and RS-485 are suitable outputs.

Information for SDM, the preferred output, is detailed below. See Appendix C, *Alternate EC100 Outputs* (p. C-1), for USB, RS-485, and analog outputs.

4.6.2.1 SDM Output

To use SDM data output, connect an SDM communications cable from the EC100 (see Section 6.3, *Wiring and Connections* *(p. 22)*) to a CR1000, CR3000, or CR5000 datalogger. On CR1000 dataloggers, the SDM protocol uses ports C1, C2, and C3. These are multipurpose control ports that are SDM-activated when an SDM instruction is used in the datalogger program. On CR3000 and CR5000 dataloggers, the SDM protocol uses SDM-dedicated ports SDM-C1, SDM-C2, and SDM-C3.

Each SDM device on the SDM bus must have a unique address. The EC150 has a factory default SDM address of 1, but may be changed to any integer value between 0 and 14 (see Appendix A.2.1, *SDM Address* *(p. A-2)*).

The sample rate for SDM output is determined by the datalogger program. Data are output from the EC100 when a request is received from the datalogger (for example, a *prompted* output mode). The number of data values sent from the EC100 to the datalogger is also set by the user in the datalogger program. CRBasic, the programming language used by Campbell Scientific dataloggers, uses the **EC100()** instruction to get data from an EC150. This instruction is explained in greater detail under Appendix A, *EC150 Settings* *(p. A-1)*, and in Appendix A.5, *EC100 Configure() Instruction* *(p. A-9)*.

4.7 Automatic Heater Control

An advantage of the EC150's low power consumption (5W) is that the instrument remains at a temperature very close to ambient air temperature, which is an important feature for eddy-covariance measurements. Under some environmental conditions, however, the analyzer can become colder than ambient air temperature which may increase the likelihood of frost or condensation building on the optical windows. This will affect signal strength. The EC150 design includes internal heaters located at the optical windows, which aid in minimizing data loss during these specific environmental conditions.

An automatic heater control algorithm can be activated from either Device Configuration or ECMon by putting in a value of −2, or deactivated by putting in a value of −1.[i] The algorithm uses the internal heaters to maintain a temperature that is a couple of degrees above the ambient dewpoint (or frost point) to prevent condensation and icing from forming on the surface of the optical windows.

The heater control will be disabled under any of the following conditions:

- Temperature of the detector housing is outside the −35 to 55 °C range
- Temperature of the source housing exceeds 40 °C
- Ambient temperature is outside the −35 to 55 °C range
- The supply voltage is below 10 V

---

[i] Automatic heater control is available in EC100 OS version 4.07 or greater and is turned on by default starting with the OPEC program version 3.2.

The algorithm uses the following environmental parameters to control the heater:

- Analyzer body temperature, measured inside the source housing (heater control does not allow the body temperature to drop below ambient air temperature)
- Ambient relative humidity (in humidity greater than 80% heaters will try to maintain internal temperature 2 degrees warmer than ambient)
- CO_2 signal level (1 min average CO_2 signal level; below 0.7 will cause the heater to turn on maximum power until the signals recover)
- Average slope of the CO_2 signal level over 1 min
- Standard deviation of the CO_2 signal over 1 min

4.8 Theory of Operation

The EC150 is a non-dispersive mid-infrared absorption analyzer. Infrared radiation is generated in the upper arm of the analyzer head before propagating along a 15.0 cm (5.9 in) optical path as shown in FIGURE 5-1. Chemical species located within the optical beam will absorb radiation at characteristic frequencies. A mercury cadmium telluride (MCT) detector in the lower arm of the gas analyzer measures the decrease in radiation intensity due to absorption, which can then be related to analyte concentration using the Beer-Lambert Law:

$$P = P_o e^{-\varepsilon c l}$$

where:

P = irradiance after passing through the optical path
P_o = initial irradiance, ε is molar absorptivity, c is analyte concentration, and
l = path length.

In the EC150, radiation is generated by applying constant power to a tungsten lamp which acts as a 2200 K broadband radiation source. Specific wavelengths are then selected using interference filters located on a spinning chopper wheel. For CO_2 measurements, light with a wavelength of 4.3 µm is selected as that corresponds to the asymmetric stretching vibrational band of the CO_2 molecule. For H_2O, the symmetric stretching vibration band is 2.7 µm.

The EC150 is a dual wavelength, single-beam analyzer. This design eliminates the need for a separate reference cell and detector. Instead, the initial intensity of the radiation is calculated by measuring the intensity of nearby, non-absorbing wavelengths (4.0 µm for CO_2 and 2.3 µm for H_2O). These measurements mitigate measurement inaccuracy that may arise from source or detector aging, as well as for low-level window contamination. For window contamination that reduces the signal strength below 0.8, windows should be cleaned as described in Section 8.3, *Cleaning Analyzer Windows* *(p. 32)*.

The chopper wheel spins at a rate of 50 revolutions per second and the detector is measured 1024 times per revolution, resulting in a detector sampling rate of 51.2 kHz. The detector is maintained at −40 °C using a three-stage thermoelectric cooler and is coupled to a low noise pre-amp module.

The EC100 electronics module digitizes and process the detector data (along with ancillary data such as ambient air temperature and barometric pressure) to give the CO_2 and H_2O density for each chopper wheel revolution (50 Hz). This high measurement rate is beneficial when there is a need to synchronize the gas measurements with additional sensors measured by the datalogger. To prevent aliasing, measurements are filtered to a bandwidth that is specified by the user.

5. Specifications

5.1 Measurements

To compute carbon dioxide and water vapor fluxes using the eddy-covariance method, the EC150 and a sonic anemometer measure:

- Absolute carbon dioxide density ($mg \cdot m^{-3}$)
- Water vapor density ($g \cdot m^{-3}$)
- Three-dimensional wind speed ($m \cdot s^{-1}$; requires the CSAT3A)
- Sonic air temperature (°C; requires the CSAT3A)
- Air temperature (°C; requires an auxiliary temperature probe)
- Barometric pressure (kPa; requires an auxiliary barometer)

These measurements are required to compute carbon dioxide and water vapor fluxes using the:

- Standard outputs:
  - CO_2 density, H_2O density
  - Gas analyzer diagnostic flags
  - Air temperature
  - Air pressure
  - CO_2 signal strength
  - H_2O signal strength
- Additional outputs from auxiliary instruments:
  - u_x, u_y, and u_z orthogonal wind components (requires the CSAT3A)
  - Sonic temperature (requires the CSAT3A, and is based on the measurement of c, the speed of sound)
  - Sonic diagnostic flags (from the CSAT3A)

Datalogger Compatibility:	CR6 CR1000 CR3000 CR5000
Measurement	
Rate:	60 Hz
Output bandwidth[ii]:	5, 10, 12.5, 20, or 25 Hz
Output rate[ii]:	10, 25 or 50 Hz
Operating temperature:	–30 to 50 °C

[ii] user selectable

Gas analyzer

Measurement precision[iii]

CO_2 density:	0.2 $mg \cdot m^{-3}$ (0.15 $\mu mol \cdot mol^{-1}$)
H_2O density:	0.004 $g \cdot m^{-3}$ (0.006 $mmol \cdot mol^{-1}$)

Factory calibrated range

CO_2:	0 to 1000 $\mu mol \cdot mol^{-1}$
H_2O:	0 to 72 mmol/mol (37 °C dewpoint)
Temperature:	–30 to 50 °C
Barometric pressure:	70 to 106 kPa

CO_2 performance

Zero max drift[iv]**:**	±0.55 $mg \cdot m^{-3} \cdot °C^{-1}$ (± 0.3 $\mu mol \cdot mol \cdot °C^{-1}$)
Gain drift:	±0.1% of reading$\cdot °C^{-1}$ (maximum)
Sensitivity to H_2O:	±1.1 x 10^{-4} $\mu mol\ CO_2 \cdot mol^{-1}\ H_2O$ (max)

H_2O performance

Zero max drift[iv]**:**	±0.04 $g \cdot m^{-3} \cdot °C^{-1}$ (± 0.05 $mmol \cdot mol^{-1} \cdot °C^{-1}$)
Gain drift:	±0.3% of reading$\cdot °C^{-1}$ (maximum)
Sensitivity to CO_2:	±0.1 mol $H_2O \cdot mol^{-1}\ CO_2$ (maximum)

CSAT3A sonic measurement precision[v]

u_x:	1.0 $mm \cdot s^{-1}$
u_y:	1.0 $mm \cdot s^{-1}$
u_z:	0.5 $mm \cdot s^{-1}$
Sonic temperature:	0.025 °C

CSAT3A sonic accuracy[vi]

Offset error

u_x, u_y:	< ±8 $cm \cdot s^{-1}$
u_z:	< ±4 $cm \cdot s^{-1}$

Gain error

Wind vector ±5° horizontal:	< ±2% of reading
Wind vector ±10° horizontal:	< ±3% of reading
Wind vector ±20° horizontal:	< ±6% of reading

[iii] noise rms, assumes:
- 25 °C
- 85 kPa
- 14 $g \cdot m^{-3}$ H_2O
- 597 $mg \cdot m^{-3}$ CO_2
- 25 Hz bandwidth

[iv] –30 to 50 °C

[v] noise rms

[vi] assumes:
- –30 to 50 °C
- wind speed <30 $m \cdot s^{-1}$
- azimuth angles between ±170°

CSAT3 sonic reporting range

Full scale wind:	±65.6 m/s
Sonic temperature:	−50 to 60 °C

Auxiliary sensors[vii]

Barometer

Internal basic barometer

Accuracy

−30 to 0 °C:	±3.7 kPa at −30 °C, falling linearly
to	±1.5 kPa at 0 °C
0 to 50 °C:	±1.5 kPa
Measurement rate:	10.0 Hz

Optional enhanced barometer

Manufacturer:	Vaisala
Model:	PTB110
Accuracy:	±0.15 kPa (−30 to 50 °C)
Measurement rate:	1.0 Hz

EC150 temperature sensor

Manufacturer:	BetaTherm
Model:	100K6A1A Thermistor
Accuracy:	±0.15 °C (−30 to 50 °C)

5.2 Output Signals

The EC100 electronics can output data from the EC150 by several means.

- Campbell Scientific SDM
- RS-485
- USB
- Analog out

Synchronous Device for Measurement communications protocol, or SDM, is a proprietary serial interface developed by Campbell Scientific for communication between a datalogger and a peripheral or sensor. In almost all cases, SDM is the preferred communications protocol with the exception of measurement heights requiring cable lengths greater than 100 meters. In this case, RS-485 output is recommended. See Section 4.6.2.1, *SDM Output* *(p. 5)*, for details on SDM output, see Appendix C, *Alternate EC100 Outputs* *(p. C-1)*, for greater detail on RS-485, USB, or analog outputs.

SDM communications are output as the FLOAT data type.

5.3 Physical Description

Optical measurement path length:	15.37 cm (6.05 in)
Spatial separation from CSAT3A sampling volume:	5.0 cm (2.0 in)

vii refer to manufacturer's product brochure or manual for details

Dimensions

Head housing diameter:	3.2 cm (1.3 in)
Head length:	29.7 cm (11.7 in)
EC100 enclosure:	24.1 cm x 35.6 cm x 14 cm (9.5 in x 14.0 in x 5.5 in)

Weight

Analyzer and cable:	2 kg (4.4 lbs)
EC100 electronics and EC100 enclosure:	3.2 kg (7.0 lbs)

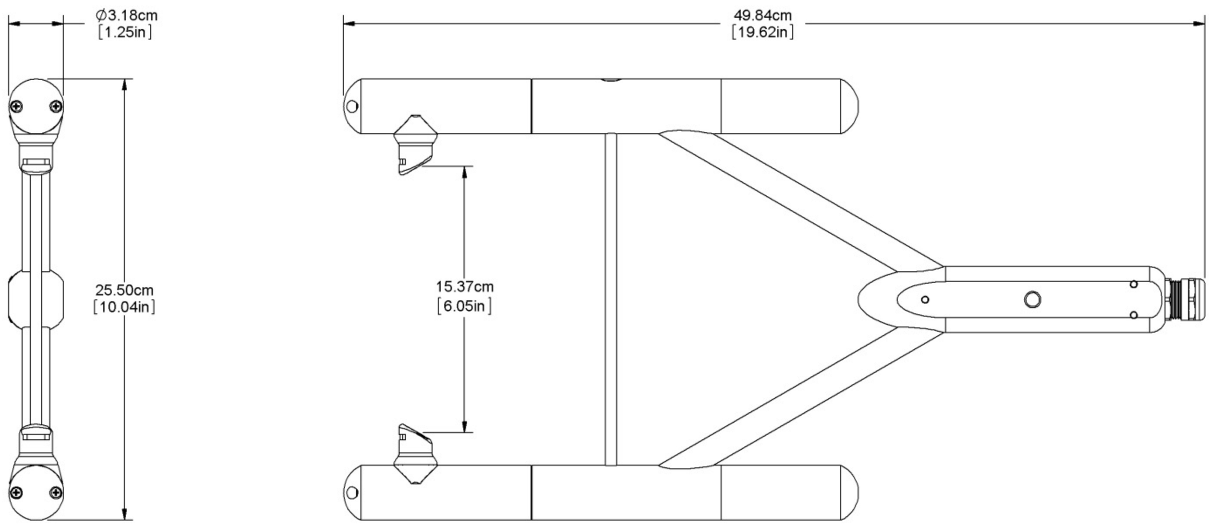

FIGURE 5-1. Optical path and envelope dimensions of EC150 analyzer head

5.4 Power Requirements

Voltage supply:	10 to 16 Vdc
Power at 25 °C excluding CSAT3A:	4.1 W
Power at 25 °C including CSAT3A:	5.0 W
Power at 25 °C in power-down mode (CSAT3A fully powered and EC150 off):	3.0 W

6. Installation

6.1 Orientation

During operation, the EC150 should be positioned vertically (±15°) so that the product label reads right side up and the upper arm (source) is directly above the lower arm (detector). If the sensor is being used with a sonic anemometer, the anemometer should be leveled and pointed into the prevailing wind to minimize flow distortion from the analyzer's arms and other supporting structures.

6.2 Mounting Analyzer to Support Hardware

The EC150 is supplied with mounting hardware to attach it to the end of a horizontal pipe of 3.33 cm (1.31 in) outer diameter, such as the CM202 (pn 17903), CM204 (pn 17904), or CM206 crossarm (pn 17905).

There are three different mounting brackets for the EC150. A head only mounting bracket (pn 26785), the EC150/CSAT3A mounting bracket (pn 26786) that was shipped with any CSAT3A with a serial number of less than 2000, and a new EC150/CSAT3A mounting bracket (pn 32065) that ships with any CSAT3A with a serial number of 2000 or greater. The three mounting brackets are shown in FIGURE 6-1.

The CSAT3A sonic anemometer head is an option when ordering the EC150 and the appropriate mounting bracket is included with the EC150 depending on if the CSAT3A is ordered. If the user is already in possession of a CSAT3A and intends to use it with the EC150, the proper mounting bracket should be specified at time of order.

NOTE The screws and bolts for either mounting bracket are easily lost in the field. Replacements are available through Campbell Scientific or can be sourced elsewhere. To use bracket 26785, use pn 15807 (screw #8-32 x 0.250 socket head) and pn 26712 (screw 3/8-16 x 0.625 hex cap). To use bracket 26786, use pn 26711 (screw #8-32 x 0.250 shoulder cap) and pn 26712 (screw 3/8-16 x 0.625 hex cap). To use bracket 32065, use pn 10393 (screw 1/4-20 X 0.375 cap socket) and pn 26712 (screw 3/8-16 x 0.625 hex cap).

FIGURE 6-1. Three mounting bracket options for the EC150: pn 26785 is for the EC150 head only, pn 26786 is for the EC150 head with CSAT3A of serial numbers less than 2000, and pn 32065 is for the EC150 head with CSAT3A serial numbers 2000 and greater.

The mounting brackets for the EC150 with CSAT3A, pn 26786 and pn 32065, allow the EC150 optical path to have various spatial separation from the CSAT3A sonic volume. Depending on the position, the spatial separation can range from 5.0 cm in the EC150's most fore position to 9.7 cm in the most aft position, as illustrated in FIGURES 6-3 and 6-4. This change in positioning allows a small but significant difference in the flux attenuation ratio.

The position of the EC150 relative to the CSAT3A should be determined by the end user based on the measurement of interest. For applications where spatial separation is of most importance, such as when the instrument is close to the ground, moving the EC150 in the most forward direction will yield the most collocated arrangement. For taller measurement applications and where flow distortion may be a measurement concern due to larger angles of attack and where spatial separation requirements become relaxed due to predominately larger eddies, the EC150 should be mounted in the most aft position. The effect of spatial separation on flux attenuation is greatest at lower measurement heights as shown in FIGURE 6-2. A Campbell Scientific application engineer can help determine the best positioning of the EC150 relative to the CSAT3A in scenarios where the measurement height is below 10 meters.

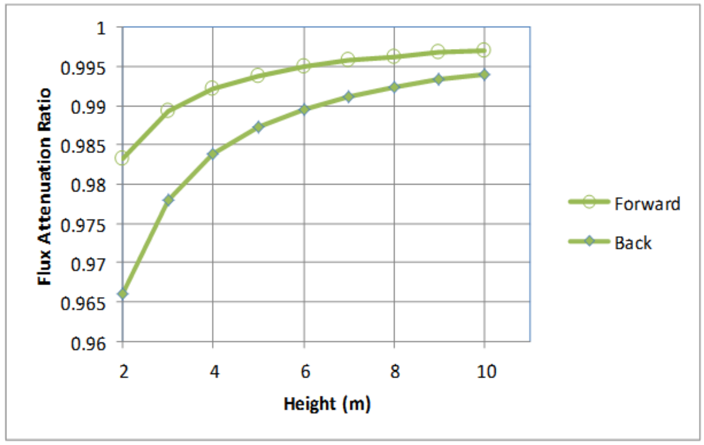

FIGURE 6-2. Changes in flux attenuation ratio relative to sensor height at the most fore and aft positions

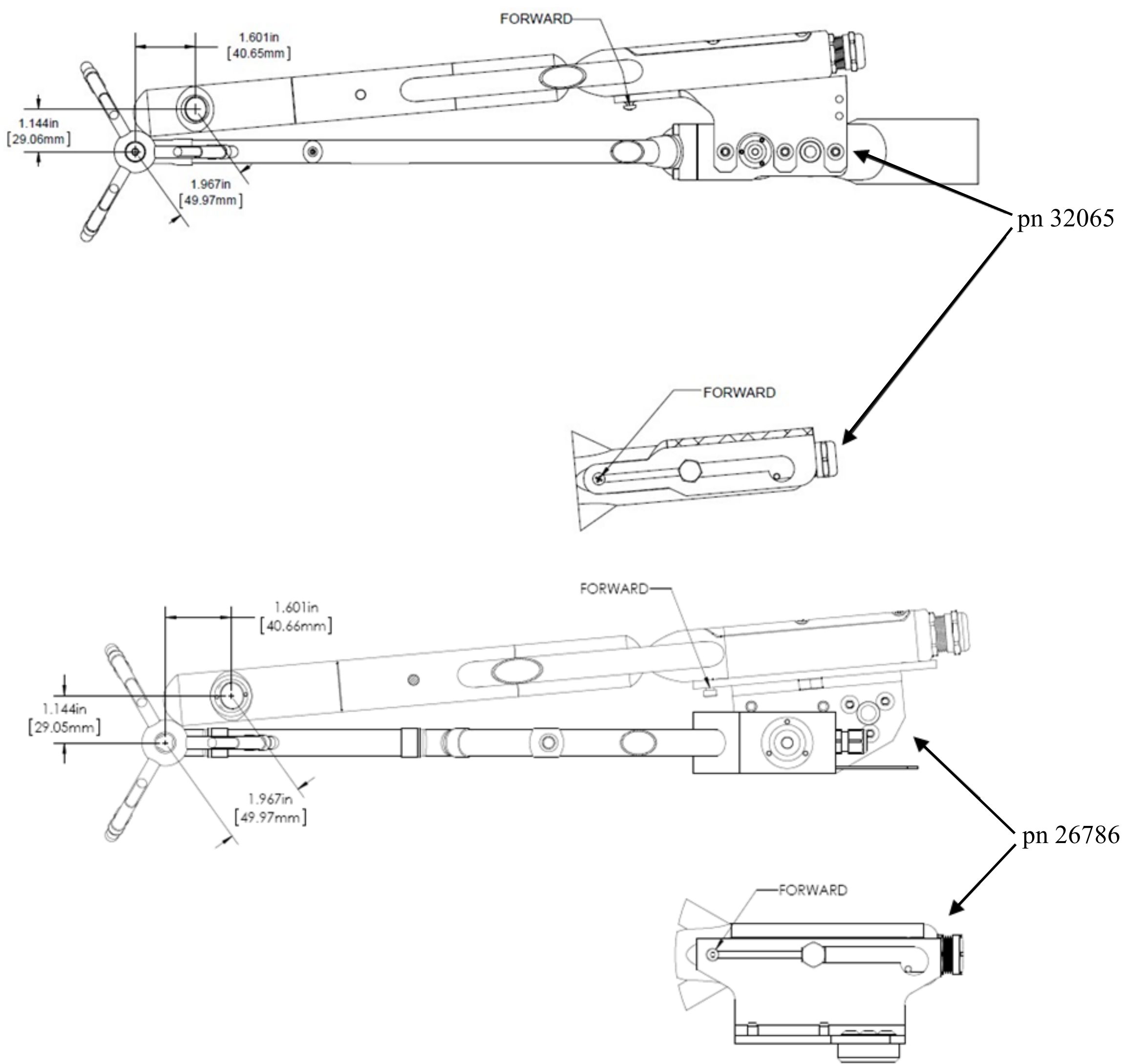

FIGURE 6-3. The most forward mounting position of the EC150 relative to the CSAT3A, resulting in a 4.9 cm sensor separation. The top images show the mounting with the current CSAT3A (CSAT3A serial numbers greater than 2000), while the bottom images show the mounting with the original version CSAT3A (serial numbers less than 2000).

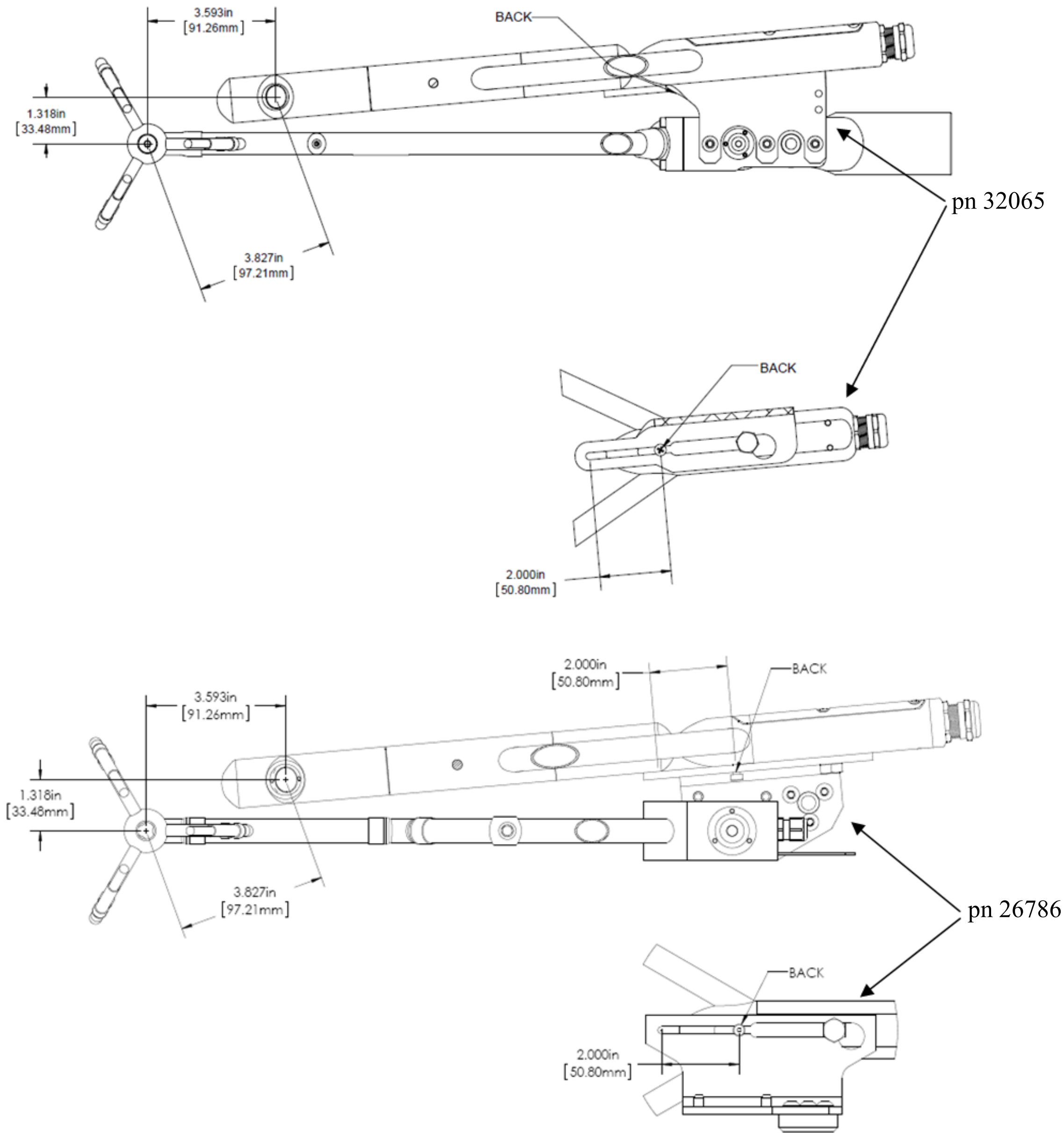

FIGURE 6-4. The most aft (back) mounting position of the EC150 relative to the CSAT3A, resulting in a spatial separation of 9.7 cm. The top images show the mounting with the current CSAT3A (CSAT3A serial numbers greater than 2000), while the bottom images show the mounting with the original version CSAT3A (serial numbers less than 2000).

The following steps describe the normal mounting procedure. Refer to FIGURE 6-6 and 6-7 throughout this section.

6.2.1 Preparing the Mounting Structure

1. Secure a CM20X crossarm to a tripod or other vertical structure using a CM210 crossarm-to-pole bracket (pn 17767).
2. Point the horizontal arm into the direction of the prevailing wind.
3. Tighten all fitting set screws.

WARNING Do not carry the EC150 by the arms or the strut between the arms. Always hold the sensor by the block where the upper and lower arms connect.

6.2.2 Mounting EC150 with Optional CSAT3A

The guideline below gives general instructions for mounting an EC150 and optional CSAT3A to a mounting structure. The order of assembly will somewhat be determined by the user's application; primarily the height of the tower. Steps 6, 7, and 8 should be performed in sequential order.

Please refer to all steps and the referenced figure of this section before deciding on an assembly strategy. In general, Campbell Scientific suggests that if the equipment is to be mounted at heights above what can be reached while standing, to preassemble as much as possible and then hoist that assembly into a position to be mounted on the appropriate crossarm.

1. Attach CSAT3A to the proper mounting bracket according to the CSAT3A serial number.
   - If using a CSAT3A with current design (serial numbers 2000 and greater), attach the EC150/CSAT3A mounting bracket (pn 32065; see FIGURE 6-1) to the CSAT3A using the three included screws and then bolt the CM250 leveling mount (pn 26559) to the threaded hole of the CSAT3A sensor block.
   - If using a CSAT3A with original design (serial numbers less than 2000), align and tighten the bolt on the pn 26786 mounting bracket to the bottom of the threaded hole on the CSAT3A sensor block. Then bolt the CM250 leveling mount (pn 26559) to the threaded hole on the bottom of the pn 26786 mounting bracket.
2. Install the assembly to the end of the crossarm by fitting the CM250 leveling mount over the end of the crossarm.
3. Tighten the set screws on the leveling mount.
4. Install the EC150 gas analyzer head to the EC150/CSAT3A mounting bracket by tightening the mounting screw and loosely thread the mounting bolt into the analyzer head.
5. Align the analyzer parallel with the vertical plate of the mounting bracket and insert the mounting screw and bolt into the slot of the mounting bracket.
6. Carefully slide the analyzer forward to the desired position. For a more detailed discussion of positioning the EC150 relative to the CSAT3A, see Section 6.2, *Mounting Analyzer to Support Hardware* ***(p. 11)***.

CAUTION Avoid crashing the arms of the sensors together. The arms of the analyzer should slide in between the claws of the CSAT3A; the sonic head may need to be loosened and repositioned to do this.

8. Tighten bolts and check that the analyzer is oriented vertically such that the label is right-side-up and the upper arm (source) is directly above the lower arm (detector).

9. If the assembly is not level, slightly loosen the bolt that holds the mounting bracket on the leveling mount and adjust the assembly until the leveling bubble on the top of the CSAT3A head is within the bullseye. Retighten the bolt.

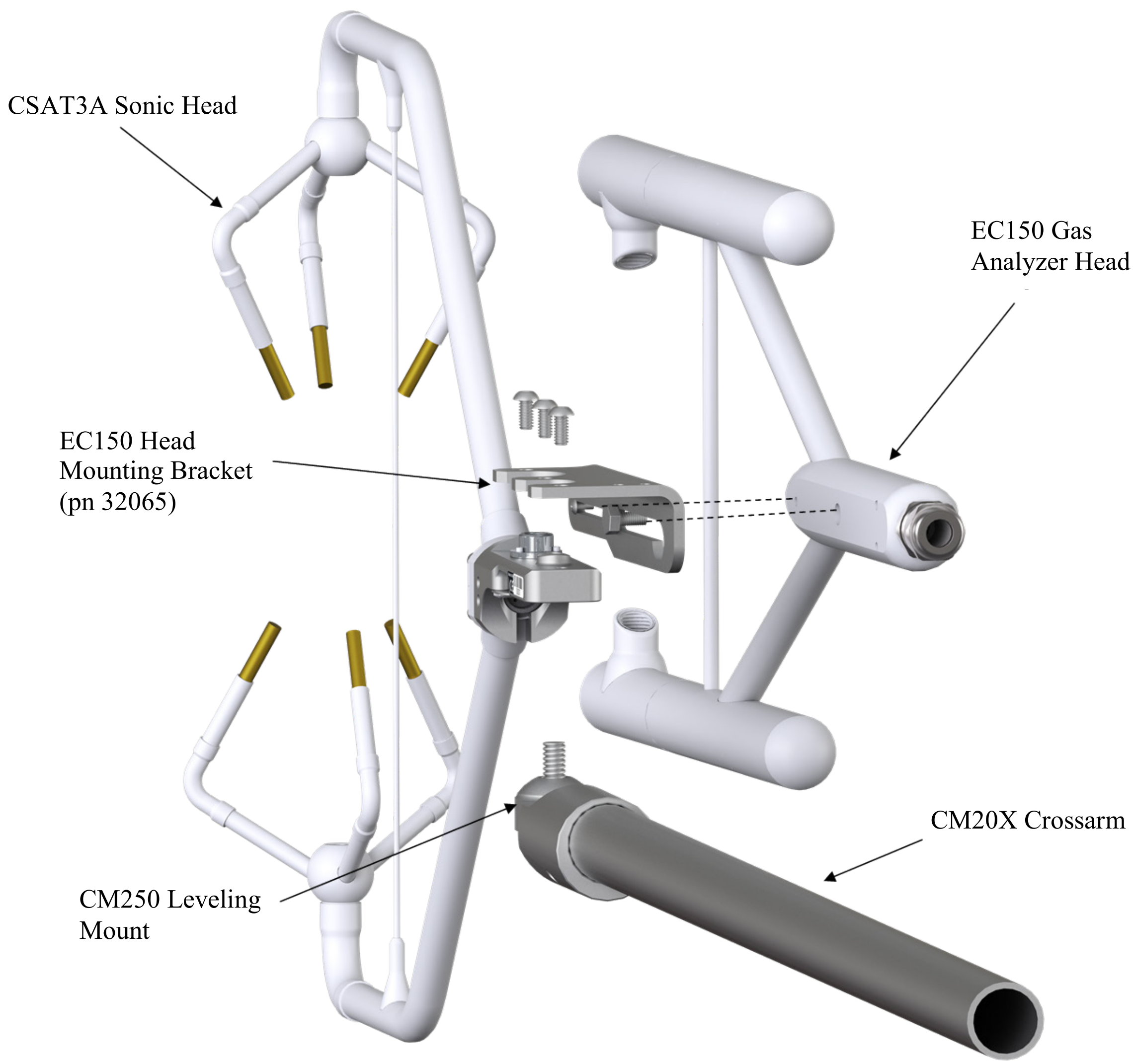

FIGURE 6-5. Exploded view of mounting CSAT3A and EC150 with mounting bracket 32065 (for CSAT3A with serial numbers 2000 and greater)

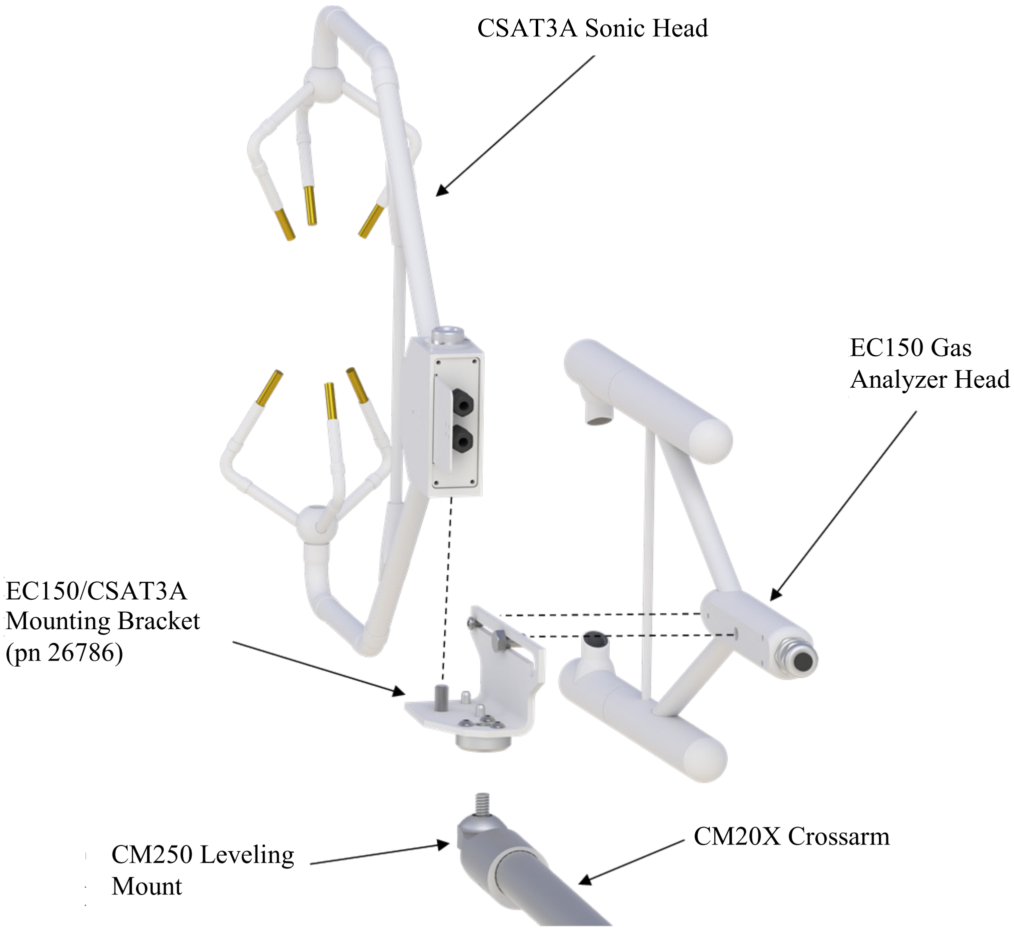

FIGURE 6-6. Exploded view of mounting CSAT3A and EC150 with mounting bracket 26786 (for CSAT3A with serial numbers less than 2000)

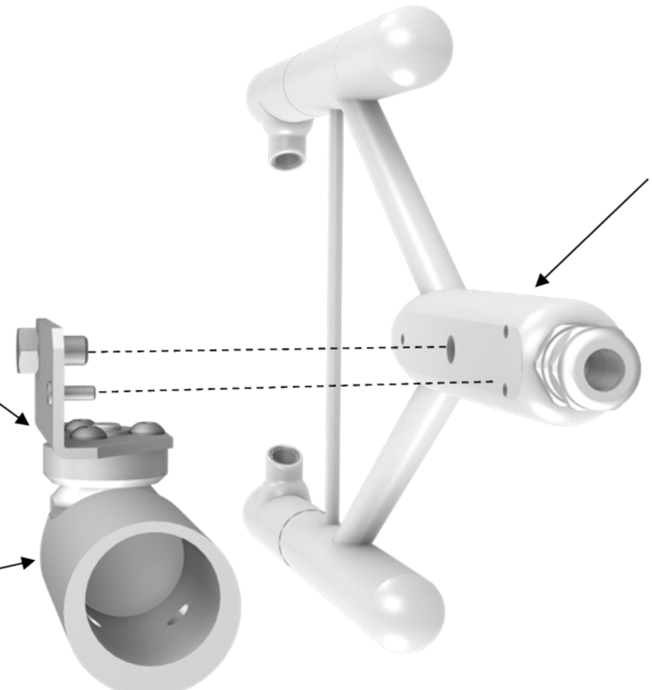

FIGURE 6-7. Exploded view of mounting the EC150 without the CSAT3A using mounting bracket pn 26785

CAUTION	Over-tightening bolts will damage or deform mounting hardware.

6.2.3 Mounting EC150 without CSAT3A

The instructions for mounting the EC150 without the CSAT3A should generally follow those in Section 6.2.2, *Mounting EC150 with Optional CSAT3A* *(p. 16)*, but requires the use of a different mounting bracket as described below and in Section 6.2, *Mounting Analyzer to Support Hardware* *(p. 11)*.

1. Bolt the EC150 head-only mounting bracket (pn 26785; see FIGURE 6-1) to the CM250 leveling mount (pn 26559).

2. Mount the EC150 gas analyzer head to the EC150 head-only mounting bracket using the bolt and set screw included with the bracket.

3. Mount this assembly to the end of the crossarm by fitting the leveling mount over the end of the crossarm.

4. Tighten the set screws on the leveling mount.

5. If the assembly is not level, slightly loosen the bolt that holds the mounting bracket on the leveling mount and adjust the assembly. Retighten the bolt.

CAUTION Use caution when handling the EC150 gas analyzer head. The optical source may be damaged by rough handling, especially while the EC150 is powered.

NOTE The CSAT3A sonic anemometer is an updated version of the CSAT3, designed to work with the EC100 electronics. An existing CSAT3 may be upgraded to a CSAT3A. Contact a Campbell Scientific application engineer for details.

6.2.4 Attaching EC100 Electronics Enclosure to Mounting Structure

The EC100 electronics enclosure can be mounted to the mast, tripod leg, or other part of the mounting structure but must be mounted within 3.0 m (10.0 ft) of the sensors due to restrictions imposed by the cable length.

1. Attach the EC100 enclosure mounting bracket (pn 26604) to the pipe of the mounting structure by loosely tightening the u-bolts around the pipe. The u-bolts are found in the mesh pocket inside the EC100 enclosure.

2. For configurations in which the pipe is not vertical (such as a tripod leg as in FIGURE 6-8) rotate the bracket to the side of the pipe so that when the enclosure is attached it will hang vertically upright. Make any necessary angle adjustments by loosening the four nuts and rotating the bracket plates relative to one another. If the necessary angle cannot be reached in the given orientation, remove the four nuts completely and index the top plate by 90° to allow the bracket to travel in the other direction (see FIGURE 6-8).

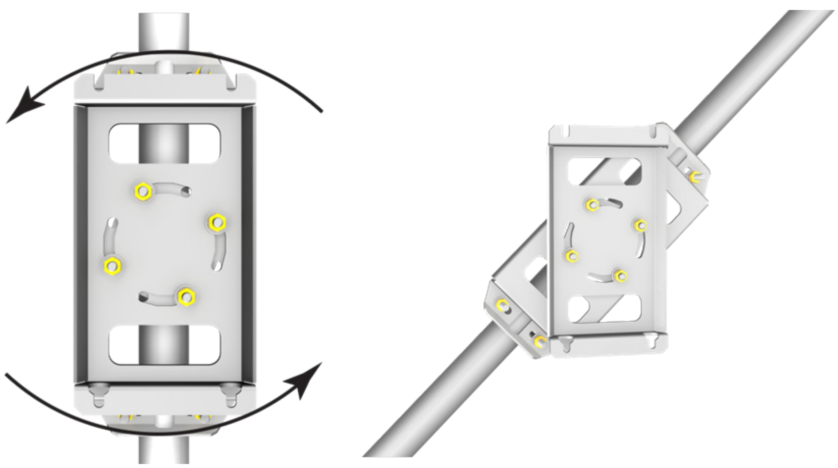

FIGURE 6-8. EC100 enclosure mounting bracket mounted on a vertical mast (left) and a tripod leg (right)

3. Tighten all nuts after final adjustments have been made.

4. Attach the EC100 enclosure to the bracket by loosening the bolts on the back of the enclosure, hanging the enclosure on the mounting

bracket (it should slide into place and be able to securely hang from the bracket), and retightening the bolts (see FIGURE 6-9).

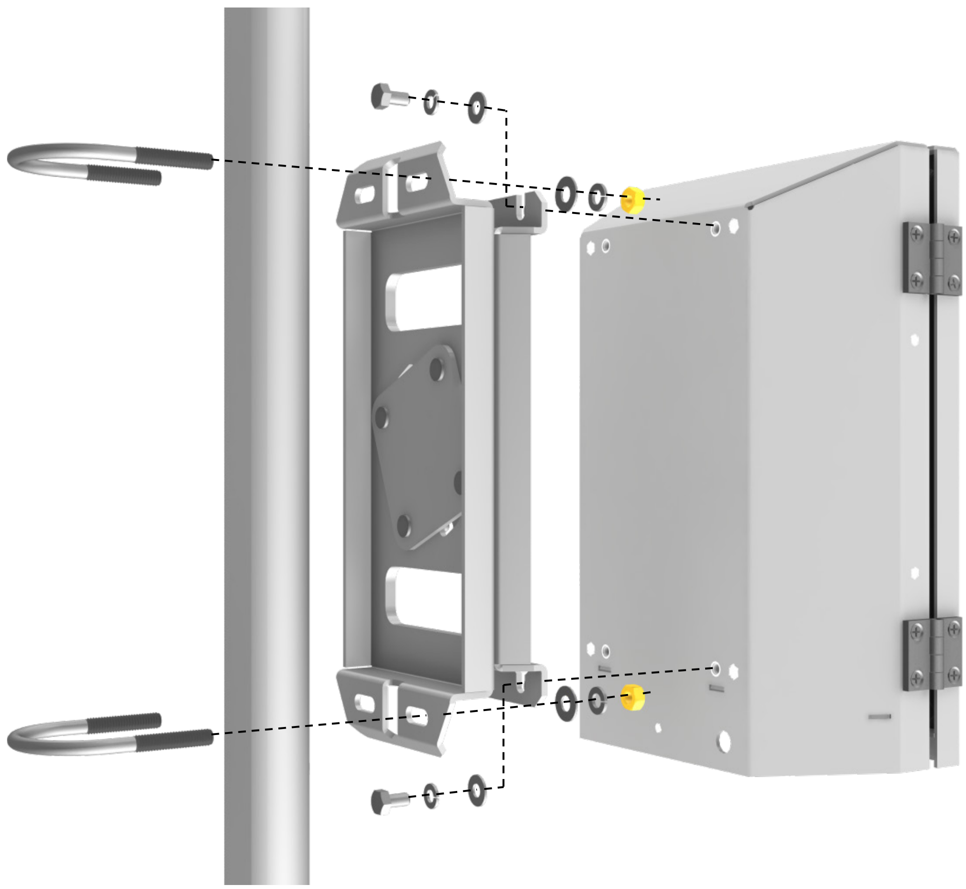

FIGURE 6-9. Exploded view of mounting the EC100 enclosure

5. Remove the EC100 enclosure desiccant from the plastic bag and put it back in the mesh pocket of the enclosure.

6. Adhere the humidity indicator card to the inside of the door of the enclosure.

6.2.5 Install the EC150 Temperature Probe

The temperature probe should be mounted such that it measures at the same height as the sample volume of the EC150 and the CSAT3A.

1. Attach the R.M. Young 41303-5A 6-plate solar radiation shield (pn 4020) to the mast with the included u-bolt.

2. Insert the end of the temperature probe into the hole on the bottom of the shield, see FIGURE 6-11.

3. Tighten screws to hold the probe in place.

FIGURE 6-10. EC150 temperature probe

FIGURE 6-11. Solar radiation shield with EC150 temperature probe

6.3 Wiring and Connections

FIGURES 6-12 and 6-13 show EC100 electronics panel and the bottom of the EC100 enclosure, respectively. Refer to these figures during the wiring and connecting of the various auxiliary sensors.

FIGURE 6-12. EC100 electronics front panel showing EC100 as shipped (left) and after completed wiring and connections (right)

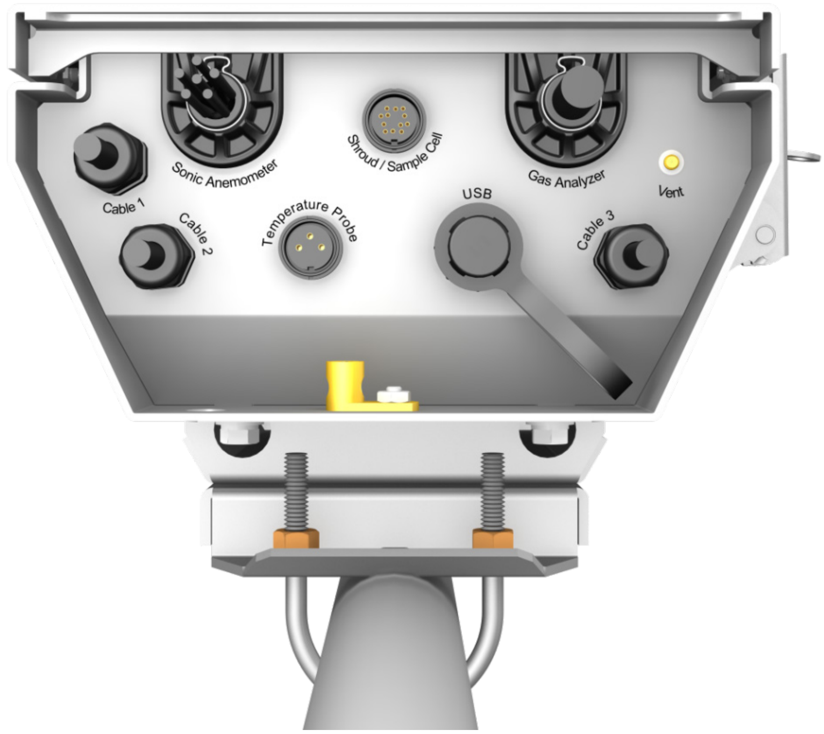

FIGURE 6-13. Bottom of EC100 enclosure

6.3.1 Connecting the EC150 Gas Analyzer Head

1. Remove the black rubber cable entry plug (pn 26224) that is located on the bottom right of the EC100 enclosure labeled **Cable 3**. (This plug can be stored in the mesh pocket of the enclosure.)

2. Insert the cable entry plug that is attached to the large cable of the EC150 gas analyzer head into the vacant slot.

3. Push the connector at the end of the cable onto its mating connector (labeled **Gas Analyzer**) and tighten the thumbscrews (see FIGURE 6-13). The EC150 gas analyzer cable is approximately 3.0 m (10.0 ft) in length.

6.3.2 Connect the CSAT3A Sonic Head

Skip the following two steps if not using a CSAT3A.

1. Similar to connecting the gas analyzer head, remove the black rubber cable entry plug found on the bottom left of the EC100 enclosure.

2. Insert the cable entry plug on the CSAT3A cable into the slot and connect the male end to the female connector labeled **Sonic Anemometer** on the EC100 electronics (see FIGURE 6-13).

NOTE Unlike previous models of the CSAT3 3D sonic anemometer, the CSAT3A sonic head and the EC150 gas analyzer head have embedded calibration information. This means that any CSAT3A and any EC150 may be used with any EC100.

6.3.3 Connect the EC150 Temperature Probe

1. Unscrew the temperature connector cover which is found on the bottom of the EC100 enclosure labeled **Temperature Probe** (see FIGURE 6-13).

2. Insert the three-prong temperature probe connector into the female connector on the enclosure and screw it firmly in place. The EC150 temperature probe cable is approximately 3.0 m (10.0 ft) in length.

6.3.4 Ground the EC100 Electronics

1. Attach a user-supplied heavy gauge wire (12 AWG would be appropriate) to the grounding lug found on the bottom of the EC100 enclosure.

2. Earth (chassis) ground the other end of the wire using a grounding rod. For more details on grounding, see the CR3000 datalogger manual grounding section.

CAUTION Grounding the EC100 is critical. Proper grounding to earth (chassis) will ensure maximum electrostatic discharge (ESD) protection and improve measurement accuracy.

CAUTION Do not connect or disconnect the EC150 gas analyzer head or CSAT3 sonic head once the EC100 is powered.

6.3.5 Connect SDM Communications to the EC100

The EC150 supports SDM communications with datalogger. SDM is the preferred communications to the EC100. RS-485 may be necessary in some situations. The USB is used mainly for diagnostic and trouble shooting. Connection instructions for these modes can be found in Appendix C, *Alternate EC100 Outputs* *(p. C-1)*.

CABLE4CBL-L (pn 21972) is used for connecting SDM communications to the EC100. The "L" designation denotes the length of the cable which is user-specified.

1. Loosen the nut on one of the cable entry seals (**Cable 1**) on the bottom of the EC100 enclosure (refer to FIGURE 6-13).

2. Remove plastic plug and store in mesh pocket of enclosure.

3. Insert the cable while referring to TABLE 6-1 for details on which color of wire in the cable should be connected to each terminal found on the SDM connector of the EC100 panel.

4. Once the wires of the cable are fully connected, retighten the nut on the appropriate cable entry.

TABLE 6-1. EC100 SDM output to a Campbell Scientific CR1000, CR3000, or CR5000 Datalogger		
EC100 Channel	**Description**	**Color**
SDM-C1	SDM Data	Green
SDM-C2	SDM Clock	White
SDM-C3	SDM Enable	Brown
G	Digital Ground	Black
G	Shield	Clear

6.3.6 Wire Power and Ground the EC100

1. Feed cable CABLEPCBL-L (pn 21969-L) through **Cable 2** at the bottom of the EC100 enclosure (see FIGURE 6-13) and attach the ends into the green EC100 power connector (pn 3768).

2. Plug the connector into the female power connector on the EC100 panel. Ensure that the power and ground ends are going to the appropriate terminals labeled 12V and ground, respectively.

3. Connect the power cable to a power source. The power and ground ends may be wired to the 12V and G ports, respectively, of a Campbell Scientific datalogger or to another 12 Vdc source.

Once power is applied to the EC100, three LED status lights on the EC100 panel will illuminate. The power LED will be green if the power supply voltage is between 10 to 16 Vdc. The gas LEDs will be orange until the gas head has warmed up. The sonic LED will be red while the sonic acquires the ultrasonic signals. The sonic and gas LEDs will turn green if there are no diagnostic warning flags. Three green LEDs indicate that the instrument is ready to make measurements.

The EC150 power-up sequence takes under two minutes to complete. During power up the gas LED will be orange. If after two minutes the gas LED turns green, power-up sequence has been completed successfully. If the gas LED turns red, a diagnostic flag has been detected. Check the individual diagnostic bits to determine the specific fault.

Diagnostics may be monitored using the Status window of ECMon (see Appendix A.3, *ECMon* *(p. A-7)*), the user interface software included with the EC150 (see Appendix A, *EC150 Settings* *(p. A-1)*), or with a datalogger. The diagnostics may reveal that the unit needs to be serviced (for example, cleaning the optical windows on the EC150, cleaning the CSAT3A transducers of ice or debris, etc. See Section 8, *Maintenance and Troubleshooting* *(p. 31)*).

7. Zero and Span

7.1 Introduction

Calibration of optical instrumentation like the EC150 may drift slightly from the calibration that was performed in the factory with time and exposure to natural elements. A zero-and span procedure should be performed after installation of the instrument to give appropriate baseline readings as a reference. A zero-and-span procedure should also be performed occasionally to assess drifts from factory calibration. In many cases, a zero and span can help resolve problems that are being experienced by the user during operating the EC150. For example, a zero-and-span procedure should always be performed on the analyzer after changing the internal chemicals. Before performing a zero-and-span procedure, clean the windows of the EC150 as described in Section 8.3, *Cleaning Analyzer Windows* *(p. 32)*.

After the first several zero-and-span procedures, the rate of drift in gain and offset (explained later in this section) should be analyzed to better determine how frequently the zero-and-span procedure should be performed once the instrument has been put into service.

The first part of the procedure listed below simply measures the CO_2 and H_2O span and zero without making any adjustments. This allows the CO_2 and H_2O gain factors to be calculated. These gain factors quantify the state of the analyzer before the zero-and-span procedure and, in theory, could be used to correct recent measurements for drift. The last part of the zero-and-span procedure adjusts internal processing parameters to correct subsequent measurements.

If the zero-and-span procedure is being performed off site (for example, in a laboratory), be sure to mount the EC150 on the zero-and-span stand (refer to FIGURE 7-1). This will ensure the analyzer is in the correct upright orientation and has the correct optical alignment.

The zero-and-span procedure must be performed correctly and not rushed. Allocate at least one hour (preferably more) for the procedure. Ensure that the readings are stable and all sensors are properly connected and functioning.

It is conceivable that there are circumstances in which both a zero and a span cannot be performed by the user. In these instances, it is recommended that the user attempt to perform a zero of the instrument even if spanning is not possible or inconvenient. The information gained through zeroing the instrument can help troubleshoot problems that may be encountered during field operations.

NOTE The water vapor measurement is used in the CO_2 concentration calculations to correct instrument and pressure broadening effects. To achieve good CO_2 calibration, it is imperative to maintain a reasonable water vapor calibration.

CAUTION Resting the analyzer on its side during the zero-and-span procedure may result in measurement inaccuracy.

7.2 Zero and Span Procedure

This section gives instructions for performing a zero-and-span procedure, and should be referred to any time a zero-and-span procedure is undertaken.

Check and then set the EC150 zero and span according to the following steps:

1. Remove power from the EC100/EC150. Unplugging the power cable from the EC100 is the easiest way to accomplish this.

2. Remove wicks from the snouts of the analyzer.

3. Clean windows and snouts with isopropyl alcohol and a lint-free, non-abrasive tissue or cloth as described in Section 8.3, *Cleaning Analyzer Windows* *(p. 32)*.

CAUTION Make sure any residual alcohol and water completely evaporate from the analyzer before proceeding with the zero-and-span procedure.

4. Position the EC150 zero-and-span shroud (pn 26390) over the upper and lower snouts. See FIGURE 7-1 for guidance with the following steps.

   a. Twist the two ends of the shroud together to minimize the length of the shroud. Make sure the rubber seals on the ends of the shroud are clean and in good condition.

   b. Position one end of the shroud over the lower snout and twist the top part of the shroud, allowing it to extend and cover the upper snout.

   c. Continue twisting the shroud until it is fully extended and covering both snouts.

   d. Twist the shroud so that the gas lines and temperature thermistor cable are directed towards the back of the sensor.

   e. Hang the lines and cable over the trunk of the sensor to alleviate any strain on the optical arms. See FIGURE 7-1.

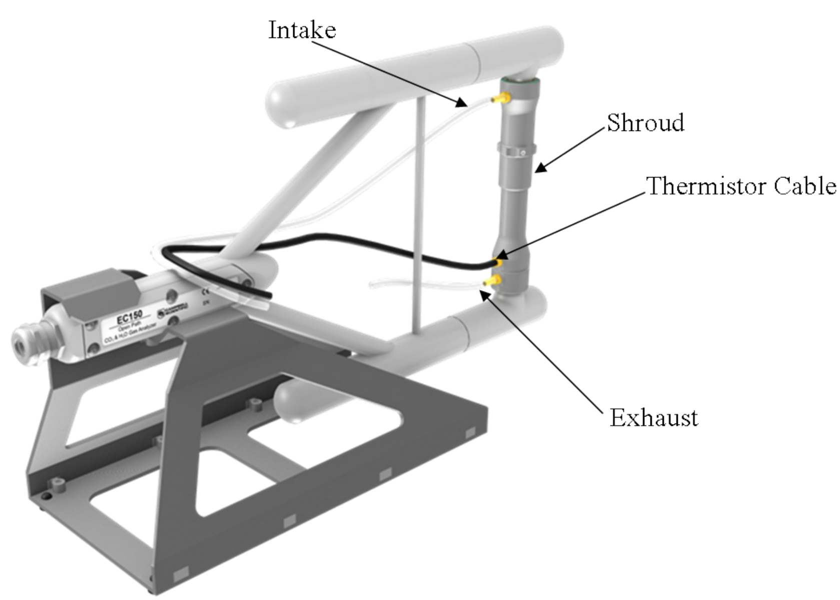

FIGURE 7-1. Zero-and-span shroud mounted on the zero-and-span stand

5. Disconnect the EC150 temperature probe from the EC100 and connect the shroud temperature probe in its place.

6. Connect the EC100 to a PC with the EC100 USB cable (pn 26563).

7. Resume power to the EC100/EC150.

8. Wait for all the **Gas** and **Power** LED status lights on the EC100 panel to turn green.

9. Launch ECMon, select the appropriate USB port, and click **Connect**. The main screen should now be reporting real-time CO_2 and H_2O concentrations.

10. Click **Zero/Span**. A graph will appear in the lower half of the zero-and-span window showing measured CO_2 and H_2O concentrations (see FIGURE 7-2).

11. Connect a gas cylinder of known CO_2 concentration to a pressure regulator, then to a flow controller, and finally to the intake of the shroud. Optimally, the concentration of span CO_2 should be near the concentration of CO_2 being measured in the field.

12. Beginning with both the pressure regulator and flow controller turned off, use the pressure regulator to slowly increase pressure to the recommended setting for the flow controller.

13. Set the flow between 0.2 and 0.4 LPM.

14. Monitor the ECMon zero-and-span graph and wait for the CO_2 measurement readings to stabilize (5 to 10 minutes). Once stable, record the reported CO_2 concentration.

NOTE Use a mixture of CO_2 in air (not nitrogen) for the CO_2 span gas. The use of pure nitrogen as the carrier gas will lead to errors because the pressure-broadening of the CO_2 absorption lines is different for oxygen and nitrogen.

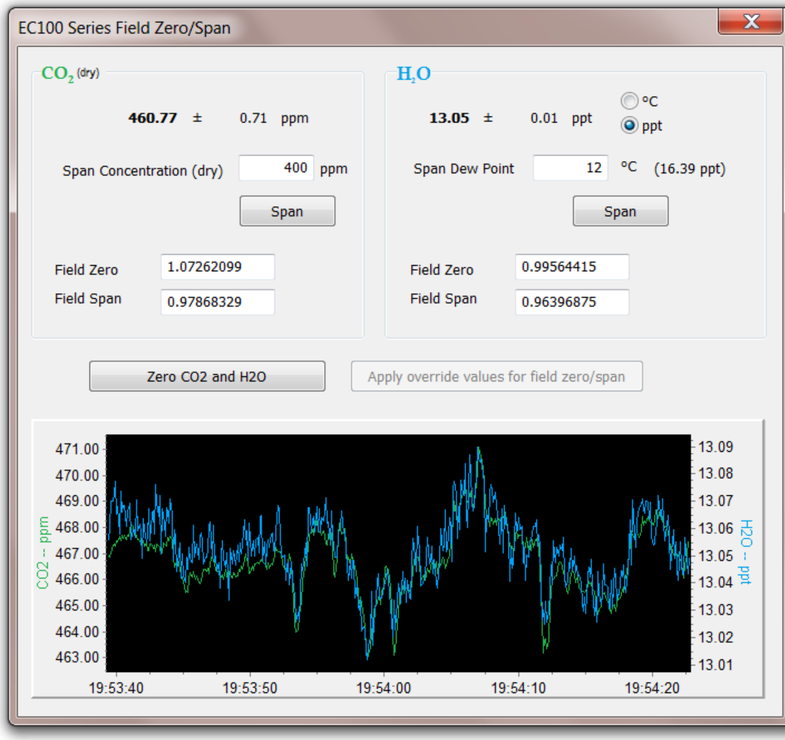

FIGURE 7-2. ECMon zero-and-span window

15. Remove the CO_2 span gas from the inlet of the shroud and replace it with H_2O span gas from a dew-point generator or another standard reference. As water molecules can adsorb to inside of the tubing and the shroud, it may take 30 minutes or more for the H_2O concentration to stabilize. The user may increase the flow rate for the first several minutes to more quickly stabilize the system before returning it to between 0.2 and 0.4 LPM to make the H_2O measurement. Record the reported H_2O concentration. If a stable reading is not achieved within 45 to 60 minutes, troubleshooting steps should be undertaken.

16. Remove the H_2O span gas, and connect a zero air source (no CO_2 or H_2O) to the inlet tube of the shroud. As described in step 11, use a pressure regulator and flow controller so that zero air flows through the shroud between 0.2 and 0.4 LPM. Wait for the measurement readings to stabilize and record the reported values for CO_2 and H_2O concentrations. If the readings remain erratic, ensure that flow of the zero air is sufficient and the shroud is correctly seated on the snouts.

NOTE If the quality of a zero gas is unknown or suspect, a desiccant and CO_2 scrubber should be added between the zero gas tank and the shroud to confirm that the gas being sampled during the zero procedure is actually a zero air source.

17. Along with recording the CO_2 and H_2O zero and span values, also record the date and time, and temperature. With this information the user can examine zero/span drift with time and temperature.

Compute the drift in instrument gain using the following equation:

$$gain = \frac{span_{actual}}{span_{meas} - zero_{meas}}$$

where,

- $span_{actual}$ = known concentration of the span gas
- $span_{meas}$ = measured concentration of the span gas
- $zero_{meas}$ = measured concentration in zero gas

Note that in the zero-and-span window of ECMon, **$span_{actual}$** is reported to the right of the box where the user enters the span dewpoint temperature. The software calculates **$span_{actual}$** by taking into account the dewpoint temperature and current ambient temperature and pressure. The equations used for this calculation may be found in Appendix D, *Useful Equations* ***(p. D-1)***. If drift (offset or gain) for CO_2 or H_2O is excessive, it may be time to replace the desiccant and CO_2 scrubber bottles (see Section 8.5, *Replacing CO2 Scrubber Bottles* ***(p. 33)***).

18. With zero air still flowing and measurements stabilized, click on the **Zero CO_2 and H_2O** button in the ECMon zero-and-span window.

NOTE Air flow into the shroud should be close to the recommended rate. If the flow is too low, the shroud will not be properly flushed. If it is too high, the air pressure within the shroud will be too high, and the analyzer will not be zeroed and spanned properly.

19. Remove the zero air source and replace it with the CO_2 span gas.

20. Allow the gas to flow through the shroud, maintaining a flow between 0.2 and 0.4 LPM. Wait for readings to stabilize.

21. In the zero-and-span window, enter the known concentration of CO_2 (in ppm) in the box labeled **Span Concentration (dry)** and press **Span**.

22. Replace the CO_2 span gas with an H_2O span gas of known dewpoint. Allow the gas to flow through the shroud. Higher flows may be desired for a couple of minutes to more quickly establish equilibrium before resuming a flow between 0.2 and 0.4 LPM. Wait for the readings to stabilize.

23. Enter the known dewpoint (in °C) in the box labeled **Span Dewpoint** and press **Span**.

24. The zero-and-span procedure is now complete. Remove the shroud, reconnect the EC150 temperature probe, and prepare the site for normal operation. Verify that readings from the instrument are reasonable. Record the zero and span coefficients for future reference and to keep track of the rate of the analyzer drift. Make sure that the coefficients are between 0.9 and 1.1. Negative or numbers larger than 1.1 are usually an indication of improper calibration.

8. Maintenance and Troubleshooting

EC150 operation requires six maintenance tasks:

- Routine site maintenance
- Wick maintenance
- Analyzer window cleaning
- Zero and span
- Replacing the analyzer desiccant/scrubber bottles
- Factory recalibration

8.1 Routine Site Maintenance

The following items should be examined periodically:

- Check the humidity indicator card in the EC100 enclosure. If the highest dot has turned pink, replace the desiccant bags. Replacement desiccant bags may be purchased as pn 6714.

- Make sure the *Power* and *Gas* LED status lights on the EC100 panel are green. If not, check the individual diagnostic bits for the specific fault. See TABLE 8-2, *Diagnostic Flags of Sonic Status LED* ***(p. 36)***, and Section 8.7.3, LED Status Lights ***(p. 35)***, for more information.

8.2 Gas Analyzer Wicks

The windows of the EC150 gas analyzer are polished and slanted at an angle to prevent water from collecting on their surfaces. However, due to increased surface tension at the interface with the snout, water can pool at the edges and partially block the optical path and attenuate the signal. To minimize the occurrence of such events and the resulting data loss, consider using the wicks listed in TABLE 8-1. The weave of the wicking fabric promotes capillary action that wicks the water away from the edge of the windows. The seam and the straight edge of the wicks are permeated with a rubberized compound to prevent them from shifting during operation.

Proper installation of the wicks is critical. They should not block or encroach on the optical path. Before installation, record signal strengths for both H_2O and CO_2. Following installation, repeat testing of signal strength and check that these values are unchanged.

TABLE 8-1. Rain Wick Replacement Parts

Wick	Campbell Scientific, Inc. Part Number	Campbell Scientific, Inc. Description
Bottom wick	28652	Fab EC150/IRGASON rain wick bottom
Top wick	28653	Fab EC150/IRGASON rain wick top

The top wick has a short seam which must be aligned with the short side of the top snout. The angled edge of the wick must closely follow the edge of the window without encroaching on the optical path. See FIGURE 8-1 for guidance on proper positioning of the wick.

The bottom wick is installed in a similar manner, except the long seam should be aligned with the long side of the bottom snout. Once in place, the wicks should fit snuggly over the cylindrical part of the snout without any creases or wrinkles. The windows should be cleaned after the installation of the wicks to ensure that there are no fingerprints left on critical surfaces. See Section 8.3, *Cleaning Analyzer Windows* (p. 32), for specifics on cleaning the EC150 windows.

Wicks are constructed with a UV-resistant fabric and should be functional for an extended period of time but should be inspected every six months. Check for contamination from dust, pollen, pitch or other debris. If needed, wash the wicks in warm water with mild detergent or replace them.

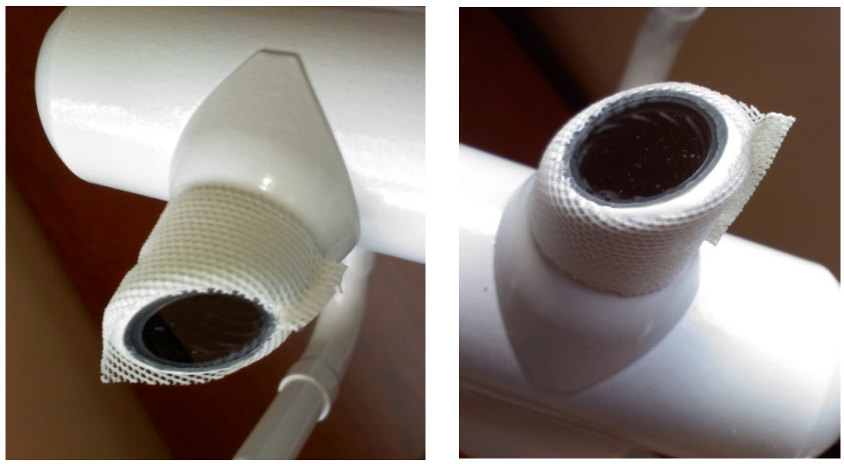

FIGURE 8-1. Proper location of the gas analyzer top wick (left) and bottom wick (right)

8.3 Cleaning Analyzer Windows

The windows of the analyzer should be cleaned if the signal strength for CO_2 or H_2O drops below 0.7 (70% of the original value). These values may be monitored in the output data, or they can be viewed with ECMon.

To clean the windows, use isopropyl alcohol and a cotton swab or a lint-free tissue or cloth. Signal strengths should be restored to values close to 1.0 after cleaning the analyzer windows. In some cases, depending on the contaminant, cleaning with distilled water can achieve better results. In severe cases a mild detergent similar to ordinary hand soap can be used.

8.4 Zero and Span

As discussed in Section 7, *Zero and Span* (p. 25), the zero-and-span procedure can resolve many of the issues a user may encounter. Along with being a valuable troubleshooting method, a zero-and-span procedure should be performed as routine maintenance even when the EC150 is producing expected results. Campbell Scientific recommends that a zero-and-span procedure be performed at least every six months, but may be required more frequently depending on conditions.

Performing frequent zero-and-span procedures when the instrument is first put into use to determine the drift from factory calibration, will give a good guideline for the frequency that the procedure should be performed.

To perform a maintenance zero and span, follow the same steps as in Section 7, *Zero and Span* *(p. 25)*.

8.5 Replacing CO_2 Scrubber Bottles

If more than one year has passed since replacing the desiccant/scrubber or if the zero-and-span readings have drifted excessively (see Section 7, *Zero and Span* *(p. 25)*), the desiccant/scrubber bottles within the EC150 analyzer head should be replaced. FIGURE 8-2 gives the details needed for the following steps.

DANGER The scrubber bottles contain strong oxidizing agents. Avoid direct contact with the chemicals inside the bottles. Also ensure your work area is well ventilated and free of any reactive compounds, including liquid water. Store used chemical bottles in a sealed container until disposal.

Replacing Scrubber Bottles

1. Twist the scrubber bottle covers of the upper and lower arms counter clockwise until they detach (they should loosen by hand).

2. Remove the EC150 chemical bottles (pn 26510) from inside the covers, and replace them with new bottles with the lid of the bottle pointing toward the snouts of the analyzer (see FIGURE 8-2).

NOTE Before opening the covers, have the chemical bottles ready so that the time the internal volume of the analyzer is exposed to the environment is minimized.

3. Screw the covers back on the arms. Do not over tighten.

4. Allow the sensor to equilibrate for at least 24 hours (longer if in high humidity).

5. After 24 hours, perform a zero-and-span procedure. If readings continue to be suspect, the sensor may need to be recalibrated at the factory (see Section 8.6, *Factory Recalibration* *(p. 34),* below).

The chemical bottles should be disposed of according to local and federal regulations. For more information, Material Safety Data Sheet (MSDS) forms for the chemicals are included in Appendix E, *Material Safety Data Sheets (MSDS)* *(p. E-1)*.

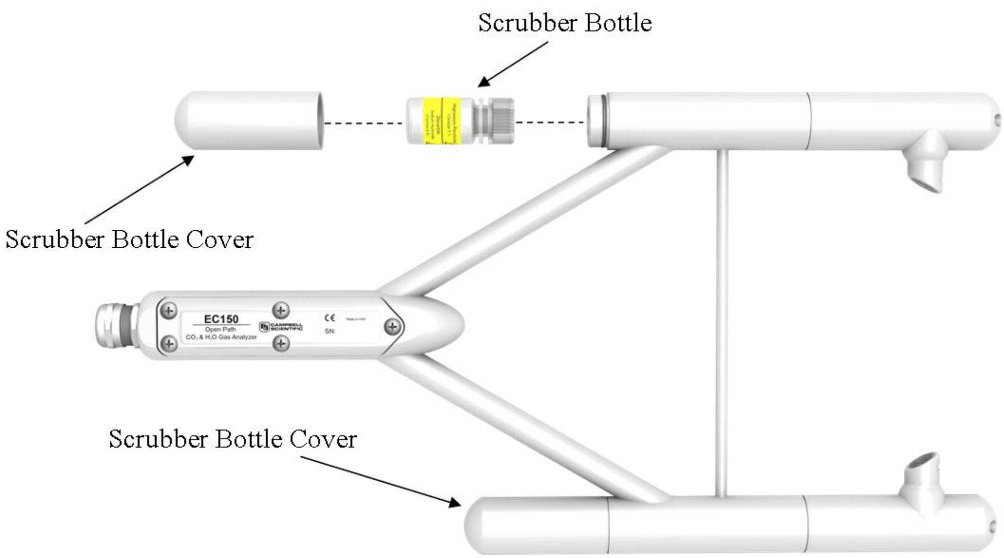

FIGURE 8-2. Replacing the desiccant/CO_2 scrubber bottles

8.6 Factory Recalibration

When the EC150 is manufactured, it goes through an extensive calibration process, covering a wide range of temperatures, pressures, and gas concentrations. All CO_2 calibration gases used in this process are mixtures of CO_2 in ambient air that are traceable to the WMO Mole Fraction Scale maintained by the Central Carbon Dioxide Laboratory and the Carbon Cycle Greenhouse Gases Group of the Global Monitoring Division/National Oceanographic and Atmospheric Administration in Boulder, CO, USA.

The long-term calibration stability of the EC150 is achieved by the use of high quality optical and electrical components, a long lasting IR source, and a stable MCT detector. The subtle, long-term aging effects are usually compensated by the user with the field zero-and-span adjustments which bring the performance of the analyzer within the original specifications. Proper handling and regular maintenance of the instrument should make factory recalibration unnecessary in most applications. If zero and span accessories and calibration standards are not available, Campbell Scientific can provide two-point calibration upon request (pn 27312).

However, if a user finds that signal strength outputs of greater than 0.75 cannot be achieved after both cleaning the windows and a subsequent zero-and-span procedure, contact Campbell Scientific. An application engineer will help determine if the instrument should be returned to Campbell Scientific for a factory recalibration.

For the CSAT3A, refer to the CSAT3 instruction manual for information on recalibration.

8.7 Troubleshooting

8.7.1 Data Loss During Precipitation Events

In extremely humid environments or after a precipitation event, data loss can occur. Wicks on the analyzer windows help mitigate some of these data loss events but cannot control for all conditions. In addition to wicking, heaters in the snouts can aid in the prevention of data loss during precipitation and condensation events. The heaters are automatically controlled by the EC100 electronics. The automatic heater control is activated using the Device Configuration or ECMon software. A value of −1 turns the automatic heater control off and a value of −2 turns it on.

8.7.2 EC100 Diagnostics for Gas Analyzer Troubleshooting

Before troubleshooting and servicing the analyzer, become familiar with Section 2, *Precautions* *(p. 1)*.

The EC100 is also programmed to recognize problems with an associated gas analyzer and reports those with LED status lights and diagnostic flags. The two types of warnings are described in the sections that follow.

8.7.3 LED Status Lights

The EC100 has three LED status lights located in the upper left corner of the front panel which provide immediate visual feedback and warn the user of potential problems with the measurements. During normal operation all **STATUS** LEDs should be green as shown in FIGURE 8-3.

FIGURE 8-3. LED status during normal operation

- **POWER** Status LED

  The **POWER** status LED will turn red if the supply voltage is outside the specified limits (see Section 5.4, *Power Requirements* *(p. 10)*). The user should check the battery voltage or the power supply voltage and ensure that the power supply cable is adequate gage and does not cause excessive voltage drop.

- **SONIC** Status LED

  The **SONIC** status LED will turn red if there is no CSAT3A connected to the EC100 electronics or if any of the six sonic diagnostic flags are set. Please refer to TABLE 8-2 and to the CSAT3A instruction manual for more detail information on sonic diagnostic flags.

TABLE 8-2. Diagnostic Flags of Sonic Status LED

Diagnostic Flag	Flag Name	Action
0	Sonic amplitude low	Clear debris from sonic path
1	Sonic amplitude high	No action
2	Poor signal lock	Clear debris from sonic Return to factory for calibration
3	Delta temperature warning flag	Return to factory for calibration
4	Sonic acquiring signals	No action
5	Signature error in reading CSAT3A sonic head calibration	Check sonic umbilical cable connection Cycle power Contact an application engineer for a new calibration file and upload procedure

- **GAS** Status LED

  The **GAS** status LED will turn red in the following situations:
  - The EC150 gas head is not connected
  - Any of the gas diagnostic flags are set

  The **GAS** status LED will turn orange during the initial power up sequence, usually 1-2 min and will turn to green when the sequence is completed and if no diagnostic flags have been set high.

8.7.4 Diagnostic Flags

The EC100 operating system has extensive self-diagnostic capabilities. TABLE 8-3 lists 23 (numbered 0 through 22) diagnostic flags that allow the user to identify problems associated with the operation and the performance of the EC100 electronics and the gas analyzer. There is one master flag (**BAD_DATA**, or flag **0**) that is set when measurements are compromised.

If any of the remaining 22 flags are set, the master flag (**BAD_DATA**) is set as well, so that the user can filter data based on this flag only. When this flag is set, more detailed information about the nature of the problem can be obtained from the 22 slave flags.

When a flag is set due to improper configuration of the analyzer, inadequate power supply voltage or grounding, extreme environmental conditions, and unreliable or missing connections, the user should try to correct the problem by checking the instrument setup, verifying that all components are properly connected and configured, and that operating conditions are within operational specifications. Other flags are associated with the proper function of the internal components of the analyzer. If any of these flags are set, consult with a Campbell Scientific application engineer for assistance in diagnosing the problem and, if necessary, arrange to send the instrument for repair.

NOTE If connected to a datalogger, the EC100 could be automatically configured under CRBasic program control. The user should verify the proper configuration in the datalogger program.

TABLE 8-3. Diagnostic Flags and Suggested Actions

Flag Number	Flag Name	Comments
0	Bad Data	Set when any of flags 1 through 22 is set. Discard all data with this flag is set. If the flag persists, identify which of flags 1 through 22 is set. When this flag is set, the **GAS** status LED on the EC100 electronics panel is illuminated red.
1	General Fault	Reserved for future use.
2	Startup	Set during the initial power up of the analyzer. It stays set only until all control loops have settled. The infrared detector temperature and the motor speed usually stabilize in 1 to 2 minutes. If the flag persists, verify that the operating conditions (temperature, pressure, supply voltage and current) are within specified limits and that all connections with the gas head and peripheral sensors are made properly. When this flag is set the **GAS** status LED turns orange. WARNING: Power off the EC100 electronics before disconnecting the gas analyzer.
3	Motor Speed	Set when the motor speed is outside the prescribed limits. It may occasionally be set for short periods of time (10 to 15 seconds), but if it persists, the user should consult with a Campbell Scientific application engineer.
4	TEC Temperature	Set when the infrared detector temperature is outside the prescribed limits. It may occasionally be set for short periods of time (10 to 15 seconds), but if it persists the user should consult the factory. Verify that ambient temperature and power supply voltage are within the specifications.

TABLE 8-3. Diagnostic Flags and Suggested Actions

Flag Number	Flag Name	Comments
5	Source Power	Set every time the infrared source power is outside the prescribed limits. It may occasionally be set for short periods of time (10 to 15 seconds), but if it persists, the user should consult a Campbell Scientific application engineer. Verify that ambient temperature and power supply voltage are within specifications.
6	Source Temperature	Set when the internal temperature is outside the specified safe operation limits (–35 to 55 °C). If this flag is set the sensor head will be turned off until the internal temperature is within the range –30 to 50 °C. If the flag is set and ambient temperature is within the specified range, consult with a Campbell Scientific application engineer.
7	Source Current	Set when the infrared source current is outside the prescribed limits. It may occasionally be set for short periods of time, but if it persists the user should consult with a Campbell Scientific application engineer.
8	Off	Set when the analyzer head is powered off by the user, the datalogger program, or the EC100 operating system when the **LIGHT_TEMP** flag is set.
9	Synchronization	Set when sampling errors are detected. Sampling errors are most often caused by strong electromagnetic interference. If the flag persists, consult with a Campbell Scientific application engineer.
10	Ambient Temperature	Set when the ambient temperature is below –30 °C or above 55 °C or when the air temperature sensor is not connected. If the user enters a fixed temperature, this temperature must be within the range –30 to 55 °C.
11	Ambient Pressure	Set when the ambient pressure is outside the specified limits (55 to 120 kPa) or the external pressure sensor is configured but not connected.

TABLE 8-3. Diagnostic Flags and Suggested Actions		
Flag Number	**Flag Name**	**Comments**
12	CO_2 I	Set if CO_2 measurement signal is outside prescribed limits. It can be turned on when the measurement path is obstructed by insects, dust, precipitation, condensation etc. If it persists, consult with a Campbell Scientific application engineer.
13	CO_2 I_o	Set if CO_2 reference signal is outside prescribed limits. It can be turned on when the measurement path is obstructed by insects, dust, precipitation, condensation etc. If it persists, consult with a Campbell Scientific application engineer.
14	H_2O I	Set if H_2O measurement signal is outside prescribed limits. It can be turned on when the measurement path is obstructed by insects, dust, precipitation, condensation etc. If it persists, consult with a Campbell Scientific application engineer.
15	H_2O I_o	Set if H_2O measurement signal is outside prescribed limits. It can be turned on when the measurement path is obstructed by insects, dust, precipitation, condensation etc. If it persists, consult with a Campbell Scientific application engineer.
16	H_2O I_o Variation	Set if fast changes in the CO_2 reference signal are detected. If it persists, consult with a Campbell Scientific application engineer.
17	CO_2 O I_oH2OIo Variation	Set if fast changes in the H_2O reference signal are detected. If it persists, consult with a Campbell Scientific application engineer.
18	CO_2 Signal Strength	Set if the ratio of the CO_2 measurement and the CO_2 reference signals are outside prescribed limits. It can be turned on when the measurement path is obstructed by insects, dust, precipitation, condensation etc. If it persists, consult with a Campbell Scientific application engineer.

TABLE 8-3. Diagnostic Flags and Suggested Actions		
Flag Number	**Flag Name**	**Comments**
19	H_2O Signal Strength	Set if the ratio of the H_2O measurement and the H_2O reference signals is outside prescribed limits. It can be turned on when the measurement path is obstructed by insects, dust, precipitation, condensation etc. If it persists, consult with a Campbell Scientific application engineer.
20	Calibration Error	Set if there is a problem reading or writing into the analyzer's head memory. Power off the EC100 and reconnect the head. If the flag persists, consult with a Campbell Scientific application engineer. For more information on the head memory refer to Section 4.3, *Gas Head Memory* *(p. 3)*.
21	Heater Ctrl Off	
22	Not Used	

Appendix A. EC150 Settings

Operation of the EC150 can be customized by changing the values of the settings. Factory defaults will work well for most applications, but the user may adjust the settings with a PC using either the ECMon software (see Appendix A.3, *ECMon (p. A-7)*) or the Device Configuration Utility (see Appendix A.4, *Device Configuration Utility (p. A-9)*), or with a datalogger using the **EC100Configure()** CR Basic instruction (see Appendix A.5, *EC100Configure() Instruction (p. A-9)*).

When the EC150 is connected to a datalogger, the settings of the analyzer can be configured automatically by the CR Basic program.

A.1 Factory Defaults

TABLE A-1 shows the default value for each of the settings.

TABLE A-1. Factory Default Settings

Setting	Default
SDM Address	1
Bandwidth	20 Hz
Unprompted Output	disabled
RS-485 Baud Rate	115200 bp
Unprompted Output Rate	10 Hz
Analog Output	disabled
ECMon Update Rate	10 Hz
Temperature Sensor	Auto-select (EC150 Temperature Probe)
Pressure Sensor	EC100 Basic or EC100 Enhanced (depends on initial order configuration)
Pressure Differential Enable	Auto-Select (Disabled for EC150)
Heater Control	Disabled

A.2 Details

This section gives an explanation for each setting. The value of each setting is stored either in the non-volatile memory of the EC100 electronics or the EC150 gas head. The section also explains the details of where settings are stored. For convenience all settings and calibration information associated with the operation of the gas head are stored in non-volatile memory located in the head.

Another group of settings pertinent to the operation of the EC100 electronics are stored in non-volatile memory. These settings are the first seven in TABLE A-1. For more details refer to the following sections.

A.2.1 SDM Address

This parameter must be set to use SDM output from the EC100. See Section 4.6.2.1, *SDM Output* *(p. 5)*, for details on using SDM output.

Each SDM device on the SDM bus must have a unique address. The EC150 has a factory default SDM address of 1, but may be changed to any integer value between 0 and 14. The value 15 is reserved as an SDM group trigger.

The SDM address is stored in non-volatile memory of the EC100 electronics.

A.2.2 Bandwidth

The EC100 has a user-selectable, low-pass filter to select the bandwidth (5, 10, 12.5, 20, or 25 Hz). Setting the bandwidth to a lower value will reduce noise. However, it must be set high enough to retain the high-frequency fluctuations in CO_2 and H_2O, or the high frequency contributions to the flux will be lost. The factory default bandwidth is set to 20 Hz which is sufficient for most flux applications. Lower bandwidth settings may be used for higher measurement heights which inherently have lower frequency content. Refer to Appendix B, *Filter Bandwidth and Time Delay* *(p. B-1)*, for more information on the digital filter options.

If a spectral analysis is performed to evaluate the experimental setup, the bandwidth should be set to the Nyquist frequency, which is half the datalogger sample rate (for SDM output) or half the unprompted output rate (for USB and RS-485 output). This ensures that the data will not be under-sampled and that higher frequency variations will not be aliased to lower frequencies.

NOTE If too small a bandwidth is selected, high frequency fluxes will be filtered.

The **Bandwidth** setting is stored in non-volatile memory of the EC100 electronics.

A.2.3 Unprompted Output

If the EC100 is to output data in one of the unprompted modes (USB or RS-485, see Appendix C.1, *USB or RS-485 Output* *(p. C-1)*), this setting must be set accordingly. The factory default is to disable the unprompted output, assuming data will be logged via SDM (see Section 4.6.2.1, *SDM Output* *(p. 5)*).

Only one unprompted output type (for example, USB or RS-485) may be selected at a given time. The rate at which the EC100 outputs these data is determined by the **Unprompted Output Rate** setting.

The **Unprompted Output Rate** setting is stored in non-volatile memory of the EC100 electronics.

A.2.4 Unprompted Output Rate

When the Unprompted output is enabled, this setting determines the output rate for unprompted output (USB or RS-485, see Appendix C.1, *USB or RS-485 Output* *(p. C-1)*). If the unprompted output is disabled, this parameter is not used. The factory default output rate is 10 Hz, but it may be set to 10, 25, or 50 Hz.

The Unprompted Output setting is stored in non-volatile memory of the EC100 electronics.

A.2.5 RS-485 Baud Rate

If the unprompted output mode is set to RS-485, the **RS-485 Baud Rate** parameter determines the baud rate. Otherwise this setting is not used. The RS-485 baud rate defaults to 115200 bps, although the user may enter another value.

The **RS-485 Baud Rate** setting is stored in non-volatile memory of the EC100 electronics.

A.2.6 Analog Output

The EC100 has two analog outputs for CO_2 and H_2O densities (see Appendix C.2, *Analog Outputs* (p. C-3)). These outputs may be enabled or disabled with this setting. The default is for analog output to be disabled.

The **Analog Output** setting is stored in non-volatile memory of the EC100 electronics.

A.2.7 ECMon Update Rate

The **ECMon Update Rate** setting determines the rate at which data are sent over the USB connection to the PC while running ECMon. The default setting of 10 Hz should be adequate in most situations.

The **ECMon Update Rate** setting is stored in non-volatile memory of the EC100 electronics.

A.2.8 Temperature Sensor

The **Temperature Sensor** setting configures the EC100 electronics to work with either an EC150 open-path gas analyzer or an EC155 closed-path gas analyzer. The EC150 measures ambient air temperature using a thermistor probe mounted in the solar radiation shield (see Section 6.3.3, *Connect the EC150 Temperature Probe* (p. 24)).

With the **Auto-Select** default setting, the EC100 will automatically detect that an EC150 is connected to the electronics and will report ambient air temperature measurements from the thermistor probe.

The EC150 temperature sensor is measured at 1Hz, and is not synchronized to the CO_2/H_2O measurements.

To diagnose problems with the temperature measurement, a fixed temperature value may be used, or the temperature sensor may be selected manually.

The **Temperature Sensor** setting is stored in the non-volatile memory of the EC150 head.

A.2.9 Fixed Temperature Value

If the Temperature Sensor setting is **None**, the EC150 will use the value of the **Fixed Temperature Value** setting for the sample temperature. This mode is intended for troubleshooting only. In normal operation, the **Temperature Sensor** is set to **Auto-Select**, and this setting is not used.

The **Fixed Temperature Value** setting is stored in non-volatile memory of the EC100 electronics.

A.2.10 Pressure Sensor

There are three options for measuring barometric pressure for the EC150 that have different corresponding **Pressure Sensor** settings.

1. The EC100 has an on-board barometer that Campbell Scientific refers to as the EC100 basic barometer. This barometer is mounted on the EC100 electronics board as shown in FIGURE A-1.

   EC100 Basic Barometer:
   The EC100 always includes the EC100 basic barometer as a factory default and the default settings is **EC100 Basic**.

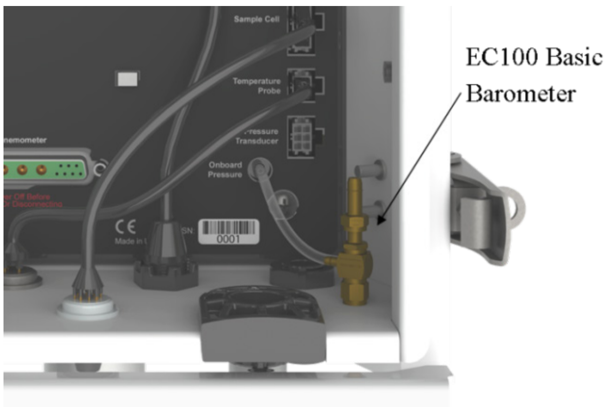

FIGURE A-1. Location of EC100 basic barometer

2. An enhanced-performance barometer can be specified when ordering an EC100 for any of Campbell's gas analyzers, and is referred to as the enhanced barometer. The enhanced barometer is installed in the factory when specified at the time of order. It will come mounted on the top wall of the EC100 environmental enclosure towards the left, as shown in FIGURE A-2.

   The enhanced barometer can provide greater accuracy in certain environmental conditions that cannot be achieved with the standard barometer. FIGURE A-3 compares the expected error relative to environmental conditions for the two barometers. Errors related to the altitude of the study site may also warrant the choice of one barometer over the other. Given the various parameters that drive the decision, the most prudent route is to provide a Campbell Scientific application engineer sufficient detail about the expected monitoring site at the time of order.

   EC100 Enhanced Barometer:
   If the EC100 is ordered with the enhanced barometer, the factory default setting is **EC100 Enhanced**.

FIGURE A-2. Location of EC100 enhanced barometer

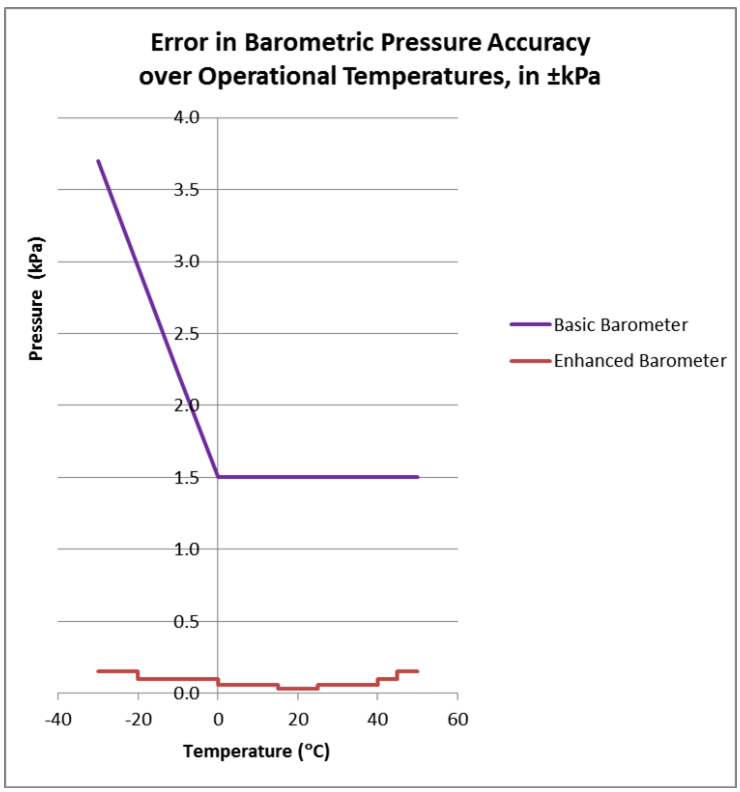

FIGURE A-3. Comparison of error in basic versus enhanced barometer over operational temperatures

3. The option of a third barometer choice is also available but is rarely used. A user-supplied barometer option can also be programmed in the EC100 electronics. This setting determines which pressure sensor will be used to measure the barometric pressure.

   User-supplied Barometer:
   When a user supplies a barometer, the setting should be changed to **User Supplied** and the appropriate values for gain and offset must be entered.

Sampling Frequency:
The enhanced barometer is sampled at 1 Hz. If the user supplies an external pressure sensor, it is sampled at 1 Hz. The on-board pressure sensor is measured at 10 Hz. In all cases, the pressure sensor measurement is not synchronized to the CO_2 and H_2O measurements.

The pressure sensor also allows the setting **None** for the **Pressure Sensor**. This mode is intended for troubleshooting only. The EC100 will use a fixed value for pressure.

The **Pressure Sensor** setting is stored in non-volatile memory in the EC150 head.

A.2.10.1 Pressure Gain

This setting is not used unless the **Pressure Sensor** is set to **User Supplied**. Then this setting gives the gain factor (kPa/V) used to convert measured voltage to pressure. If the **Pressure Sensor** is set to **EC100 Basic** or **EC100 Enhanced**, this setting is not used.

The **Pressure Gain** setting is stored in non-volatile memory of the EC100.

A.2.10.2 Pressure Offset

This setting is not used unless the **Pressure Sensor** is set to **User Supplied**. Then this setting gives the offset (kPa) used to convert measured voltage to pressure. If the **Pressure Sensor** is set to **EC100 Basic** or **EC100 Enhanced**, this setting is not used.

The **Pressure Offset** setting is stored in the EC100 electronics.

A.2.10.3 Fixed Pressure Value

If the **Pressure Sensor** setting is **None**, the EC150 will use the value of this setting for the barometric pressure. This mode is intended for troubleshooting only. In normal operation this setting is not used.

The **Fixed Pressure Value** setting is stored in the EC100 electronics.

A.2.11 Pressure Differential Enable

This setting should remain disabled. It is used only for closed-path analyzers.

The **Pressure Differential Enable** setting is stored in non-volatile memory in the EC150 head.

A.2.12 Heater Control

When set to automatic, this setting applies a voltage between 0 and 4600 mV to heaters near the optical windows of the analyzer. Heated windows inhibit the formation of condensation, such as dew and frost, and help the analyzer recover more quickly when precipitation has blocked the optical path.

The **Heater Control** setting is stored in non-volatile memory in the EC150 head.

A.2.13 Head Power Off

When enabled, the EC150 gas head is turned off. The head may be turn on/off under datalogger control to conserve power or under EC100 control if the gas head temperature is outside the operating range. The *EC100Configure() Instruction*s in the CRBasic program is used to turn the gas head on/off under datalogger control.

The **Head Power Off** setting is stored in non-volatile memory of the EC100.

A.3 ECMon

Settings for the EC150 are easily verified and/or changed by using the Windows PC support software ECMon (ECMon is short for Eddy Covariance Monitor), which is found on the *EC150 & EC155 Support CD* (pn 27007) or at *www.campbellsci.com/downloads*.

Before installing ECMon, read the file named *Read.me.text* found on the *EC150 & EC155 Support CD*. This will direct the user to install USB drivers (also found on the Support CD) which are required for communications between the PC and the EC100 via the EC100 USB cable (pn 26563). Some newer PC operating systems will automatically find and download the USB drivers from the internet when the USB cable is connected to the PC.

Once the drivers are installed, download and run the *ECMon.exe* install file. Launch ECMon and connect the EC100 electronics to the PC with the included EC100 USB cable (pn 26563). The USB connection for the EC100 electronics is found on the bottom of the enclosure (see FIGURE 6-13). Once connected, select the appropriate communications port in the ECMon Main Page and click **Connect** (see FIGURE A-4). Next click on the **Setup** button. All of the above settings are now available for the user to change (see FIGURE A-5).

Besides changing settings, ECMon is also a useful tool for other common tasks such as:

- Monitoring real-time data from the EC150 using the Main window
- Performing a manual zero and span of the instrument (see Section 7, *Zero and Span* *(p. 25)*)
- Troubleshooting and monitoring diagnostics using the Status window

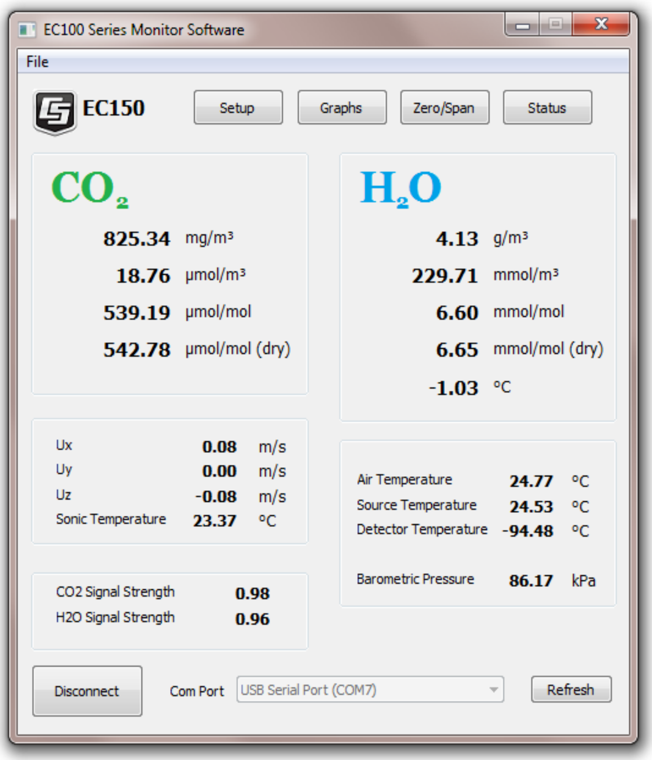

FIGURE A-4. Main screen of ECMon

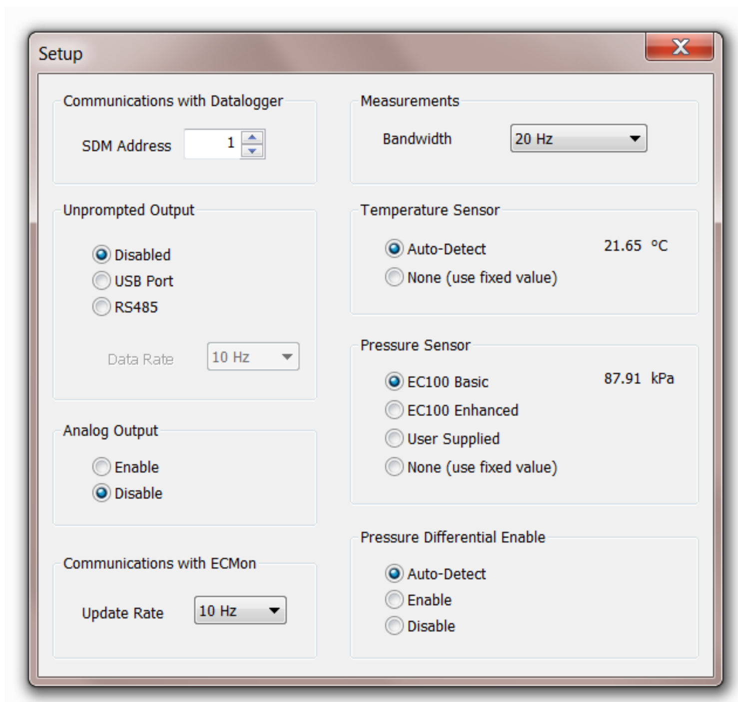

FIGURE A-5. Setup screen in ECMon

A.4 Device Configuration Utility

The Device Configuration Utility software may also be used to change settings, although ECMon is generally preferred as the user interface is more intuitive.

Device Configuration may be downloaded from the *EC150 & EC155 Support CD* (pn 27007), or at *www.campbellsci.com/downloads*.

Device Configuration requires a USB driver to communicate with the EC100, similar to ECMon. See Appendix A.3, *ECMon* *(p. A-7)*, for notes on installing a USB driver.

After launching the **Device Configuration Utility**, the user should select **EC100** from the list of device types. The EC100 electronics should be connected to the PC with the EC100 USB cable (pn 26563) and the appropriate USB port selected before connecting. Once connected, the settings tab displays all the current settings. The **Apply** button must be clicked to save any changes.

The Device Configuration Utility is also used to send an updated operating system to the EC100 electronics. The **Send OS** tab gives directions on this procedure. For a video tutorial on updating the operating system, a video tutorial is available at *http://www.youtube.com/watch?v=dpRXoCv36YI*.

A.5 EC100Configure() Instruction

EC100Configure() is an alternate way to retrieve and modify setting. While ECmon and Device Configuration Utility software are user-interactive, the **EC100Configure()** instruction allows automated control under CRBasic datalogger programming.

EC100Configure() is a processing task instruction. When running in pipeline mode, the datalogger will execute the instruction from the processing task. This functionality allows the instruction to be placed in conditional statements. Execution from processing also introduces ramifications when attempting to execute the **EC100Configure()** instruction while other SDM instructions are executing in pipeline mode. This instruction locks the SDM port during the duration of its execution. If the pipelined SDM task sequencer needs to run while the SDM is locked, it will be held off until the instruction completes. This locking will likely result in skipped scans when reconfiguring an EC150.

NOTE For the EC150 to save settings, it must go through a lengthy write-read-verify process. To avoid saving the settings after each set command, the resulting code can be used to determine if any settings were modified from their original value. When a change is detected, the save settings command (command code **99**) can then be sent to the EC150. The *DestSource* parameter variable should be set to **2718** to save the settings. The reception of this command is acknowledged but since it takes up to a second to complete, a successful return code does not mean that all of the data was successfully written to the appropriate non-volatile memory.

The instruction syntax is:

```
EC100Configure(Result,SDMAddress,ConfigCmd,DestSource)
```

Result is a variable that contains a value indicating the success or failure of the command. A result code of *0* means that the command was successfully executed. If reading a setting, *0* in the result code means that the value in the *DestSource* variable is the value the desired setting has in the EC150. When writing a setting, if the result code is *0*, the value and setting were compatible, but the value was not changed because it contained the same value that was sent. A return code of *1* from the set operation means that the value was valid, different, set and acknowledged. This allows CRBasic code to control whether or not to save the settings. *NAN* (not a number) indicates that the setting was not changed or acknowledged or a signature failure occurred.

SDMAddress defines the address of the EC150 to configure. Valid SDM addresses are 0 through 14. Address 15 is reserved for the **SDMTrigger()** instruction.

ConfigCmd is a variable that indicates whether to get or set a setting. The options are listed in TABLE A-2.

DestSource is a variable that will contain the value to read when getting a setting, or that will contain the value to send when writing a setting to the EC150.

TABLE A-2. ConfigCmd Values for Setting and Retrieving Settings

ConfigCmd Variable		Setting Description (some settings list possible values for the DestSource variable)
Set	Retrieve	
0	100	Bandwidth: • 5 = 5 Hz • 10 = 10 Hz • 12 = 12.5 Hz • 20 = 20 Hz • 25 = 25 Hz
1	101	Unprompted Output: • 10 = 10 Hz • 25 = 25 Hz • 50 = 50 Hz
2	102	Pressure Sensor: • 0 = EC100 Basic • 1 = User-supplied • 2 = EC100 Enhanced • 3 = None (use fixed value)
3	103	Differential Pressure: • 0 = Disable • 1 = Enable
4	104	Fixed Pressure Value
5	105	Pressure Offset

TABLE A-2. ConfigCmd Values for Setting and Retrieving Settings		
ConfigCmd Variable		**Setting Description (some settings list possible values for the DestSource variable)**
Set	**Retrieve**	
6	106	Pressure Gain
7	107	Temperature Sensor: • 0 = EC150 Temperature Probe • 1 = EC155 Sample Cell Thermistor • 2 = EC155 Sample Cell Thermocouple • 3 = None (use fixed value) • 4 = Auto-Select
8	108	Fixed Temperature Value
9	109	Unprompted Output Mode: • 0 = Disable • 1 =USB • 2 = RS-485
10	110	RS-485 Baud Rate
11	111	Span/Zero Control: • 0 = Inactive • 1 = Zero • 2 = Span CO_2 • 3 = Span H_2O (See Appendix A.5.1, *ConfigCmd 11 Zero-and-Span Control* *(p. A-12)*.)
12	112	CO_2 Span Concentration
13	113	H_2O Span Dewpoint Temperature
14	114	CO_2 Zero
15	115	CO_2 Span
16	116	H_2O Zero
17	117	H_2O Span
18 or 218	118	Heater Voltage (0 to 4.5375V, −1 = Off)
19	119	Reserved
20	120	Analog Output Enable: • 0 = Disable • 1 = Enable
21	121	PowerDown: • 0 = Gas Head On • 1 = Gas Head Off
99	N/A	Save Settings to EEPROM memory

A.5.1 ConfigCmd 11 Zero-and-Span Control

To perform zeroing of CO_2 and H_2O, ***ConfigCmd 11*** is set to **1**. After the EC150 completes the zero, it will write the value to **–1**. The datalogger can poll this value or simply wait for a period of time to allow the zeroing to complete. To perform CO_2 span, the ***CO_2 Span Concentration*** setting (***ConfigCmd 12***) must be written to the proper value in ppm CO_2 prior to setting the Span/Zero Control setting (***ConfigCmd 11***) to 2. After the CO_2 span is completed, the value of the ***Span/Zero Control*** setting will change to **–2**. H_2O span is similar to CO_2. First the ***H_2O Dew Point*** value (***ConfigCmd 13***) must be written to the desired value. Then the ***Span/Zero Control*** setting is set to **3**. After the EC150 completes the span, the span control setting is written as **–3**. ***ConfigCmds 14*** through ***17*** automatically store the results of the zero-and-span procedure. Each result is a coefficient used in the gas analyzer's algorithms for calculating gas concentrations.

A.6 Example CRBasic Program

```
'CR3000 Series Datalogger

Public sonic_irga(12)
Alias sonic_irga(1) = Ux
Alias sonic_irga(2) = Uy
Alias sonic_irga(3) = Uz
Alias sonic_irga(4) = Ts
Alias sonic_irga(5) = diag_sonic
Alias sonic_irga(6) = CO2
Alias sonic_irga(7) = H2O
Alias sonic_irga(8) = diag_irga
Alias sonic_irga(9) = cell_tmpr
Alias sonic_irga(10) = cell_press
Alias sonic_irga(11) = CO2_sig_strgth
Alias sonic_irga(12) = H2O_sig_strgth
Units Ux = m/s
Units Uy = m/s
Units Uz = m/s
Units Ts = C
Units diag_sonic  = arb
Units CO2 = mg/m^3
Units H2O = g/m^3
Units diag_irga  = arb
Units cell_tmpr = C
Units cell_press = kPa
Units CO2_sig_strgth = arb
Units H2O_sig_strgth = arb

DataTable (ts_data,TRUE,-1)
  DataInterval (0,0,mSec,10)

  Sample (12,Ux,IEEE4)
EndTable

BeginProg
  Scan (100,mSec,0,0)
    EC100 (Ux,1,1)
    CallTable ts_data
  NextScan
EndProg
```

Appendix B. Filter Bandwidth and Time Delay

The EC100 measures CO_2 and H_2O from the EC150 gas analyzer head. It will also measure wind velocity and sonic temperature if the optional CSAT3A sonic head is being used. EC100 measurements occur at 100z and then a user-selectable, low-pass filter is applied. The available filter bandwidths are 5, 10, 12.5, 20, and 25 Hz.

FIGURE B-1 shows the amplitude response of these filters. The EC100 filters provide a flat pass band, a steep transition from pass band to stop band, and a well-attenuated stop band. FIGURE B-2 compares the EC100 10-Hz filter to a 50-ms moving average filter with approximately the same bandwidth.

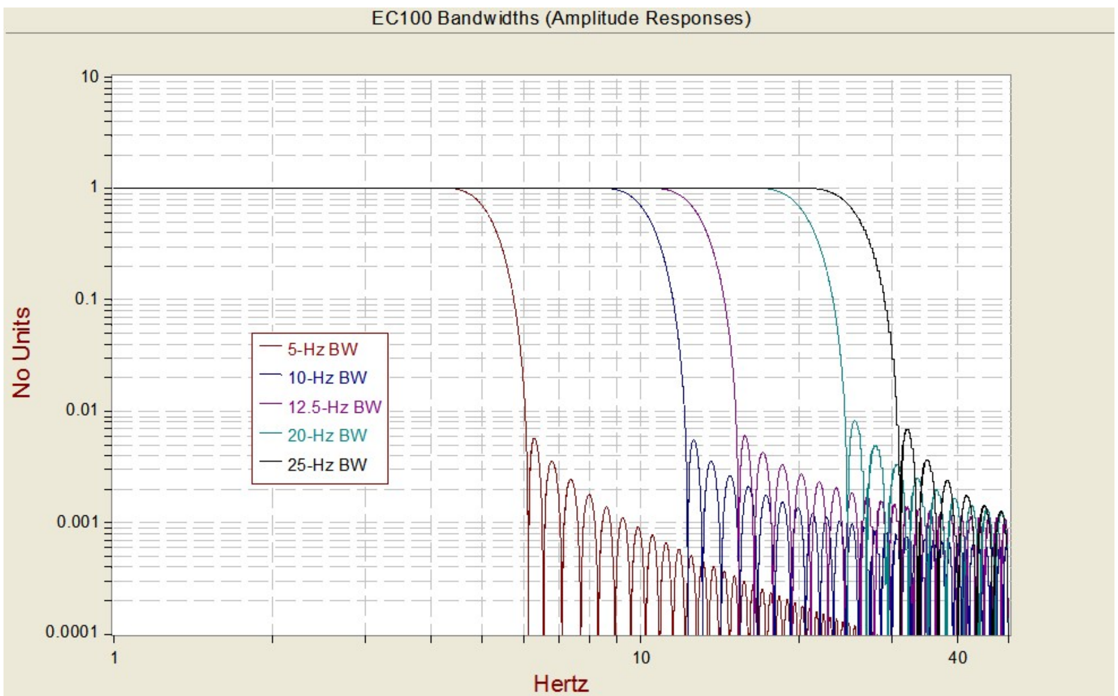

FIGURE B-1. Amplitude response of EC100 filter at various bandwidths

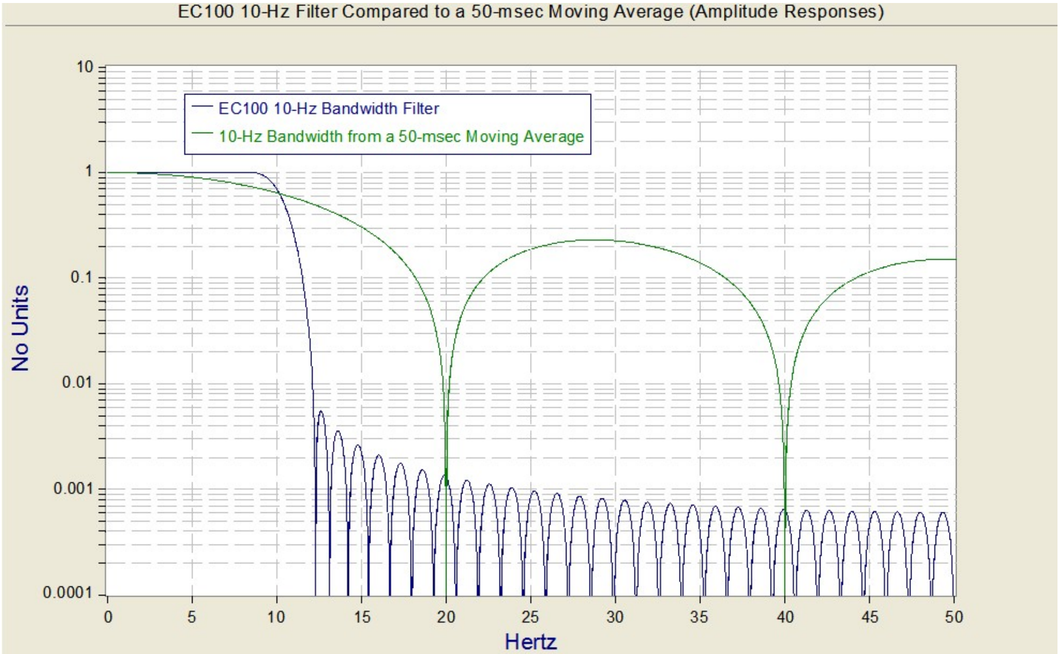

FIGURE B-2. Frequency response comparison of EC100 10-Hz bandwidth and a 50-msec moving average

The ideal eddy-covariance filter is one that is wide enough to preserve the low-frequency signal variations that transport flux, yet narrow enough to attenuate high-frequency noise. In addition, to minimize aliasing (defined as the misinterpretation of high-frequency variation as lower-frequency variation), the measurement bandwidth must be less than half of the sample rate or the datalogger scan rate.

Two factors complicate choosing the ideal eddy-covariance bandwidth. First, the flux signal bandwidth varies from one installation to another, and the flux signal bandwidth varies with mean wind speed at a given installation. Second, the fast sample rate required to anti-alias a desired signal bandwidth may result in large, unwieldy data sets.

Fortunately, the covariance calculation itself relaxes the need for the ideal bandwidth. The time-averaged (typically thirty minutes) covariance calculations inherently reduce noise, and second, aliasing does not degrade the accuracy of covariance calculations. The factory default for the EC100 bandwidth (20 Hz) is rather wide to preserve the signal variations that transport flux. The default bandwidth is suitable for most flux applications. Additional bandwidths are available for users desiring to match the EC100 filter bandwidth to their data acquisition sample rate to avoid aliasing. In this case, the selected bandwidth should be one-half of the sample rate. However, users should be careful to avoid attenuation of flux-carrying signals.

The EC100 electronics synchronously sample the EC150 analyzer and the CSAT3A sonic head. However, users wishing to synchronize their EC100 data with other measurements (for example, a fine-wire thermocouple) in the data acquisition system must account for the time delay of the EC100 filter. TABLE B-1 shows the delay for each of the filter bandwidths. The EC100 provides a constant time delay for all spectral components within each filter's pass band.

TABLE B-1. Filter Time Delays for Various Bandwidths	
Bandwidth (Hz)	**Time Delay (ms)**
5	800
10	400
12.5	320
20	200
25	160

The following examples show how to use TABLE B-1. To synchronize EC100 data to other datalogger measurements when the datalogger scan rate is 25 Hz and the EC100 bandwidth is set to 20 Hz (a 200-msec time delay from TABLE B-1), delay the non-EC100 data by five datalogger scans. Similarly, for a 10-Hz datalogger scan rate and the same 20-Hz EC100 bandwidth, delay the non-EC100 data by two datalogger scans to match the EC100 data. For the best synchronicity, choose a datalogger scan interval that is an integer multiple of the EC100 filter delay.

The EC100 measures the gas and wind data at 150 Hz, and the 150-Hz data are down-sampled to the datalogger's scan rate through SDM communications (see Section 4.6.2, *EC100 Outputs* *(p. 4)*). This process synchronizes the EC100 gas and wind data with other signals measured by the datalogger to within ±3.33 ms (plus or minus one-half of the inverse of 150 Hz).

Alternately, when sending data to a data acquisition system that is not manufactured by Campbell Scientific, the EC100 down-samples its USB and RS-485 outputs to a user-selectable rate of 10, 25, or 50 Hz. Although the gas and wind data from the EC100 remain synchronized with one another, the user must consider the down-sampled output interval when synchronizing the EC100 data with other measurements in their system. These slower output intervals will increase the asynchronicity of EC100 data with other system measurements.

Appendix C. Alternate EC100 Outputs

C.1 USB or RS-485 Output

C.1.1 Specifications

Digital

RS-485

Data type:	ASCII
Output Rate[viii]**:**	5 to 50 Hz
Baud rate[viii]**:**	1200 to 230400 bps **USB**

USB

Data type:	ASCII
Output rate[viii]**:**	10, 25, or 50 Hz

C.1.2 Detailed Information

In contrast to the SDM output mode, which is prompted by a datalogger, data can also be output from the EC100 via USB or RS485 in an unprompted mode. In this case, the EC100 sends out data without initiation from the receiving device at a rate determined by the EC100. Only one unprompted output type (USB or RS-485) may be selected at a given time. USB output is used to connect a PC to the EC100 when using Device Configuration Utility or ECMon software. RS-485 output is recommended over SDM for sending data to a datalogger if the cable length exceeds 100 meters.

To use USB or RS-485 output, connect a USB (pn 26563) or RS-485 (pn 26987) cable from the EC100 to the receiving device (see Section 6.3, *Wiring and Connections* (p. 22)), and configure the settings.

The *Unprompted Output* parameter must be set to USB or RS-485.

If RS-485 is selected, the *RS-485 Baud Rate* must be set.

The *Unprompted Output Rate* must be set to the desired output rate.

All output data will be in ASCII format, with each data element separated by a comma. Each record will terminate with a carriage return and line feed. TABLE C-1 below lists the elements in each output array, and FIGURE C-1 shows an example USB data feed in terminal mode.

TABLE C-1. USB and RS-485 Output Elements

Data Element	Description	Units or Comments
1	Ux	m/s
2	Uy	m/s
3	Uz	m/s
4	Sonic Temperature	°C

[viii] user selectable

TABLE C-1. USB and RS-485 Output Elements

Data Element	Description	Units or Comments
5	Sonic Diagnostic Flag	
6	CO_2 Density	$mg \cdot m^{-3}$
7	H_2O Density	$g \cdot m^{-3}$
8	Gas Diagnostic Flag	
9	Air Temperature	°C
10	Air Pressure	kPa
11	CO_2 Signal Strength	Nominally 0.0 to 1.0
12	H_2O Signal Strength	Nominally 0.0 to 1.0
13	Pressure Differential (used for EC155 only, disregard for IRGASON)	kPa
14	Source Housing Temperature	°C
15	Detector Housing Temperature	°C
16	Counter	Arbitrary
17	Signature	Arbitrary in hexadecimal

Terminal

```
0.06839,-0.06224,-0.02411,22.46829,0,974.604,6.063,0,20.578,87.568,0.924,0.881,0.081,145948,31c2
0.06837,-0.06242,-0.02403,22.50268,0,974.850,6.064,0,20.575,87.569,0.924,0.881,0.081,145963,91ea
0.06840,-0.06241,-0.02407,22.49048,0,974.671,6.067,0,20.581,87.567,0.924,0.881,0.081,145978,df30
0.06837,-0.06238,-0.02408,22.44196,0,974.606,6.064,0,20.578,87.567,0.924,0.881,0.081,145993,bbe6
0.06830,-0.06261,-0.02400,22.46109,0,974.561,6.064,0,20.572,87.568,0.924,0.881,0.080,146008,e80d
0.06824,-0.06271,-0.02410,22.51471,0,974.700,6.066,0,20.571,87.567,0.924,0.881,0.080,146023,4d22
```

FIGURE C-1. USB data output in terminal mode

The final data element in each row or output array is the signature which can be used to identify transmission errors similar to a Cyclic-Redundancy-Check (CRC). The signature is a four character hexadecimal value that is a function of the specific sequence and number of bytes in the output array. To check for transmission errors, the recording device (such as a PC or datalogger) calculates its own signature using each transmitted byte until encountering the transmitted signature. The computed signature and the transmitted signature are compared. If they match, the data were received correctly

If signatures do not match, the data should be disregarded.

The block of code below is an example implementation of Campbell Scientific's signature algorithm in the programming language C. To generate the signature of an output array of bytes, the *seed* needs to be initialized to 0xaaaa and a pointer passed to the first byte of the output array. The number of bytes in the output array should be entered in as the *swath*. The returned value is the computed signature.

```
//signature(), signature algorithm.
// Standard signature is initialized with a seed of 0xaaaa.
// Returns signature.
unsigned short signature( unsigned char* buf, int swath,
unsigned short seed ) {
unsigned char msb, lsb;
unsigned char b;
int i;
msb = seed >> 8;
lsb = seed;
for( i = 0; i < swath; i++ ) {
  b = (lsb << 1) + msb + *buf++;
  if( lsb & 0x80 ) b++;
  msb = lsb;
  lsb = b;
  }
return (unsigned short)((msb << 8) + lsb);
}
```

C.2 Analog Output

C.2.1 Specifications

Analog (two outputs for CO_2 and H_2O densities)

Voltage range:	0 mV to 5000 mV
Resolution:	76 µV (16 bit)
Update rate:	60 Hz
Accuracy (at 25 °C):	± 3 mV
CO_2 density equation:	$mg \cdot m^{-3} = 0.38632 \cdot (mV_{out}) - 102.59$
Full scale range:	-103 to 1829 $mg \cdot m^{-3}$
H_2O density equation:	$g \cdot m^{-3} = 0.00865 \cdot (mV_{out}) - 2.26$
Full scale range:	-2 to 41 $g \cdot m^{-3}$

C.2.2 Detailed Information

Although digital outputs are generally preferred, analog outputs are available on the EC100 for compatibility with simple recording devices that cannot use the digital outputs. Analog outputs are subject to additional noise and digitization errors. Digital outputs include additional diagnostic data to assist with data quality assessment and troubleshooting. If analog output is enabled, the EC100 will output two analog signals that correspond to CO_2 density and H_2O density. These signals range from 0 to +5 V. TABLE C-2 gives the multipliers and offsets for the analog outputs.

Analog output may also be used, however only CO_2 density and H_2O density will be output. For analog output, use cable CABLE2TP-L (pn 26986-L), the length of which is specified by the user when ordering. The connector labeled Analog Outputs on the EC100 panel indicates where each wire should be connected (CO_2 voltage signal, H_2O voltage signal, and two ground connections).

TABLE C-2. Multipliers and Offsets for Analog Outputs		
Density ($mg \cdot m^{-3}$)	**Voltage Output Multiplier ($mg \cdot m^{-3}\ V^{-1}$)**	**Offset ($mg \cdot m^{-3}$)**
CO_2	386.32	−102.59
H_2O	8.65	−2.26

Appendix D. Useful Equations

The following table lists all the variables and constants used in the equations below:

TABLE D-1. Variables and Constants		
Variable or Constant	**Description**	**Units**
ρ_c	CO_2 mass density	$mg\cdot m^{-3}$
ρ_v	H_2O mass density	$g\cdot m^{-3}$
ρ_d	Mass density of dry air	$g\cdot m^{-3}$
X_c	CO_2 molar mixing ratio (concentration relative to dry air)	$\mu mol\cdot mol^{-1}$
X_v	H_2O molar mixing ratio (concentration relative to dry air)	$mmol\cdot mol^{-1}$
M_c	Molecular weight of CO_2	$44\ mg\cdot mmol^{-1}$
M_d	Molecular weight of dry air	$0.029\ g\cdot mmol^{-1}$
M_v	Molecular weight of H_2O	$0.018\ g\cdot mmol^{-1}$
P	Ambient pressure	kPa
R	Universal gas constant	8.3143×10^{-6} kPa·m3·$K^{-1}\cdot mmol^{-1}$
T	Ambient temperature	°C
e	Vapor pressure	kPa
f	Enhancement factor	Arbitrary
T_d	Dewpoint temperature	°C
T_{d_tmp}	Temporary variable for dewpoint calculation	Arbitrary

Mass Density from Molar Mixing Ratios

$$\rho_c = \frac{X_c M_c}{10^6}\left(\frac{P}{R(T+273.15)} - \frac{\rho_v}{M_v}\right) \tag{D-1}$$

$$\rho_v = \frac{X_v P M_v}{R(T+273.15)(1000+X_v)} \tag{D-2}$$

$$\rho_d = \frac{(P-e)M_d}{R(T+273.15)} \tag{D-3}$$

$$\rho_d = \frac{\left(P - \frac{X_v P}{1000 + X_v}\right) M_d}{R(T + 273.15)} \tag{D-4}$$

$$\rho_d = \left(\frac{P M_d}{R(T + 273.15)}\right)\left(1 - \frac{X_v}{1000 + X_v}\right) \tag{D-5}$$

Dew Point from Molar Mixing Ratio

$$T_d = \frac{240.97\, T_{d\_tmp}}{17.502 - T_{d\_tmp}} \tag{D-6}$$

$$T_{d\_tmp} = ln\left(\frac{X_v P}{0.61121 \cdot f(1000 + X_v)}\right) \tag{D-7}$$

$$f = 1.00072 + \left(3.2 \times 10^{-5}\right)P + \left(5.9 \times 10^{-9}\right)PT^2 \tag{D-8}$$

Water Vapor Molar Mixing Ratio from Dew Point

$$X_v = \frac{e}{P - e} 1000 \tag{D-9}$$

$$e = 0.61121 \cdot f \cdot EXP\left(\frac{17.502 T_d}{240.97 + T_d}\right) \tag{D-10}$$

Water Vapor Mass Density from Dew Point

$$\rho_v = \frac{(0.018)(0.61121) f}{R(T + 273.15)} EXP\left(\frac{17.502 T_d}{240.97 + T_d}\right) \tag{D-11}$$

Vapor Pressure from Molar Mixing Ratio and Water Vapor Density

$$e = \frac{X_v P}{1000 + X_v} \tag{D-12}$$

$$e = \frac{\rho_v R(T + 273.15)}{M_v} \tag{D-13}$$

Equations (D-1) and (D-2) were derived from:

Leuning, R.: 2005, “Measurements of Trace Gas Fluxes in the Atmosphere Using Eddy Covariance: WPL Corrections Revisited”, *Handbook of Micrometeorology*, **29**, 119-132.

Equations (D-3), (D-4), (D-5), (D-7), (D-9), and (D-13) were derived from:

Bolton, D.: 1980, “The Computation of Equivalent Potential Temperature”, *Monthly Weather Review*, **108**, 1046-1053.

Equations (D-6), (D-8), (D-10) and (D-11) were derived from:

Buck, A. L.: 1981; “New Equations for Computing Vapor Pressure and Enhancement Factor”, *Journal of Applied Meteorology*, **20**, 1528-1532.

Appendix E. Material Safety Data Sheets (MSDS)

E.1 Magnesium Perchlorate MSDS

GFS CHEMICALS

SAFETY DATA SHEET

1. Identification

Product identifier	**MAGNESIUM PERCHLORATE, ANHYDROUS, REAGENT (ACS)**
Other means of identification	
Product code	55
Recommended use	professional, scientific and technical activities: scientific research and development
Recommended restrictions	None known.

Manufacturer/Importer/Supplier/Distributor information

Company name	GFS Chemicals, Inc.	
Address	P.O. Box 245 Powell OH 43065 US	
Telephone	Phone	740-881-5501
	Toll Free	800-858-9682
	Fax	740-881-5989
Website	www.gfschemicals.com	
E-mail	service@gfschemicals.com	
Emergency phone number	Emergency Assistance	Chemtrec 800-424-9300

2. Hazard(s) identification

Physical hazards	Oxidizing solids	Category 2
Health hazards	Serious eye damage/eye irritation	Category 2A
	Specific target organ toxicity, single exposure	Category 3 respiratory tract irritation
OSHA hazard(s)	Not classified.	

Label elements

Signal word	Danger
Hazard statement	May intensify fire; oxidizer. Causes serious eye irritation. May cause respiratory irritation.
Precautionary statement	
Prevention	Keep/Store away from clothing and other combustible materials. Keep away from heat. Use only outdoors or in a well-ventilated area. Take any precaution to avoid mixing with combustibles. Avoid breathing dust. Wash thoroughly after handling. Wear protective gloves/eye protection/face protection.
Response	If inhaled: Remove person to fresh air and keep comfortable for breathing. If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Call a POISON CENTER or doctor/physician if you feel unwell. If eye irritation persists: Get medical advice/attention. In case of fire: Use appropriate media for extinction.
Storage	Store in a well-ventilated place. Keep container tightly closed. Store locked up.
Disposal	Dispose of contents/container to an appropriate treatment and disposal facility in accordance with applicable laws and regulations, and product characteristics at time of disposal.
Hazard(s) not otherwise classified (HNOC)	Not classified.

3. Composition/information on ingredients

Substances

Hazardous components

Chemical name	Common name and synonyms	CAS number	%
MAGNESIUM PERCHLORATE		10034-81-8	100

*Designates that a specific chemical identity and/or percentage of composition has been withheld as a trade secret.

4. First-aid measures

Inhalation	If dust from the material is inhaled, remove the affected person immediately to fresh air. Call a POISON CENTER or doctor/physician if you feel unwell.
Skin contact	Immediately flush skin with plenty of water. Get medical attention if irritation develops and persists.
Eye contact	Immediately flush eyes with plenty of water for at least 15 minutes. Remove contact lenses, if present and easy to do. Continue rinsing. If eye irritation persists: Get medical advice/attention.
Ingestion	Have victim rinse mouth thoroughly with water. Drink 1 or 2 glasses of water.
Most important symptoms/effects, acute and delayed	Irritation of eyes and mucous membranes.
Indication of immediate medical attention and special treatment needed	Provide general supportive measures and treat symptomatically.
General information	Ensure that medical personnel are aware of the material(s) involved, and take precautions to protect themselves.

5. Fire-fighting measures

Suitable extinguishing media	Water.
Unsuitable extinguishing media	None known.
Specific hazards arising from the chemical	May intensify fire; oxidizer.
Special protective equipment and precautions for firefighters	Firefighters must use standard protective equipment including flame retardant coat, helmet with face shield, gloves, rubber boots, and in enclosed spaces, SCBA.
Fire-fighting equipment/instructions	Move containers from fire area if you can do it without risk. Move containers from fire area if you can do so without risk. In the event of fire, cool tanks with water spray. For massive fire in cargo area, use unmanned hose holder or monitor nozzles, if possible. If not, withdraw and let fire burn out.
Specific methods	Cool containers exposed to flames with water until well after the fire is out.

6. Accidental release measures

Personal precautions, protective equipment and emergency procedures	Keep unnecessary personnel away. Local authorities should be advised if significant spillages cannot be contained. Use a NIOSH/MSHA approved respirator if there is a risk of exposure to dust/fume at levels exceeding the exposure limits. Do not touch damaged containers or spilled material unless wearing appropriate protective clothing. Keep people away from and upwind of spill/leak. Keep upwind. Keep out of low areas. Ventilate closed spaces before entering them. Avoid inhalation of dust from the spilled material. Wear appropriate personal protective equipment.
Methods and materials for containment and cleaning up	ELIMINATE all ignition sources (no smoking, flares, sparks or flames in immediate area). Keep combustibles (wood, paper, oil, etc.) away from spilled material. This product is miscible in water. After removal flush contaminated area thoroughly with water. If sweeping of a contaminated area is necessary use a dust suppressant agent which does not react with the product. Sweep up or vacuum up spillage and collect in suitable container for disposal. Collect dust using a vacuum cleaner equipped with HEPA filter. Avoid the generation of dusts during clean-up. Dilute with plenty of water. Following product recovery, flush area with water. Prevent entry into waterways, sewer, basements or confined areas. For waste disposal, see section 13 of the MSDS.
Environmental precautions	Avoid discharge into drains, water courses or onto the ground. Prevent further leakage or spillage if safe to do so.

7. Handling and storage

Precautions for safe handling	Avoid dust formation. Do not breathe dust from this material. In case of insufficient ventilation, wear suitable respiratory equipment. Take any precaution to avoid mixing with combustibles. Keep away from heat. Guard against dust accumulation of this material. Provide appropriate exhaust ventilation at places where dust is formed. Avoid contact with skin and eyes. Wash hands thoroughly after handling. Practice good housekeeping.
Conditions for safe storage, including any incompatibilities	Do not store around flammable or combustible materials. Keep away from heat. Store in a well-ventilated place. Keep container tightly closed. Avoid dust formation. Do not store near combustible materials. Guard against dust accumulation of this material. Keep out of the reach of children. Store in a cool, dry place out of direct sunlight.

8. Exposure controls/personal protection

Occupational exposure limits	No exposure limits noted for ingredient(s).
Biological limit values	No biological exposure limits noted for the ingredient(s).
Appropriate engineering controls	Ventilation should be sufficient to effectively remove and prevent buildup of any dusts or fumes that may be generated during handling or thermal processing. An eye wash and safety shower must be available in the immediate work area.

Individual protection measures, such as personal protective equipment

Eye/face protection	Wear eye/face protection. Use tight fitting goggles if dust is generated. Eye wash fountains are required.
Skin protection	
Hand protection	Wear protective gloves.
Other	Wear suitable protective clothing. Wear protective gloves.
Respiratory protection	Respirator must be worn if exposed to dust. Wear respirator with dust filter.
Thermal hazards	Not available.
General hygiene considerations	Do not breathe dust. Avoid contact with eyes. Wash hands before breaks and immediately after handling the product. Handle in accordance with good industrial hygiene and safety practice.

9. Physical and chemical properties

Appearance	Granular. and Powder.
Physical state	Solid.
Form	Solid.
Color	White.
Odor	Odorless.
Odor threshold	Not available.
pH	Not available.
Melting point/freezing point	482 °F (250 °C)
Initial boiling point and boiling range	Not available.
Flash point	Not available.
Evaporation rate	Not available.
Flammability (solid, gas)	Not applicable.
Upper/lower flammability or explosive limits	
Flammability limit - lower (%)	Not available.
Flammability limit - upper (%)	Not available.
Explosive limit - lower (%)	Not available.
Explosive limit - upper (%)	Not available.
Vapor pressure	Not available.
Vapor density	Not available.
Relative density	Not available.
Solubility(ies)	Very soluble with evolution of heat
Partition coefficient (n-octanol/water)	Not available.
Auto-ignition temperature	Not available.
Decomposition temperature	> 482 °F (> 250 °C) When heated to decomp, emits toxic fumes of magnesium oxide and hydrogen chloride.
Viscosity	Not available.
Other information	
Density	2.20 g/cm3 estimated
Molecular formula	$Mg(ClO_4)_2$
Molecular weight	223.23 g/mol
pH in aqueous solution	5 - 8 (5% solution)

Specific gravity 2.2

10. Stability and reactivity

Reactivity	Combustible material.
Chemical stability	Material is stable under normal conditions. Risk of ignition.
Possibility of hazardous reactions	Hazardous polymerization does not occur.
Conditions to avoid	Avoid spread of dust. Drying of this product on clothing or combustible materials may cause fire. Excessive heat.
Incompatible materials	Exothermic reaction on contact with water will release heat and steam. Organic materials Strong acids.
Hazardous decomposition products	Hydrogen chloride.

11. Toxicological information

Information on likely routes of exposure

Ingestion	Due to lack of data the classification is not possible.
Inhalation	Inhalation of dusts may cause respiratory irritation.
Skin contact	Due to lack of data the classification is not possible.
Eye contact	Causes serious eye irritation.
Symptoms related to the physical, chemical and toxicological characteristics	Not available.

Information on toxicological effects

Acute toxicity

Product	Species	Test Results
MAGNESIUM PERCHLORATE (CAS 10034-81-8)		
Acute		
Other		
LD50	Mouse	1500 mg/kg

* Estimates for product may be based on additional component data not shown.

Skin corrosion/irritation	Due to lack of data the classification is not possible.
Serious eye damage/eye irritation	Causes serious eye irritation. Dust in the eyes will cause irritation.
Respiratory sensitization	Due to lack of data the classification is not possible.
Skin sensitization	Due to lack of data the classification is not possible.
Germ cell mutagenicity	Due to lack of data the classification is not possible.
Carcinogenicity	This product is not considered to be a carcinogen by IARC, ACGIH, NTP, or OSHA.
Reproductive toxicity	Due to lack of data the classification is not possible.
Specific target organ toxicity - single exposure	Respiratory tract irritation.
Specific target organ toxicity - repeated exposure	The perchlorate ion competes with iodide in the mechanism that governs uptake into the thyroid gland for growth hormone production. This effect is routinely countered by ensuring sufficient dietary intake of iodine, as perchlorate does not accumulate in the body. Studies on workers in plants where perchlorates are manufactured have shown no thyroid abnormalities; various clinical studies are ongoing. Perchlorates occur naturally in trace amounts in the environment, and are not classified as carcinogenic. Due to lack of data the classification is not possible
Aspiration hazard	Due to lack of data the classification is not possible.
Further information	This product has no known adverse effect on human health.

12. Ecological information

Ecotoxicity	This material is not expected to be harmful to aquatic life.
Persistence and degradability	None known.
Bioaccumulative potential	Not available.
Mobility in soil	Not available.
Other adverse effects	Not available.

13. Disposal considerations

Disposal instructions	Collect and reclaim or dispose in sealed containers at licensed waste disposal site. This material and its container must be disposed of as hazardous waste. Do not allow this material to drain into sewers/water supplies. Do not contaminate ponds, waterways or ditches with chemical or used container. If discarded, this product is considered a RCRA ignitable waste, D001. Dispose of contents/container in accordance with local/regional/national/international regulations.
Local disposal regulations	Not available.
Hazardous waste code	D001: Waste Flammable material with a flash point <140 F
Waste from residues / unused products	Dispose of in accordance with local regulations. Empty containers or liners may retain some product residues. This material and its container must be disposed of in a safe manner (see: Disposal instructions). Not applicable.
Contaminated packaging	Empty containers should be taken to an approved waste handling site for recycling or disposal. Since emptied containers may retain product residue, follow label warnings even after container is emptied. Offer rinsed packaging material to local recycling facilities.

14. Transport information

DOT

UN number	UN1475
UN proper shipping name	Magnesium perchlorate
Transport hazard class(es)	5.1
Subsidary class(es)	Not available.
Packing group	II
Special precautions for user	Read safety instructions, SDS and emergency procedures before handling.
Labels required	5.1
Special provisions	IB6, IP2, T3, TP33
Packaging exceptions	152
Packaging non bulk	212
Packaging bulk	242

IATA

UN number	UN1475
UN proper shipping name	Magnesium perchlorate
Transport hazard class(es)	5.1
Subsidary class(es)	-
Packaging group	II
Environmental hazards	No
Labels required	Not available.
ERG Code	5L
Special precautions for user	Not available.

IMDG

UN number	UN1475
UN proper shipping name	MAGNESIUM PERCHLORATE
Transport hazard class(es)	5.1
Subsidary class(es)	-
Packaging group	II
Environmental hazards	
Marine pollutant	No
Labels required	Not available.
EmS	F-H, S-Q
Special precautions for user	Not available.

Transport in bulk according to Annex II of MARPOL 73/78 and the IBC Code	No information available.

DOT

IATA; IMDG

15. Regulatory information

US federal regulations This product is a "Hazardous Chemical" as defined by the OSHA Hazard Communication Standard, 29 CFR 1910.1200.
CERCLA/SARA Hazardous Substances - Not applicable.

All components are on the U.S. EPA TSCA Inventory List.

TSCA Section 12(b) Export Notification (40 CFR 707, Subpt. D)

Not regulated.

US. OSHA Specifically Regulated Substances (29 CFR 1910.1001-1050)

Not on regulatory list.

CERCLA Hazardous Substance List (40 CFR 302.4)

Not listed.

Superfund Amendments and Reauthorization Act of 1986 (SARA)

Hazard categories	Immediate Hazard - Yes Delayed Hazard - Yes Fire Hazard - Yes Pressure Hazard - No Reactivity Hazard - No
SARA 302 Extremely hazardous substance	No
SARA 311/312 Hazardous chemical	No

Other federal regulations

Clean Air Act (CAA) Section 112 Hazardous Air Pollutants (HAPs) List

Not regulated.

Clean Air Act (CAA) Section 112(r) Accidental Release Prevention (40 CFR 68.130)

Not regulated.

Safe Drinking Water Act (SDWA) Not regulated.

Drug Enforcement Administration (DEA). List 2, Essential Chemicals (21 CFR 1310.02(b) and 1310.04(f)(2) and Chemical Code Number

Not listed.

Drug Enforcement Administration (DEA). List 1 & 2 Exempt Chemical Mixtures (21 CFR 1310.12(c))

Not regulated.

DEA Exempt Chemical Mixtures Code Number

Not regulated.

Food and Drug Administration (FDA) Not regulated.

US state regulations California Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65): This material is not known to contain any chemicals currently listed as carcinogens or reproductive toxins.

US. Massachusetts RTK - Substance List

MAGNESIUM PERCHLORATE (CAS 10034-81-8)

US. New Jersey Worker and Community Right-to-Know Act

Not regulated.

US. Pennsylvania RTK - Hazardous Substances

MAGNESIUM PERCHLORATE (CAS 10034-81-8)

US. Rhode Island RTK

MAGNESIUM PERCHLORATE (CAS 10034-81-8)

US. California Proposition 65

US - California Proposition 65 - Carcinogens & Reproductive Toxicity (CRT): Listed substance

Not listed.

International Inventories

Country(s) or region	Inventory name	On inventory (yes/no)*
Australia	Australian Inventory of Chemical Substances (AICS)	Yes
Canada	Domestic Substances List (DSL)	Yes
Canada	Non-Domestic Substances List (NDSL)	No
China	Inventory of Existing Chemical Substances in China (IECSC)	Yes
Europe	European Inventory of Existing Commercial Chemical Substances (EINECS)	Yes
Europe	European List of Notified Chemical Substances (ELINCS)	No
Japan	Inventory of Existing and New Chemical Substances (ENCS)	Yes
Korea	Existing Chemicals List (ECL)	Yes
New Zealand	New Zealand Inventory	Yes
Philippines	Philippine Inventory of Chemicals and Chemical Substances (PICCS)	Yes
United States & Puerto Rico	Toxic Substances Control Act (TSCA) Inventory	Yes

*A "Yes" indicates this product complies with the inventory requirements administered by the governing country(s)

16. Other information, including date of preparation or last revision

Issue date March-26-2013

Version # 01

Further information Not available.

Disclaimer The information in the sheet was written based on the best knowledge and experience currently available. The information given is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

Revision Information

Product and Company Identification: Alternate Trade Names
Hazards Identification: US Hazardous
Composition / Information on Ingredients: Ingredients
Physical & Chemical Properties: Multiple Properties
Transport Information: Proper Shipping Name/Packing Group
Regulatory Information: United States
HazReg Data: International Inventories

E.2 Decarbite MSDS

P. W. PERKINS CO., INC.
221 Commissioners Pike – Woodstown, NJ 08098-2032 USA
1-(856) 769-3525 Fax 1-(856) 769-2177

www.pwperkins.com
www.decarbite.com
sales@pwperkins.com

MATERIAL SAFETY DATA SHEET

IDENTITY	**DECARBITE®**

SECTION I

MANUFACTURER'S NAME:
P. W. PERKINS CO., INC.
221 COMMISSIONERS PIKE
WOODSTOWN NJ 08098-2032 USA

EMERGENCY TELEPHONE NUMBER: 1-800-424-9300 (CHEMTREC)
(INTERNATIONAL: CALL CHEMTREC COLLECT 1-703-527-3887

DATE PREPARED: May 3, 2010

SECTION II – Hazardous Ingredients/Identity Information

HMIS HAZARD RATINGS, Health Hazard 3; Fire Hazard, 0; Reactivity 2
WHMIS Classification: Class E, Corrosive Material
Hazardous Components: Sodium Hydroxide, caustic soda, CAS #1310-73-2
Chemical formula: NaOH
DOT ID: UN1823
DOT Shipping name: Sodium Hydroxide, Solid
DOT Hazard Class: 8, corrosive, Packaging Group II
PEL = 2mg/m^3
TLV = 2mg/m^3
Hazardous Substance: RO 1000
Proprietary formulation indicating CO_2 Adsorbent
Sodium Hydroxide: CAS #1310-73-2
Non Fibrous Silicate: CAS #1318-00-9

SECTION III – PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point: @ 760 mm Hg: 1388° C
Vapor Pressure (mm Hg.): 42 mm Hg @ 1000° C
Vapor Density (Air =): NA
Specific Gravity (H_20 = 1) 2.13 @ 20° C
Melting Point: NA
Evaporation Rate (Butyl Acetate = 1) NA
Solubility in Water: Completely soluble
Appearance and Odor: tan, no distinct odor

SECTION IV – Fire and Explosion Hazard Data
Flash Point (Method Used): No flash to 550° F ASTM D-56
Flammable Limits: Non flammable
LEL: NA
UEL: NA
Extinguishing Media: Product not combustible. Foam/CO_2 or dry chemical can Be used. Direct contact with water can cause a violent exothermic reaction.

Special Fire Fighting Procedures: Protective clothing/self contained breathing apparatus should be worn by fire fighters in area where product is stored.

Unusual Fire and Explosion Hazards: Material is stable (non explosive), nonflammable. Will react with varying degrees of intensity on exposure to water and strong acids.

SECTION V – Reactivity Data
Stability: Stable
Conditions to Avoid: Contact with water causes strong exothermic reaction. Avoid strong acids contact.

Incompatibility (Materials to Avoid): Water, strong acids, aluminum, tin, zinc.

Hazardous Decomposition or Byproducts: Exposure to air results in formation of H_2O and carbonate.

Hazardous Polymerization: Will Not Occur

Conditions to Avoid: Material not known to polymerize.

SECTION VI – Health Hazard Date
Route(s) of Entry: Inhalation? 4-Extreme; Skin? 4-Extreme;
Ingestion? 3-Severe

Health Hazards (Acute and Chronic): Corrosive to all body tissue which it comes in contact. The chronic local effect may consist of multiple areas of superficial destruction of the skin. Inhalation of dust may cause varying degrees of irritation.

Carcinogenicity: NTP? NA; IARC Monographs? NA;
OSHA Regulated? NA Not listed as a carcinogen.

Signs and Symptoms of Exposure: Itching, burning of skin or eyes. Temporary discomfort of breathing passages.

Medical Conditions Generally Aggravated by Exposure: Increased susceptibility to respiratory illness.

Emergency and First Aid Procedures: Flush with water. Seek medical attention. Eyes – flush with large amounts of clean water, followed by boric acid eye wash solution.

SECTION VII – Precautions for Safe Handling and Use

Steps to Be Taken in Case Material is Released or Spilled: Wash area with 1 molar Hydrochloric Acid or use caustic spill kit. Wash with clean water.

Waste Disposal Method: Appropriate disposal should conform with local and state health regulations.

Precautions to Be Taken in Handling and Storing: Wear protective clothing, use adequate ventilation where dust may be generated.

Other Precautions: Respirator, eye protection, gloves, lab coat or other clothing to cover exposed skin area.

SECTION VIII – Control Measures

Respiratory Protection (Specify, Type): Advantage 3000 Respirator, full face mask, model 3200 Twin Port or NIOSH approved respirator.

Ventilation:	Local Exhaust: Exhaust fan	Special: NA
	Mechanical (General) NA	Other: NA

Protective Gloves: Impervious

Eye Protection: Goggles/face shield

Other Protective Clothing or Equipment: Coveralls, chemically resistant shoes.

Work/Hygienic Practices: Wash contaminated clothes; showers and eye wash should be accessible.

Appendix F. Packing Information

F.1 EC150-GH Packing Information

The EC150 components are placed in a foam cutout that helps protect them from damage during shipment. The EC150 should look like the photographs below. After unpacking, it is recommended to save the foam cutout as the EC150 components should be placed in the foam cutout whenever the EC150 is transported to another location.

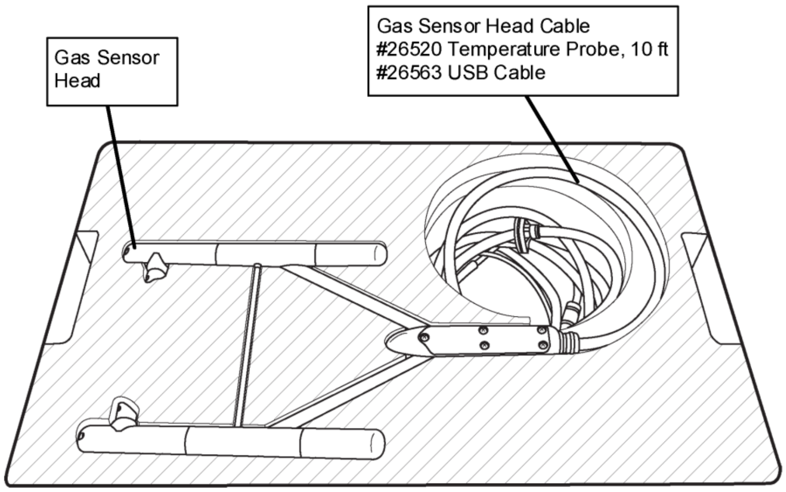

FIGURE 1. Foam Cutout and Components in Upper Level of Packaging

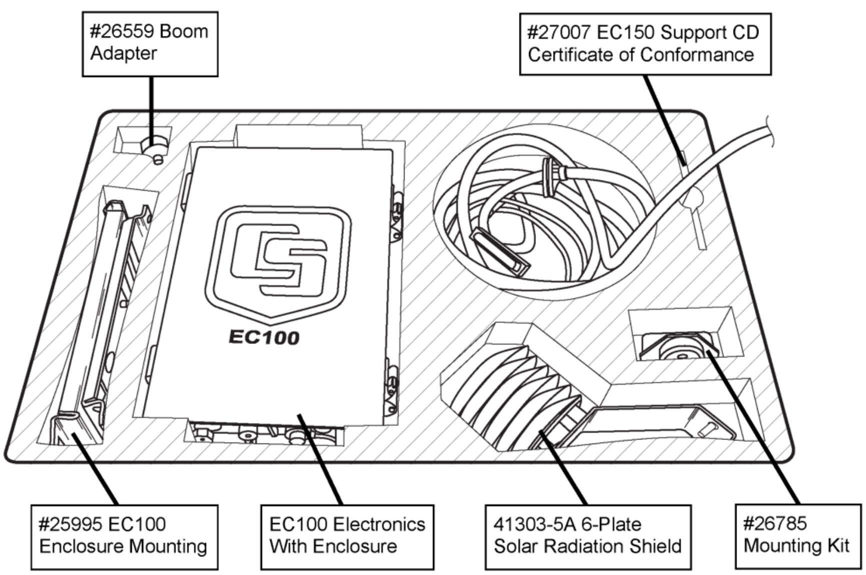

FIGURE 2. Foam Cutout and Components in Lower Level of Packaging

F.2 EC150-SH Packing Information

The EC150 components are placed in a foam cutout that helps protect them from damage during shipment. The EC150 should look like the photographs below. After unpacking, it is recommended to save the foam cutout as the EC150 components should be placed in the foam cutout whenever the EC150 is transported to another location.

Another box containing the Sonic Head and its components will also be shipped.

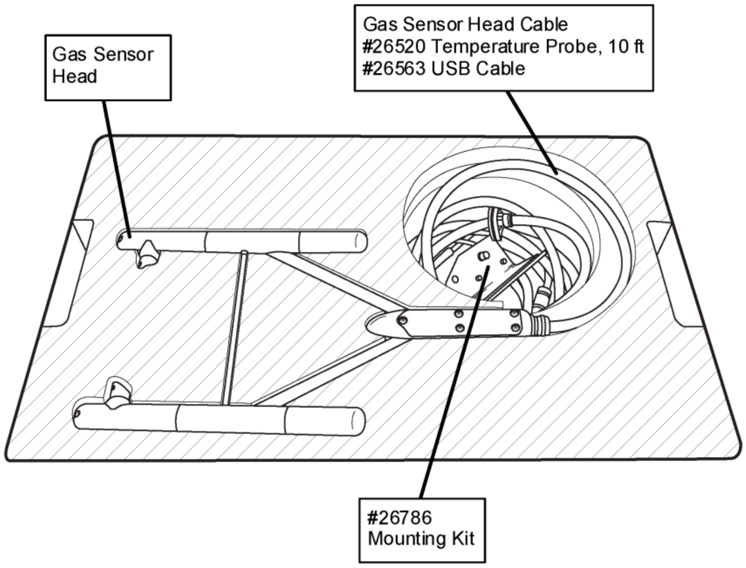

FIGURE 1. Foam Cutout and Components in Upper Level of Packaging

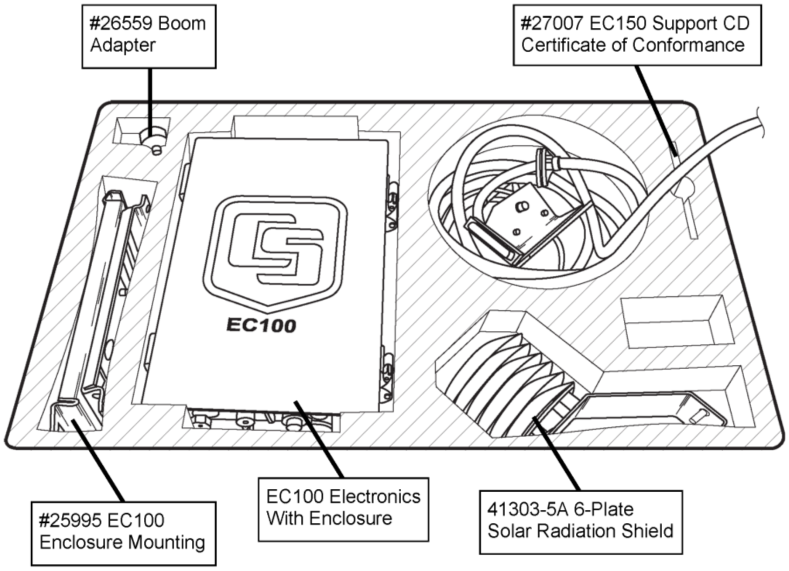

FIGURE 2. Foam Cutout and Components in Lower Level of Packaging

Campbell Scientific Companies

Campbell Scientific, Inc.
815 West 1800 North
Logan, Utah 84321
UNITED STATES
www.campbellsci.com • info@campbellsci.com

Campbell Scientific Canada Corp.
14532 – 131 Avenue NW
Edmonton AB T5L 4X4
CANADA
www.campbellsci.ca • dataloggers@campbellsci.ca

Campbell Scientific Africa Pty. Ltd.
PO Box 2450
Somerset West 7129
SOUTH AFRICA
www.campbellsci.co.za • cleroux@csafrica.co.za

Campbell Scientific Centro Caribe S.A.
300 N Cementerio, Edificio Breller
Santo Domingo, Heredia 40305
COSTA RICA
www.campbellsci.cc • info@campbellsci.cc

Campbell Scientific Southeast Asia Co., Ltd.
877/22 Nirvana@Work, Rama 9 Road
Suan Luang Subdistrict, Suan Luang District
Bangkok 10250
THAILAND
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Campbell Scientific Ltd.
Campbell Park
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Campbell Scientific do Brasil Ltda.
Rua Apinagés, nbr. 2018 ─ Perdizes
CEP: 01258-00 ─ São Paulo ─ SP
BRASIL
www.campbellsci.com.br • vendas@campbellsci.com.br

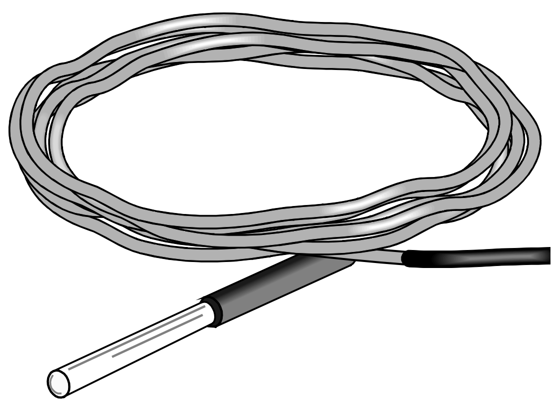
Campbell Scientific Spain, S. L.
Avda. Pompeu Fabra 7-9, local 1
08024 Barcelona
SPAIN
www.campbellsci.es • info@campbellsci.es

Please visit www.campbellsci.com to obtain contact information for your local US or international representative.

INSTRUCTION MANUAL

Model 108 Temperature Probe

Revision: 10/16



Limited Warranty

“Products manufactured by CSI are warranted by CSI to be free from defects in materials and workmanship under normal use and service for twelve months from the date of shipment unless otherwise specified in the corresponding product manual. (Product manuals are available for review online at *www.campbellsci.com*.) Products not manufactured by CSI, but that are resold by CSI, are warranted only to the limits extended by the original manufacturer. Batteries, fine-wire thermocouples, desiccant, and other consumables have no warranty. CSI’s obligation under this warranty is limited to repairing or replacing (at CSI’s option) defective Products, which shall be the sole and exclusive remedy under this warranty. The Customer assumes all costs of removing, reinstalling, and shipping defective Products to CSI. CSI will return such Products by surface carrier prepaid within the continental United States of America. To all other locations, CSI will return such Products best way CIP (port of entry) per Incoterms ® 2010. This warranty shall not apply to any Products which have been subjected to modification, misuse, neglect, improper service, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied. The warranty for installation services performed by CSI such as programming to customer specifications, electrical connections to Products manufactured by CSI, and Product specific training, is part of CSI's product warranty. **CSI EXPRESSLY DISCLAIMS AND EXCLUDES ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE**. **CSI hereby disclaims, to the fullest extent allowed by applicable law, any and all warranties and conditions with respect to the Products, whether express, implied or statutory, other than those expressly provided herein.**

Assistance

Products may not be returned without prior authorization. The following contact information is for US and international customers residing in countries served by Campbell Scientific, Inc. directly. Affiliate companies handle repairs for customers within their territories. Please visit *www.campbellsci.com* to determine which Campbell Scientific company serves your country.

To obtain a Returned Materials Authorization (RMA), contact CAMPBELL SCIENTIFIC, INC., phone (435) 227-9000. Please write the issued RMA number clearly on the outside of the shipping container. Campbell Scientific's shipping address is:

CAMPBELL SCIENTIFIC, INC.
RMA#_____
815 West 1800 North
Logan, Utah 84321-1784

For all returns, the customer must fill out a "Statement of Product Cleanliness and Decontamination" form and comply with the requirements specified in it. The form is available from our website at *www.campbellsci.com/repair*. A completed form must be either emailed to *repair@campbellsci.com* or faxed to (435) 227-9106. Campbell Scientific is unable to process any returns until we receive this form. If the form is not received within three days of product receipt or is incomplete, the product will be returned to the customer at the customer's expense. Campbell Scientific reserves the right to refuse service on products that were exposed to contaminants that may cause health or safety concerns for our employees.

Safety

DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND **TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC**. FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at www.campbellsci.com or by telephoning (435) 227-9000 (USA). You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified engineer. If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

General

- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations, such as those of the FAA in the USA.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a **hardhat** and **eye protection**, and take **other appropriate safety precautions** while working on or around tripods and towers.
- **Do not climb** tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

Utility and Electrical

- **You can be killed** or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in **contact with overhead or underground utility lines**.
- Maintain a distance of at least one-and-one-half times structure height, 20 feet, or the distance required by applicable law, **whichever is greater**, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.

Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

WHILE EVERY ATTEMPT IS MADE TO EMBODY THE HIGHEST DEGREE OF SAFETY IN ALL CAMPBELL SCIENTIFIC PRODUCTS, THE CUSTOMER ASSUMES ALL RISK FROM ANY INJURY RESULTING FROM IMPROPER INSTALLATION, USE, OR MAINTENANCE OF TRIPODS, TOWERS, OR ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.

Table of Contents

PDF viewers: These page numbers refer to the printed version of this document. Use the PDF reader bookmarks tab for links to specific sections.

Figures

Tables

CRBasic Examples

Model 108 Temperature Probe

1. Introduction

The 108 Temperature Probe uses a thermistor to measure temperature in air, soil, and water. It is compatible with all CRBasic dataloggers except the CR200(X) and CR9000(X). See Section 6, *Specifications* *(p. 4)*, for a list of compatible CRBasic dataloggers.

For Edlog datalogger support, check the availability of an older manual at *www.campbellsci.com/old-manuals*, or contact Campbell Scientific for assistance.

2. Precautions

- READ AND UNDERSTAND the *Safety* section at the front of this manual.

- Santoprene® rubber, which composes the black outer jacket of the 108 cable, will support combustion in air. It is used because of its resistance to temperature extremes, moisture, and UV degradation. It is rated as slow burning when tested according to U.L. 94 H.B. and passes FMVSS302. However, local fire codes may preclude its use inside buildings.

3. Initial Inspection

- Check the packaging and contents of the shipment. If damage occurred during transport, immediately file a claim with the carrier. Contact Campbell Scientific to facilitate repair or replacement.

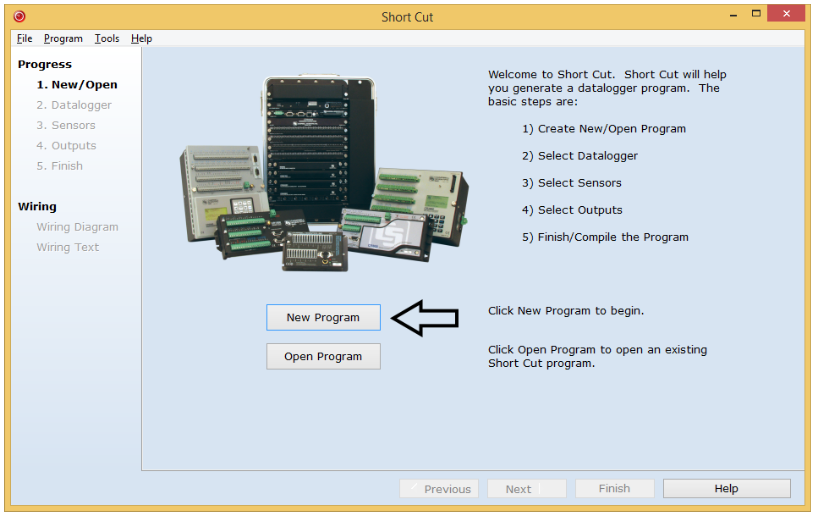
- Check model information against the shipping documents to ensure the expected products and the correct lengths of cable are received. Model numbers are found on each product. On cables and cabled items, the model number is usually found at the connection end of the cable. Report any shortages immediately to Campbell Scientific.

4. QuickStart

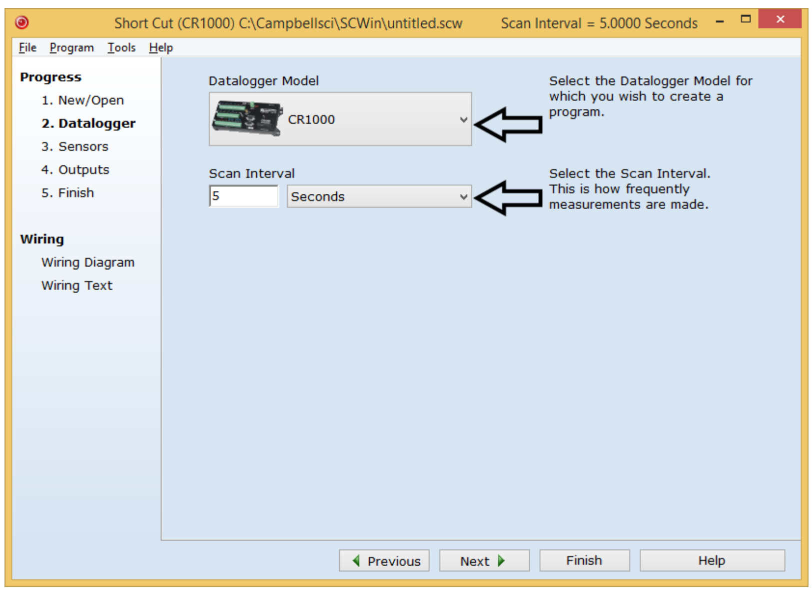
Short Cut is an easy way to program your datalogger to measure the 108 probe and assign datalogger wiring terminals. *Short Cut* is available as a download on *www.campbellsci.com* and the *ResourceDVD*. It is included in installations of *LoggerNet*, *PC200W*, *PC400*, or *RTDAQ*.

Use the following procedure to get started.

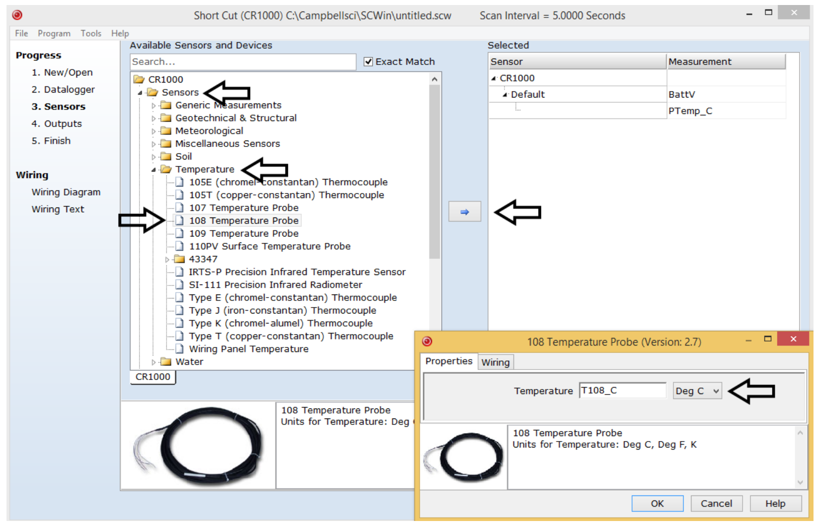
1. Open *Short Cut*. Click **New Program**.



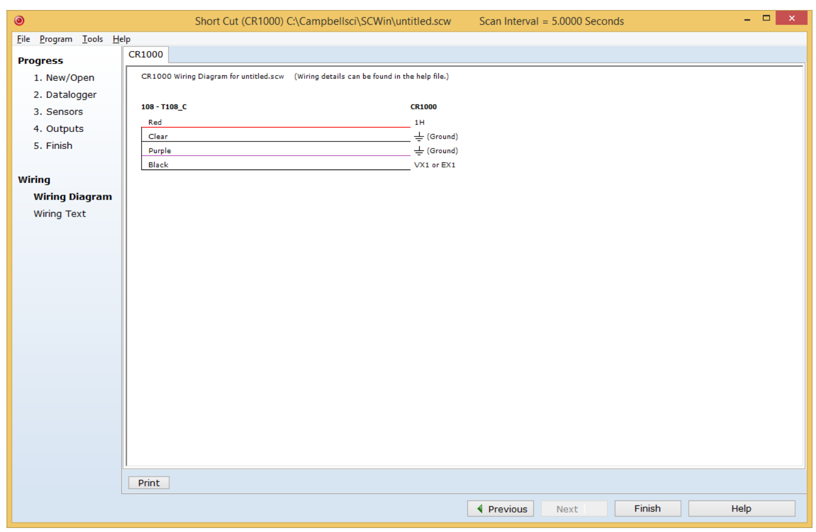
2. Select **Datalogger Model** and **Scan Interval** (default of **5** seconds is OK for most applications). Click **Next**.



3. Under the **Available Sensors and Devices** list, select the **Sensors** folder, then select the **Temperature** sub-folder. Select **108 Temperature Probe**. Click [button] to move the selection to the **Selected** device window. Data defaults to degree Celsius. This can be changed by clicking the **Deg C** box and selecting **Deg F,** for degrees Fahrenheit, or **K,** for Kelvin.



4. After selecting the sensor, click **Wiring Diagram** to see how the sensor is to be wired to the datalogger. The wiring diagram can be printed now or after more sensors are added.



5. Select any other sensors you have, and then finish the remaining *Short Cut* steps to complete the program. The remaining steps are outlined in *Short Cut Help*, which is accessed by clicking on **Help | Contents | Programming Steps**.

6. If *LoggerNet*, *PC400*, *RTDAQ*, or *PC200W* is running on your PC, and the PC to datalogger connection is active, you can click **Finish** in *Short Cut* and you will be prompted to send the program just created to the datalogger.

7. If the sensor is connected to the datalogger, as shown in the wiring diagram in step 4, check the output of the sensor in the datalogger support software data display to make sure it is making reasonable measurements.

5. Overview

The 108 is a rugged probe that accurately measures air, soil, or water temperature in a variety of applications. The sensor consists of a thermistor encapsulated in an epoxy-filled aluminum housing. This design allows the probe to be buried or submerged in water to 15 m (50 ft) or 21 psi. When measuring air temperature, a six-plate radiation shield is normally used to mount the 108 and limit solar radiation loading. See *Specifications* for a complete list of compatible dataloggers.

6. Specifications

Features

- Measures air, soil, or water temperature
- Compatible with AM16/32-series multiplexers
- Easy to install or remove
- Durable
- Compatible with the following CRBasic dataloggers: CR300 series, CR6 series, CR800 series, CR1000, CR3000, and CR5000

Sensor Element:	Measurement Specialties 100K6A1iA thermistor
Survival Range:	–50 to 100 °C
Measurement Range:	–5 to 95 °C
Time Constant in Air:	200 ± 10 s
Maximum Cable Length:	305 m (1000 ft)
Accuracy[1]	
Worst case:	±0.3 °C (–3 to 90 °C) ±0.7 °C (–5 to 95 °C)
Interchangeability Error:	±0.10 °C (0 to 70 °C) ±0.14 °C at –5 °C ±0.25 °C at 85 °C ±0.35 °C at 95 °C
Steinhart-Hart Equation Error:	≤ ±0.01 °C
Probe Weight and Dimensions	
Weight with 10 ft cable:	136 g (5 oz)
Length:	10.4 cm (4.1 in)
Diameter:	0.762 cm (0.3 in)
Compliance:	View the EU Declaration of Conformity at *www.campbellsci.com/108*

[1]Overall probe accuracy is a combination of thermistor interchangeability, bridge-resistor accuracy, and error of the Steinhart-Hart equation. Interchangeability is the principle component error. For 0 to 50 °C, the interchangeability error is predominantly offset and can be determined with a single- point calibration. Offset can be entered in the **Therm108()** instruction ***Offset*** parameter. Bridge resistors have 0.1% tolerance with a 10 ppm temperature coefficient.

7. Installation

If you are programming your datalogger with *Short Cut*, skip Section 7.1, *Wiring to Datalogger* (p. 5), and Section 7.2, *Datalogger Programming* (p. 5). *Short Cut* does this work for you. See Section 4, *QuickStart* (p. 1), for a *Short Cut* tutorial.

7.1 Wiring to Datalogger

TABLE 7-1. Wire Color, Function, and Datalogger Connection

Wire Color	Wire Function	Datalogger Connection Terminal
Black	Voltage-excitation input	**U** configured for voltage excitation[1], **EX**, **VX** (voltage excitation)
Red	Analog-voltage output	**U** configured for single-ended analog input[1], **SE** (single-ended, analog-voltage input)
Purple	Bridge-resistor lead	**AG** or ⏚ (analog ground)
Clear	EMF shield	**AG** or ⏚ (analog ground)

[1]**U** channels are automatically configured by the measurement instruction.

7.2 Datalogger Programming

Short Cut is the best source for up-to-date datalogger programming code. Programming code is needed when:

- Creating a program for a new datalogger installation
- Adding sensors to an existing datalogger program

If your data acquisition requirements are simple, you can probably create and maintain a datalogger program exclusively with *Short Cut*. If your data acquisition needs are more complex, the files that *Short Cut* creates are a great source for programming code to start a new program or add to an existing custom program.

NOTE *Short Cut* cannot edit programs after they are imported and edited in *CRBasic Editor*.

A *Short Cut* tutorial is available in Section 4, *QuickStart* *(p. 1)*. If you wish to import *Short Cut* code into *CRBasic Editor* to create or add to a customized program, follow the procedure in Appendix A, *Importing Short Cut Code Into CRBasic Editor* *(p. A-1)*. Programming basics are provided in the following section. A complete program example can be found in Appendix B, *Example Programs* *(p. B-1)*.

If the 108 probe is to be used with long cable lengths or in electrically noisy environments, consider employing the measurement programming techniques outlined in Section 8.3, *Electrically Noisy Environments* *(p. 10)*, and Section 8.4, *Long Cable Lengths* *(p. 10)*.

Details of 108 probe measurement and linearization of the thermistor output are provided in Section 8.2, *Measurement and Output Linearization* *(p. 9)*.

7.2.1 Therm108() Instruction

The **Therm108()** measurement instruction programs CRBasic dataloggers to measure the 108 probe. It applies a precise excitation voltage, makes a half-bridge resistance measurement, and converts the result to temperature using the Steinhart-Hart equation. See Section 8.2, *Measurement and Output Linearization* *(p. 9)*, for more information. **Therm108()** instruction and parameters are as follows:

```
Therm108(Dest, Reps, SEChan, VxChan, SettlingTime, Integ/Fnotch,
       Mult, Offset)
```

Variations:

- Temperature reported as °C — set ***Mult*** to ***1*** and ***Offset*** to ***0***
- Temperature reported as °F — set ***Mult*** to ***1.8*** and ***Offset*** to ***32***
- AC mains noise filtering — set ***Integ/Fnotch*** to ***_60Hz*** or ***_50Hz*** (see Section 8.3, *Electrically Noisy Environments* *(p. 10)*)
- Compensate for long cable lengths — Set ***SettlingTime*** to ***20000*** (see Section 8.4, *Long Cable Lengths* *(p. 10)*)

7.3 Air Temperature Installation

For air temperature measurements, locate probes over an open level area at least 9 m (EPA) in diameter. The surface should be covered by short grass or the natural earth surface where grass does not grow. Sensors should be located at a distance of at least four times the height of any nearby obstruction, and at least 30 m (EPA) from large paved areas. Sensors should be protected from thermal radiation and adequately ventilated.

Standard air temperature measurement heights:

1.25 to 2.0 m (WMO)
2.0 m (EPA)
2.0 m and 10.0 m for temperature difference (EPA)

When exposed to sunlight, the 108 should be housed in a six-plate solar radiation shield. Six-plate shields offered by Campbell Scientific are models 41303-5A, 41303-5B, or RAD06.

The white color of these shields reflects solar radiation, and the louvered construction allows air to pass freely through, thereby keeping the probe at or near ambient temperature. The RAD06 uses a double-louvered design that offers improved sensor protection from insect intrusion and driving rain and snow. In addition, the RAD06 shield has lower self-heating in bright sunlight combined with higher temperatures (> 24 °C (75 °F)) and low wind speeds (< 2 m/s (4.5 mph)), giving a better measurement.

The 41303-5A and RAD06 attach to a crossarm, mast, or user-supplied pipe with a 2.5 to 5.3 cm (1.0 to 2.1 in) outer diameter. The 41303-5B attaches to a CM500-series pole or a user-supplied pole with a 5.1 cm (2.4 in) outer diameter.

Tools required for installing on a tripod or tower:

- 1/2 inch open-end wrench
- small screwdriver provided with datalogger
- small Phillips screwdriver
- UV-resistant cable ties
- small pair of diagonal-cutting pliers
- adjustable wrench with a minimum 1-1/2 inch jaw size

FIGURE 7-1. Installing a 108 and 41303-5A Radiation Shield on a CM200-Series Crossarm

FIGURE 7-2. 108 and 41303-5A Radiation Shield on a tripod mast (left). 108 and RAD06 Radiation Shield on a CM200-Series Crossarm (right).

The 108 is held in the 41303-5A radiation shield by a mounting clamp at the bottom (FIGURE 7-1 and FIGURE 7-2 left). Loosen the mounting clamp screws, and insert the probe through the clamp. Tighten the screws to secure the sensor, and route the sensor cable to the instrument enclosure.

The 108 is held in the RAD06 radiation shield by inserting the sensor through the sensor gland at the bottom of the shield FIGURE 7-2 right). Loosen the nut on the gland, and insert the probe into the shield. Tighten the nut on the sensor gland using an adjustable wrench until the sensor is securely held in place. Route the sensor cable to the instrument enclosure.

Secure the cable to the tripod or tower using cable ties.

7.4 Water Temperature Installation

108 probes can be submerged to 15 m (50 ft) or 21 psi. The 108 is not weighted, so a weighting system should be added, or the probe secured to a submerged object such as a piling.

7.5 Soil Temperature

The 108 tends to measure the average temperature over its length, so it is usually buried such that the measurement tip is horizontal to the soil surface at the desired depth. The maximum burial depth for soil that could become saturated with water is dictated by the maximum water pressure allowed for the sensor, which is 21 psi.

One or two coils of cable should also be buried in a shallow installation. Burial of some cable mitigates the effect of solar heating of the above ground cable on the temperature measurement.

Placement of the cable inside a rugged conduit may be necessary for long cable runs, especially in locations subject to digging, mowing, traffic, use of power tools, or lightning strikes.

8. Operation

8.1 Sensor Schematic

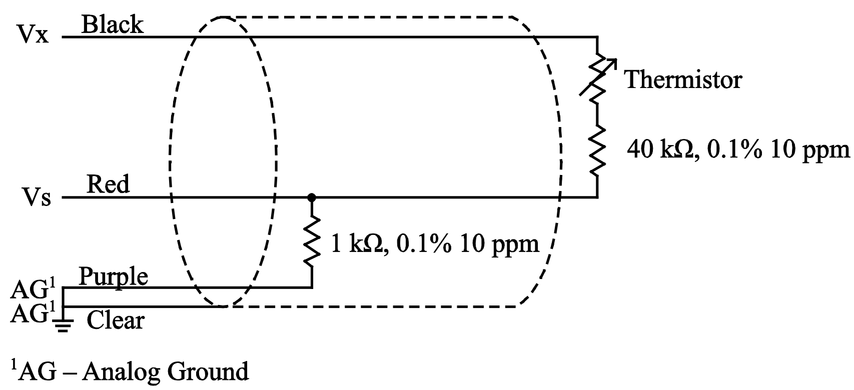


FIGURE 8-1. 108 thermistor probe schematic

8.2 Measurement and Output Linearization

CRBasic instruction **Therm108()** measures the 108 probe thermistor and automatically converts the result to temperature. With reference to the previous FIGURE 8-1, *108 thermistor probe schematic*, **Therm108()** applies 1000 mV excitation at the Vx line and measures the voltage drop across the 1 kΩ resistor at the Vs line.

The ratio of measured voltage (Vs) to excitation voltage (Vx) is related to thermistor resistance (Rs), and the 1 kΩ and 40 kΩ fixed resistors as described in the following equation:

$$Vs/Vx = 1000 / (Rs + 40000\ \Omega + 1000\ \Omega)$$

Solving for Rs:

$$Rs + 41000\ \Omega = 1000 \bullet (Vx/Vs)$$

$$Rs = 1000 \bullet (Vx/Vs) - 41000\ \Omega$$

The relationship of Rs to temperature is tabulated in Appendix C, *Thermistor Resistance and Temperature* *(p. C-1)*, but is calculated by **Therm108()** using the Steinhart-Hart equation, described as follows:

$$T_c = (1 / (A + B \bullet \ln(R_s) + C \bullet (\ln(R_s))^3)) - 273.15$$

where:

T_c = temperature in degrees Celsius (°C)

A[1] = 8.271111E–4

B[1] = 2.088020E–4

C[1] = 8.059200E–8

[1]Coefficients provided by Measurement Specialties™.

8.3 Electrically Noisy Environments

EMF noise emanating from the ac mains power grid can be a significant source of measurement error. 60 Hz noise is common in the United States. 50 Hz noise is common in Europe and other regions. Depending on the datalogger model, this noise can usually be filtered out.

The following code snips filter 60 Hz noise by placing the ***_60Hz*** argument in the ***Integ/Fnotch*** parameter (in bold type).

For CR6-series dataloggers:

```
Therm108(T108_C,1,U1,U10,0,_60Hz,1.0,0.0)
```

For CR300-series, CR800-series, CR1000, CR3000, and CR5000 dataloggers:

```
Therm108(T108_C,1,1,Vx1,0,_60Hz,1.0,0.0)
```

8.4 Long Cable Lengths

Long cable lengths may require longer than normal analog measurement settling times. Settling times are increased by adding a measurement delay to the datalogger program.

The 60 Hz and 50 Hz integration options include a 3 ms settling time; longer settling times can be entered into the ***Settling Time*** parameter. The following code snips increase settling time by 20000 µs by placing ***20000*** as the argument in the ***SettlingTime*** parameter:

For CR6-series dataloggers:

```
Therm108(T108_C,1,U1,U10,20000,_60Hz,1.0,0.0)
```

For CR300-series, CR800-series, CR1000, CR3000, and CR5000 dataloggers:

```
Therm108(T108_C,1,1,1,20000,_60Hz,1.0,0.0)
```

9. Troubleshooting and Maintenance

NOTE All factory repairs and recalibrations require a returned material authorization (RMA) and completion of the "Declaration of Hazardous Material and Decontamination" form. Refer to the *Assistance* page at the beginning of this manual for more information.

9.1 Troubleshooting

Symptom: Temperature is reported as **NAN, –INF**, or incorrect temperature.

Verify wire leads are connected to the terminals specified in the **Therm108()** instruction: red to single-ended analog input (**SE** or **U**), black to switched excitation (**VX**/**EX** or **U**), and purple to ground (⏚).

Symptom: Incorrect temperature is reported.

Verify the ***Mult*** and ***Offset*** arguments in **Therm108()** are correct for the desired units (Section 7.2, *Datalogger Programming* ***(p. 5)***). Check the cable for signs of damage and possible moisture intrusion.

Symptom: Unstable temperature is reported.

Probably a result of electromagnetic interference. Try using the ***_50Hz*** or ***_60Hz Integ*** or ***Fnotch*** options, and/or increasing the settling time as described in Section 8.3, *Electrically Noisy Environments* ***(p. 10)***, and Section 8.4, *Long Cable Lengths* ***(p. 10)***. Ensure the clear wire is connected to datalogger ground, and the datalogger is properly grounded.

9.2 Maintenance

The 108 probe requires minimal maintenance. For air temperature measurements, check the radiation shield monthly to make sure it is free from dust and debris. To clean the shield, first remove the sensor. Dismount the shield. Brush all loose dirt off. If more effort is needed, use warm, soapy water and a soft cloth or brush to thoroughly clean the shield. Allow the shield to dry before remounting.

Periodically check cabling for signs of damage and possible moisture intrusion.

9.3 Calibration

Calibration of the 108 probe is not necessary unless the application requires removal of the thermistor interchangeability offset described in Section 6, *Specifications* ***(p. 4)***.

10. Attributions and References

Santoprene® is a registered trademark of Exxon Mobile Corporation.

EPA installation standard: *Quality Assurance Handbook for Air Pollution Measurement Systems – Volume IV: Meteorological Measurements Version 2.0*

WMO standard: *WMO No. 8, Seventh edition, 6 Aug 2008 Guide to Meteorological Instruments and Methods of Observation*

Appendix A. Importing Short Cut Code Into CRBasic Editor

This tutorial shows:

- How to import a *Short Cut* program into a program editor for additional refinement
- How to import a wiring diagram from *Short Cut* into the comments of a custom program

Short Cut creates files, which can be imported into *CRBasic Editor*. Assuming defaults were used when *Short Cut* was installed, these files reside in the C:\campbellsci\SCWin folder:

- .DEF (wiring and memory usage information)
- .CR300 (CR300-series datalogger code)
- .CR6 (CR6-series datalogger code)
- .CR8 (CR800-series datalogger code)
- .CR1 (CR1000 datalogger code)
- .CR3 (CR3000 datalogger code)
- .CR5 (CR5000 datalogger code)

Use the following procedure to import *Short Cut* code and wiring diagram into *CRBasic Editor*.

1. Create the *Short Cut* program following the procedure in Section 4, *QuickStart* *(p. 1)*. Finish the program and exit *Short Cut*. Make note of the file name used when saving the *Short Cut* program.
2. Open *CRBasic Editor*.
3. Click **File | Open**. Assuming the default paths were used when *Short Cut* was installed, navigate to C:\CampbellSci\SCWin folder. The file of interest has the .CR300, .CR6, .CR8, .CR1, .CR3, or .CR5 extension. Select the file and click **Open**.
4. Immediately save the file in a folder different from C:\Campbellsci\SCWin, or save the file with a different file name.

NOTE Once the file is edited with *CRBasic Editor*, *Short Cut* can no longer be used to edit the datalogger program. Change the name of the program file or move it, or *Short Cut* may overwrite it next time it is used.

5. The program can now be edited, saved, and sent to the datalogger.
6. Import wiring information to the program by opening the associated .DEF file. Copy and paste the section beginning with heading "-Wiring for CRXXX–" into the CRBasic program, usually at the head of the file. After pasting, edit the information such that an apostrophe (**'**) begins each line. This character instructs the datalogger compiler to ignore the line when compiling.

Appendix B. Example Programs

This following example can be used directly with CR300-series, CR800-series, CR1000, CR3000, and CR5000 dataloggers.

CRBasic Example B-1. Program Example for CR300-Series, CR800-Series, CR1000, CR3000, and CR5000 Dataloggers

```
'Program measures one 108 temperature probe once a second and
'stores the average temperature every 60 minutes.

'Wiring Diagram
'==============
'  108
'  Probe
'  Lead                                           CR1000
'  Color      Function                            Terminal
'  -----      --------                            ------
'  Black      Voltage-excitation input            VX1/EX1
'  Red        Analog-voltage output               SE1
'  Purple     Bridge-resistor ground              Ground Symbol
'  Clear      Shield                              Ground Symbol

'Declare the variables for the temperature measurement
Public T108_C

'Define a data table for 60 minute averages:
DataTable(Table1,True,-1)
  DataInterval(0,60,Min,0)
  Average(1,T108_C,IEEE4,0)
EndTable

BeginProg
  Scan(1,Sec,1,0)
    'Measure the temperature
    Therm108(T108_C,1,1,Vx1,0,_60Hz,1.0,0.0)
    'Call Data Table
    CallTable(Table1)
  NextScan
EndProg
```

The following example can be used directly with CR6-series dataloggers.

CRBasic Example B-2. Program Example for CR6-Series Dataloggers

```
'Program measures one 108 temperature probe once a second and
'stores the average temperature every 60 minutes.

'Wiring Diagram
'==============
'  108
'  Probe
'  Lead                                      CR6
'  Color      Function                       Terminal
'  -----      --------                       ------
'  Black      Voltage-excitation input       U10
'  Red        Analog-voltage output          U1
'  Purple     Bridge-resistor ground         Ground Symbol
'  Clear      Shield                         Ground Symbol

'Declare the variables for the temperature measurement
Public T108_C

'Define a data table for 60 minute averages:
DataTable(Table1,True,-1)
  DataInterval(0,60,Min,0)
  Average(1,T108_C,IEEE4,0)
EndTable

BeginProg
  Scan(1,Sec,1,0)
    'Measure the temperature
    Therm108(T108_C,1,U1,U10,0,_60Hz,1.0,0.0)
    'Call Data Table
    CallTable(Table1)
  NextScan
EndProg
```

Appendix C. Thermistor Resistance and Temperature

TABLE C-1. 108 Thermistor Resistance and Temperature[1]

Actual Temperature (°C)	100K6A1iA Thermistor Resistance (Ω)	CRBasic Therm108() Output (°C)
-10	612407	-10.00
-9	578366	-9.00
-8	546408	-8.00
-7	516394	-7.00
-6	488196	-6.00
-5	461695	-5.00
-4	436779	-4.00
-3	413346	-3.00
-2	391300	-2.00
-1	370551	-1.00
0	351017	0.00
1	332620	1.00
2	315288	2.00
3	298954	3.00
4	283555	4.00
5	269034	5.00
6	255335	6.00
7	242408	7.00
8	230206	8.00
9	218684	9.00
10	207801	10.00
11	197518	11.00
12	187799	12.00
13	178610	13.00
14	169921	14.00
15	161700	15.00
16	153921	16.00
17	146558	17.00
18	139586	18.00
19	132983	19.00
20	126727	20.00
21	120799	21.00
22	115179	22.00
23	109850	23.00
24	104795	24.00
25	100000	25.00
26	95449	26.00
27	91129	27.00
28	87027	28.00
29	83131	29.00
30	79430	30.00
31	75913	31.00
32	72569	32.00
33	69390	33.00

34	66367	34.00
35	63491	35.00
36	60755	36.00
37	58150	37.00
38	55670	38.00
39	53309	39.00
40	51060	40.00
41	48917	41.00
42	46875	42.00
43	44929	43.00
44	43073	44.00
45	41303	45.00
46	39615	46.00
47	38005	47.00
48	36467	48.00
49	35000	49.00
50	33599	50.00
51	32262	51.00
52	30984	52.00
53	29763	53.00
54	28596	54.00
55	27481	55.00
56	26415	56.00
57	25395	57.00
58	24420	58.00
59	23487	59.00
60	22594	60.00
61	21740	61.00
62	20922	62.00
63	20138	63.00
64	19388	64.00
65	18670	65.00
66	17981	66.00
67	17322	67.00
68	16689	68.00
69	16083	69.00
70	15502	70.00
71	14945	71.00
72	14410	72.00
73	13897	73.00
74	13405	74.00
75	12932	75.00
76	12478	76.00
77	12043	77.00
78	11625	78.00
79	11223	79.00
80	10837	80.00
81	10466	81.00
82	10109	82.00
83	9767	83.00
84	9437	84.00
85	9121	85.00
86	8816	86.00
87	8523	87.00
88	8241	88.00
89	7970	89.00

90	7708	90.00
91	7457	91.00
92	7215	92.00
93	6982	93.00
94	6758	94.00
95	6541	95.00
96	6333	96.00
97	6132	97.00
98	5939	98.00
99	5753	99.00
100	5573	100.00
[1]Data from Measurement Specialties™		

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